CEER – 5
October 1977

PUERTO RICO NUCLEAR CENTER ANNUAL REPORT

July 1, 1975 – September 30, 1976

CENTER FOR ENERGY AND ENVIRONMENT RESEARCH
FORMERLY PUERTO RICO NUCLEAR CENTER: UNIVERSITY OF PUERTO RICO

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OFFICE OF THE DIRECTOR

On July 1, 1976, the Puerto Rico Nuclear Center (PRNC) became the Center for Energy and Environment Research (CEER) of the University of Puerto Rico. The 12-month period from July 1, 1975, through June 30, 1976, represents the final year of operation of PRNC, and therefore an Annual Report for this period is being published. This section indicates the reasons for the transition and describes the new objectives.

CEER's BASIC OBJECTIVES

In harmony with the Action Memorandum* of April 11, 1976, ERDA's National Plan for Energy Research and Development, and Puerto Rico's energy and environmental needs, the UPR Center for Energy and Environment Research has these principal objectives:

To aid in the national effort to achieve energy independence while contributing to Puerto Rico's own effort to achieve the same goal for itself.

To serve as focal point for energy and environmental research and training in Puerto Rico and to cooperate on research and training with other countries in the tropical and subtropical zones, particularly the Caribbean and Latin America.

To help Puerto Rico develop its manpower needs in energy and energy-related areas.

To continue training programs in Puerto Rico for students and personnel from the Caribbean and Latin America.

In order to achieve these objectives, the Center will:

Support sound research and training programs.

Attract and develop University System talent in energy and environmental research.

Promote and coordinate efforts which draw on expertise wherever located in the University System.

Promote academic excellence in the development of energy curricula and thus help to promote cooperation between the University, industry, government, and the community at large.

The Center's major research programs now encompass environmental sciences and medicine. The aim is to add to these a strong energy program which will emphasize conservation and solar sciences and engineering, including ocean thermal energy conversion and materials research and development. CEER also stands ready to provide the necessary technical support for ERDA's proposed Energy Extension Service in Puerto Rico if the Governor designates the University for this role, or to play any supporting part in this program.

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* Request for approval of change in the arrangements with the University of Puerto Rico for management of the Puerto Rico Nuclear Center.

Table 1: Socio-Economic and Energy Indicators in Selected Fiscal Years Terminating on June 30

ITEM	1950	1960	1970	1971	1972	1973	1974	1975	1980
Gross Product, (millions 1954 dollars)	879	1,473	2,836	2,984	3,186	3,355	3,414	3,333	11,600 [a]
Per Cent Increase From Previous Year	7.3	7.6	6.2	5.2	6.2	5.9	1.8	-2.4	33.0
Gross Product, Per Capita (1954 dollars)	399	630	1,044	1,087	1,122	1,153	1,141	1,085	n.a.
Per Cent Increase From Previous Year	7.0	7.9	5.0	4.1	3.4	2.6	1.0	-4.9	n.a.
Population (thousands)	2,218	2,360	2,716	2,777	2,868	2,952	3,030	3,113	3,213 [b]
Labor Force	684	625	765	789	837	858	884	872	n.a.
Employment	596	542	686	700	737	757	775	738	n.a.
Unemployment	88	83	79	89	100	101	109	134	n.a.
Motor Vehicles In Use	60,727	179,657	614,000	686,659	674,051	681,596	738,465	773,742	n.a.
New Motor Vehicle Registrations	8,236	25,806	91,178	96,457	106,676	138,086	95,801	72,657	n.a.
Gasoline Sales (thousands of gallons)		166,980	407,750	447,910	505,060	561,309	569,187	575,350	n.a.
Electricity, Production (millions of KWH)	539	2,022	7,542	8,507	10,155	11,727	12,149	12,089	15,800 [b]
Electricity, Consumption (millions of KWH)	412	1,667	6,495	7,268	8,895	10,277	10,578	10,410	13,800 [b]
Imports, Total (millions of dollars)	345	915	2,556	2,879	3,108	3,496	4,261	4,951	n.a.
From U.S.A.	318	761	1,964	2,202	2,270	2,537	2,676	3.005	n.a.
From Foreign Countries	27	151	568	648	809	929	1,533	1,867	n.a.
Imports Expressed as Per Cent of Gross Product in Current Dollars	45	56	55	56	55	56	63.5	69.5	n.a.

a/ Projection in current dollars b/ Estimate na: Not available Source: PUERTO RICO PLANNING BOARD

PUERTO RICO's ENERGY REQUIREMENTS

A. Current Needs

Puerto Rico's economy at present depends almost entirely (>99%) on energy derived from imported petroleum. In 1975, the latest year for which comprehensive figures are available, the Office of Petroleum Fuels Affairs (OPFA) of the Puerto Rican Government reports that Puerto Rico imported 70.3 million barrels of crude oil, mostly from the Middle East and Venezuela, and 31.9 million barrels of naptha, mostly from other foreign countries. From these imports the Island's petroleum refineries and petrochemical plants produced practically all the fuel oil, gasoline, and other products used locally and exported substantial quantities, mainly to the United States.

According to OPFA, local consumption of petroleum in 1975 amounted to 59.9 million barrels. The Puerto Rico Water Resources Authority (PRWRA), a government corporation which is the sole vendor of electric power in the Island, consumed 18.7 million barrels, or nearly one-third; the manufacturing sector, 19.7; the transportation sector, 17.9 (including 14 in the form of gasoline for surface transportation); and others, including the agricultural sector, 3.6. Exports amounted to 38.3 million barrels.

Until the OPEC nations raised petroleum prices sharply in 1973, the value of Puerto Rico's total imports had been averaging 55 to 56% of the gross product (GP) in current dollars (Table 1). In 1975, a year of deep recession in which petroleum imports declined, the cost of total imports was 69.5% of the GP. The increase was caused principally by higher petroleum prices.

B. Near-Term Needs (1977–1985)

For the near-term Puerto Rico's energy system will continue to depend on imported petroleum to about the same extent that it does now. The Puerto Rico Planning Board, the government agency responsible for indicative economic and social forecasting, estimates that, if the economic recovery haltingly begun in 1976 gains strength and continues, Puerto Rico's gross product could increase by an average of about 7%/yr during the next four or five years, if a very low rate of population growth is assumed (Table 1). On the basis of historical trends and the Planning Board's projections, OPFA estimates that, with a 7%/yr GP growth, petroleum consumption would increase by close to 10%/yr, assuming no special effort to reduce energy consumption through continuing or new conservation programs or use of alternative energy sources or technologies. Thus, petroleum consumption could reach 98 million barrels in 1980 and could be expected to rise through 1985 if GP continued to rise.

PRWRA forecasts of electric power consumption trends indicate that demand will increase at an average rate of about 6%/yr over the near-term. Thus, PRWRA petroleum consumption would increase steadily until at least 1984. Nuclear power could begin to provide part of the electric energy supply in 1985 if the Puerto Rican Government decides within the next few months to go ahead with construction of a 600-MW plant previously planned and then postponed. For electric power alone, PRWRA estimates the petroleum need in fiscal year 1986 at 26.9 million barrels, costing \$31 a barrel or \$833 million, and, assuming the first nuclear plant goes into operation, the uranium need at ∿450,000 pounds, costing \$45 to \$50 a pound or ∿\$23 million. If nuclear capacity does not go into operation by 1985, the petroleum fuel requirement for electricity would be 33.9 million barrels, costing >$1 billion; if this again represented about one-third of total energy, Puerto Rico's total petroleum bill would exceed $3 billion.

Whether energy consumption increases by only 6 or as much as 10%/yr, the impact of petroleum costs will be increasingly felt. The Planning Board's projection would give the Island a GP in 1980 of about $11.6 billion in current dollars compared with $3.3 billion in 1975. Calculations based on OPFA estimates, PRWRA forecasts, and currently known OPEC intentions indicate that Puerto Rico could be spending between $1.5 and $2.0 billion for petroleum in 1980-81, or 13 to 17% of the GP compared with 8.8% in 1975.

C. Mid- and Long-Term Needs (1985-2000)

The best projections now available are those of the PRWRA, which cover only electric power and are based on a steady 6%/yr consumption increase into the 1990's. Assuming that one nuclear plant can go into operation in 1985, PRWRA considers it feasible that three others, each of 800-MW capacity, could go into operation in the next few years so that by 1991 nuclear plants would be generating two-thirds of the island's electricity and oil-fired plants one-third. (At present, however, only one nuclear plant site is in the process of being certified.) If the projected nuclear capacity were realized, the PRWRA's need for petroleum would decline steadily after FY 1986, being, for FY 1991, 15.3 million barrels of oil costing $50 a barrel, or a total of $753 million (plus ∿1,750,000 pounds of nuclear fuel at $60, or a total of $106 million); if not, the petroleum need would be 44.7 million barrels costing >$2.2 billion. If the petroleum needed for electricity continued to be one-third of total usage, the total oil bill in 1991 would reach $6.6 billion. Assuming that GP could grow 5 to 7%/yr up to 1991, it would reach ∿$20 billion. With exclusive reliance on petroleum, the cost of oil imports could be 32% of GP. Considering the capital costs of replacing and/or adding oil-fired electricity generation capacity, plus the needs of other energy using sectors, it is obvious that reliance on foreign petroleum leads to disaster.

If ERDA's programs for the development of synthetic liquid and gaseous fuels from coal and oil shale were successful, Puerto Rico might look to such alternatives for 1985 to 2000 and even beyond, but to count heavily on this possibility now would be unwise. It seems best to follow the conclusions of the recent interim report to ERDA of the National Research Council's Committee on Nuclear and Alternative Energy Systems, especially the emphasis on the potential for energy conservation.

From the foregoing it is clear that anything Puerto Rico can do to increase its conservation efforts and to develop energy alternatives that will reduce its dependence on imported petroleum, while at the same time striving to achieve a good rate of economic growth and assuring protection of the environment, will be beneficial to the people of Puerto Rico and, directly or indirectly, to the United States. The energy situation and outlook in most of the island societies of the Caribbean and the countries of Central America is similar to Puerto Rico's since they also lack significant fossil-fuel or uranium resources, and they would benefit from the same kinds of programs and policies as Puerto Rico.

ENERGY STRATEGIES FOR PUERTO RICO

A. Conservation

Energy conservation is a major factor in the development of strategies to meet future energy requirements. Conservation is listed as ERDA's top priority in one recent report. In another a scenario is analyzed in which energy growth rate is kept at slightly less than 2%/yr to the year 2000. Both show how substantial energy savings can be had with no appreciable change in life style. Both call for an enlightened, involved public aware of the seriousness of future energy choices.

Energy conservation is definitely on Puerto Rico's agenda and must remain there, with future efforts exceeding those of the past. The Island's industrial sector, including the oil refining and petrochemical industries, which are major direct consumers through their use of electricity, has already made some encouraging strides in raising energy efficiency and is taking other steps.

The new administration is, or soon will be, examining numerous energy-saving options. Recovery of municipal and industrial wastes for production of energy and industrial materials is one area of interest. Studies already completed show the value of processing and recovery of solid wastes. One study indicates that a pyrolitic recovery plant serving the San Juan metropolitan area could generate electricity from waste equal to that from >900,000 barrels of fuel oil a year by 1980. Such a plant would cost upwards of $42 million and, at present prices for imported fuel and recovered raw materials, would lose about $3 million a year; but at the petroleum prices forecast for 1980, it could pay for itself and begin to yield a net profit during the 1980's.

B. Alternative Energy Sources

Puerto Rico has long considered nuclear power as one of its best options. PRWRA was planning a 600-MW nuclear plant, had already purchased the components for it, and was planning to begin construction on a coastal site near the northern city of Arecibo when the recession caused a drop in energy consumption, a decline in PRWRA revenues, and a dim outlook for the issuance of bonds in the capital markets. It therefore shelved construction plans and put the components up for sale, although it is proceeding with licensing of the site. Ironically, seismic studies during the site selection process raised the possibility of petroleum reserves off the north coast, but confirmation of economically significant reserves will require time and highly expensive and sophisticated drilling technology. Whether such reserves would belong to Puerto Rico or to the Federal government remains a question.

With Puerto Rico's climate and geography, solar energy in its manifold aspects offers a potential attractive even in the near-term and substantial for the mid-term. The island has high insolation, averaging >2500 hours/yr for San Juan and up to 2800 for other areas, particularly the dry southern and southwestern coasts, and for nearby islands such as Culebra and Vieques. One obvious option is to use solar energy for heating water for residential, commercial, and industrial use. Another is to use it for air conditioning, as PRWRA estimates that 20% of its electric output is used for this purpose.

Although the higher areas of Puerto Rico need only a minimum of air conditioning, the San Juan area and the smaller towns, where most of the island's factories and business activity are located, need air conditioning most of the year for workers to be comfortable and productive. Conceivably flat-plate solar collectors efficient enough to provide most of the energy for air conditioning systems might be developed. The principal factor limiting the adoption of solar energy in regions such as Puerto Rico is the lack of well engineered, economically manufactured, and adequately distributed solar heat collectors; innovative marketing concepts and general acceptance by both builders and owners also remain to be realized.

The world's fossil fuel reserves are the product of natural conversion of solar energy into plant materials through photosynthesis and subsequent concentration of the stored energy. The managed production of plant tissues such as trees, grasses, water plants, and algae with more efficient use of solar energy could provide additional plant materials, either for direct combustion or for conversion to enriched fuel. Other organic materials that could be used this way include the large amounts of wastes-- agricultural, animal, industrial, and urban-- that are now serious environmental and political problems but are potentially a source of energy.

Oceans, which cover 71% of the earth surface, constitute a natural solar energy collection and storage system. As sources of usable energy, the tropical oceans are particularly attractive. In several hundred million square miles of ocean between the tropics of Cancer and Capricorn the temperature difference between the surface and subsurface levels, where there are cold currents emanating from the polar regions, is $\sim$35° F. Theoretically, this almost infinite heat sink directly beneath a surface reservoir at a nearly constant 82° F could be used to operate a heat engine with an efficiency approaching 9%. The Gulf Stream between Florida and Puerto Rico carries 1000 to 1500 million cubic feet per second of near-tropical sea water. Within a 500-mile length of that path the thermal difference between surface and depths ranges from 28° to 38° F. Such a difference, with a surface temperature of $\sim$71° F, would permit a theoretical maximum conversion of heat into useful work of 5%. Even operating at a more realistic 2%, a plant tapping this heat source could produce an annual energy supply of 0.7×10^{15} Btu. Since both the heat reservoir and the heat sink are replenished by solar energy, this, in effect, represents an unlimited renewable resource.

Considering that Puerto Rico imported petroleum equivalent to 0.6×10^{15} Btu in 1974-75, if it could realize 5 to 10% of the available ocean thermal energy, it would gain a substantial contribution to its energy balance. Because of Puerto Rico's vulnerability to foreign oil prices, the economics of exploring ocean thermal energy conversion (OTEC) are much more favorable than for the mainland U.S., which has many more options. Within 1.6 miles from the southeast coast of Puerto Rico, the thermal gradients are large enough to allow the cold water to be piped to a land based facility, which presents much fewer technical problems than a floating platform and more favorable economics. In this unique situation the possibility of coupling a nuclear plant to an OTEC plant seems very promising.

A much discussed system for converting sunlight to electricity involves arrays of mirrors that collect solar heat and transfer it to a working fluid for use in a Rankine-cycle turbine. The vast land areas required by such a system make it impractical for an island such as Puerto Rico with only 3400 square miles of land for nearly 4 million people.

Wind generators may be a possibility, particularly in the western reaches of the Island. It has been shown that even medium and large size (>100-kW) wind-electric plants can be built and operated successfully. If small systems of low cost and high reliability were available, a sizable market could be developed for a network of them for individual home or small-enterprise use. The major problems would be siting environments, capital costs of components and systems, and environmental impacts.

Finally, from an environmental as well as an energy perspective, Puerto Rico should also be looking to the potential of electric and hybrid vehicles for surface transportation; of fuel cells and photovoltaic cells for a variety of applications; and of agricultural and marine food production systems using low petroleum inputs.

Simple solar energy technologies will not provide a magical solution for Puerto Rico's energy problem. PRWRA, has estimated,for example, that if all of its 227,000 electric hot water heaters were supplemented with solar collectors, total electricity demand would drop by $\sim$6%, or the equivalent of 1.2 million barrels of oil. Further savings could be gained by using solar air conditioners, and still more by substituting flat plate and concentrator collectors for process heat in manufacturing. Such savings, totaling perhaps 20 to 25% of electric power demand, would certainly be worth making. But a substantial capital cost would have to be considered.

The possibility of utilization of all options, including all solar options, needs further study and analysis. This points up the need for the development of a regional energy model of the type proposed by OPFA. It would help to indicate, for example, the extent to which Puerto Rico might be able to depend on energy derived from U.S. coal rather than on imported petroleum, which presents a balance of payments problem to the United States as well as an economic problem to Puerto Rico. The energy equation is also subject to great variation as a result of population growth. Planning Board estimates of a very low rate of growth have to be weighed along with others that put Puerto Rico's population in the year 2000 at 5,000,000 or more. One is forced to conclude that Puerto Rico's time-table for energy conservation and for the development of alternative energy sources and technologies is, if anything, more critical than that of the United States. The challenge for CEER, for the University as the largest single pool of scientific and technical skills, for the Government, and for society at large is great and urgent.

PUERTO RICO's STATE SYSTEM OF HIGHER EDUCATION

The University of Puerto Rico, a member of the national system of state universities and land-grand colleges, is an island-wide university with some 51,000 students. It has three large campuses, two four-year university colleges, and five community colleges, plus an agricultural research network and a cooperative extension service (see organization chart). The top policy-making body is the Council on Higher Education, whose nine members are appointed by the Governor for staggered terms. The President is the chief executive officer. Chancellors direct the main campuses: Rio Piedras, Medical Sciences, and Mayagüez, and the Regional Colleges Administration. They have a considerable degree of autonomy in their own jurisdictions.

The Rĭo Piedras campus, oldest and largest unit in the system, with roughly half the total enrollment, includes a large Faculty of Natural Sciences that has substantial laboratory facilities and equipment for research in biology, chemistry, and physics. The campus also includes a large Computer Center and Schools of Architecture, Business Administration, Law, Planning and Public Administration. The Mayagüez campus includes the School of Engineering, the

Faculty of Arts and Sciences, a Department of Marine Sciences, the Agricultural Experiment Station network, and the Cooperative Extension Service. Facilities and equipment for research are substantial, including a unique pilot-plant facility for the biochemical conversion of biomass to fuels. The Medical Sciences campus, also a center for research, comprises the School of Medicine and six others, including the School of Pharmacy and the School of Medical Technology.

The Center for Energy and Environment Research operates under the Office of the President of the University of Puerto Rico System (see chart). ERDA facilities associated with the CEER had an acquisition value of about $9 million. They are located at four sites on the Island.

Rio Piedras Site: In the San Juan area are well-equipped medically-oriented facilites located adjacent to the UPR Medical School. These facilities include a biomedical building, animal quarters, and maintenance shop.

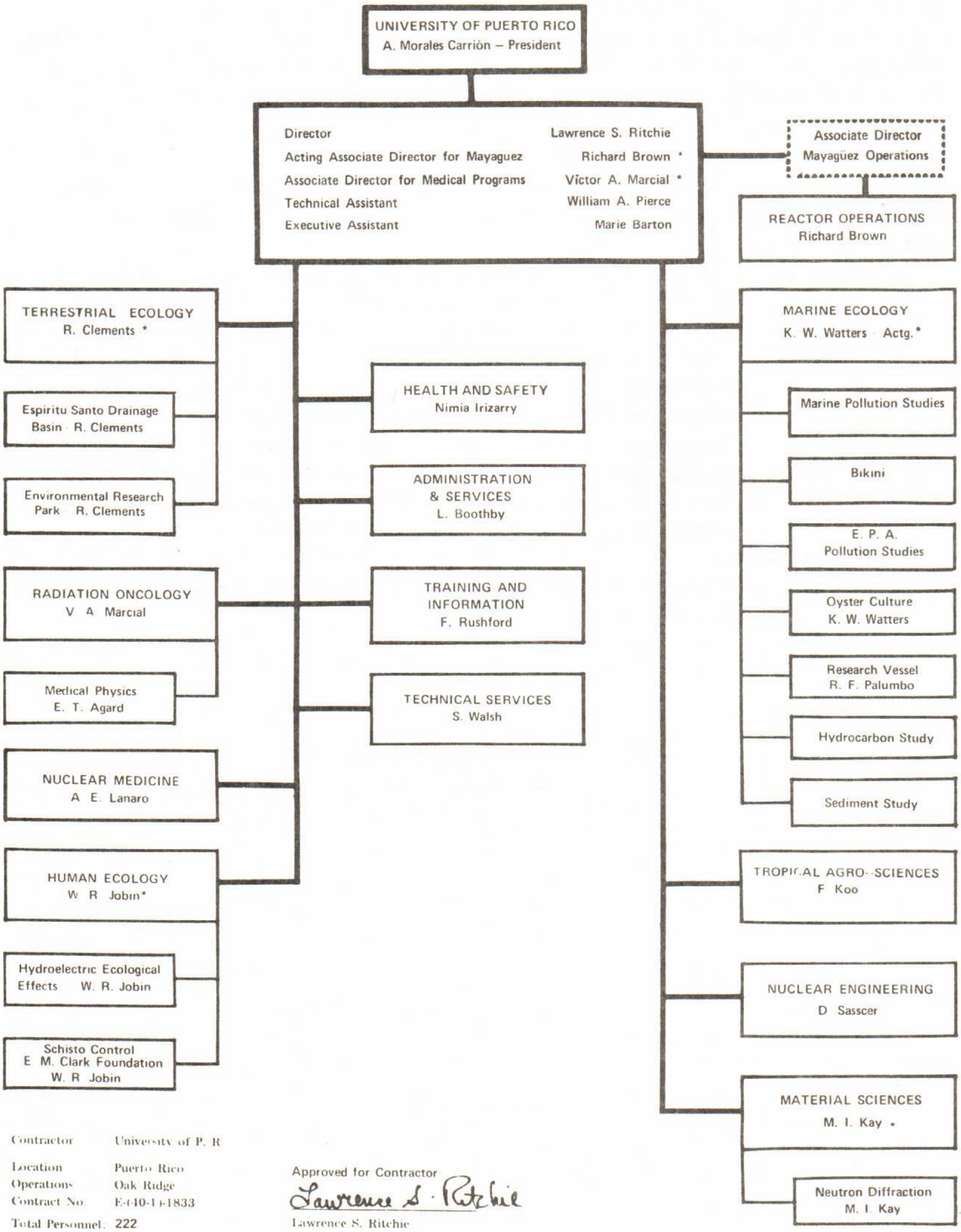
Mayagüez Site: The principal nuclear facilities of the Center are located on 20 acres of property adjacent of the UPR campus in the city of Mayagüez. These facilities include laboratories and several adjacent structures housing offices, nuclear engineering facilities, maintenance shops, and a greenhouse.

Cornelia Hill Site: Near Mayagüez are the facilities housing the marine ecology program. These are relatively new and well-equipped environmental analysis laboratories located on the ocean adjacent to the pier.

Luquillo National Forest Site: In the Luquillo Rain Forest there is a data acquisition laboratory which has recently been expanded.

PUERTO RICO NUCLEAR CENTER

ORGANIZATION CHART – JANUARY 1, 1976



Contractor University of P. R

Location Puerto Rico
Operations Oak Ridge
Contract No. E-(40-1)-1833

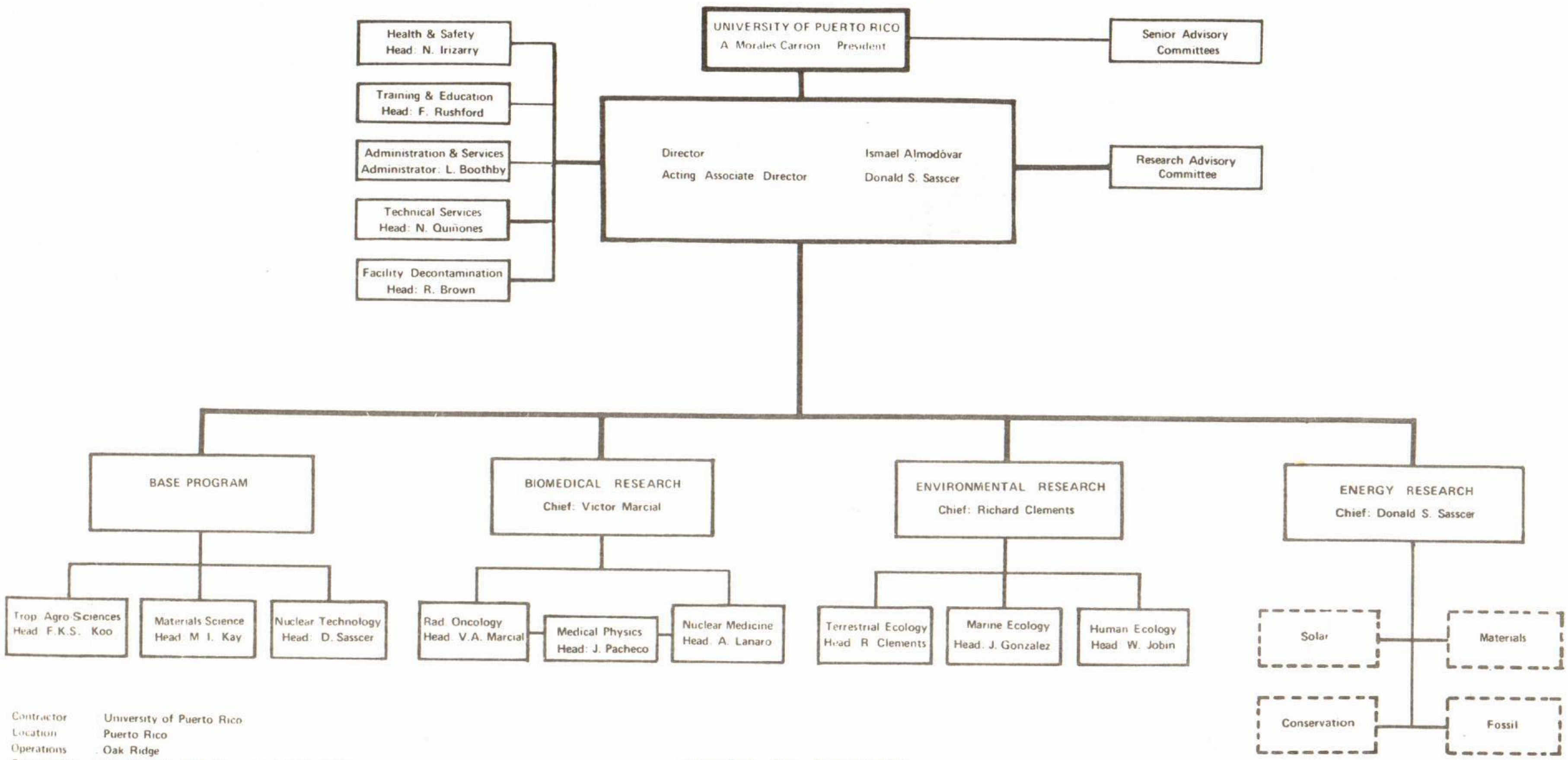
Total Personnel: 222

Approved for Contractor
Lawrence S. Ritchie
Lawrence S. Ritchie
Director

* MULTIPLE FUNCTION

CENTER FOR ENERGY AND ENVIRONMENT RESEARCH

ORGANIZATION CHART   JANUARY 10, 1977



Contractor: University of Puerto Rico
Location: Puerto Rico
Operations: Oak Ridge
Contract No.: EY-76-C-05-1833 (Formerly E-40-1)-1833)
Total Personnel: 152

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* Terminated before June 30, 1976

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Vance P. Vicente	Research Associate II	M.S.	University of Puerto Rico	Marine Microbiology
* Nelson Acosta	Research Associate I	B.S.	University of Puerto Rico	Biology

* Terminated before June 30, 1976

★ Eugene Johnson	Research Associate I	D.D.S.	University of Oregon	Dentistry
James Patus	Research Associate I	B.A.	Indiana University	Zoology
Hilda Rojas de Hernández	Research Associate I	B.S.	University of Maryland	Zoology
★ Trisha Smith	Research Associate I	B.S.	University of Washington	Oceanography

Environmental Sciences--Terrestrial Ecology

Richard G. Clements	Head	Ph.D.	University of Georgia	Agronomy
★ George A. Drewry	Scientist II	Ph.D.	University of Texas	Zoology
Arthur McB. Block	Scientist I	Ph.D.	Rutgers University	Physical Chemistry
Elvira Cuevas	Scientific Associate III	B.S.	University of Puerto Rico	Biology
Brent Holben	Scientific Associate III	M.S.	Colorado State University	Bioclimatology
★ Fred La Caro	Scientific Associate III	M.S.	University of Puerto Rico	Biology
Jose A. Colón	Research Associate II	B.S.	University of Puerto Rico	Biology
Felix A. Santos	Research Associate I	B.S.	University of Puerto Rico	Chemistry

Tropical Agro-Sciences

Francis K. S. Koo	Head	Ph.D.	University of Minnesota	Plant Genetics
José A. Ferrer-Monge	Senior Scientist I	Ph.D.	Louisiana State University	Genetics
★ David W. Walker	Senior Scientist I	Ph.D.	Washington State University	Entomology
Arthur Cedeño	Scientist I	Ph.D.	University of California	Plant Physiology
★ Shreekant N. Deshpande	Scientist I	Ph.D.	Purdue University	Food Technology
José Cuevas-Ruiz	Senior Associate	M.S.	University of Puerto Rico	Biology
★ Kenneth P. MacKay	Research Associate II	B.Ch.E.	Lawrence Institute of Technology	Metallurgy

(Nuclear Applications–Nuclear Science and Technology) Materials Science

★ Julio A. Gonzalo	Head	Ph.D.	University of Madrid	Solid State Physics
Mortimer I. Kay	Senior Scientist I	Ph.D.	University of Connecticut	Physical Chemistry
★ Rastko Maglic	Scientist II	Ph.D.	Mass. Institute of Technology	Physics
Florencio Vasquez	Scientist II	Ph.D.	University of Madrid	Electrical Engineering
★ Pier Paolo Delsanto	Scientist I	Ph.D.	University of Torino	Physics
★ Federico A. Herrero	Scientist I	Ph.D.	University of Florida	Physics
★ Rupert A. Lee	Scientist I	Ph.D.	University of London	Chemistry
Ramar Shankar Singh	Scientist I	Ph.D.	University of Rhode Island	Electrical Engineering

Nuclear Applications–Nuclear Engineering

Donald S. Sasscer	Head	Ph.D.	Iowa State University	Nuclear Engineering
★ Aviva E. Gileadi	Senior Scientist I	Ph.D.	Petrus Pazmany University	Physics
Eddie Ortiz Muñiz	Senior Scientist I	Ph.D.	Texas A & M University	Physics
Néstor Azziz	Scientist II	Ph.D.	Pennsylvania State University	Physics
Knud G. Pedersen	Scientist II	Ph.D.	Iowa State University	Nuclear Engineering
Heriberto Plaza Rosado	Scientist II	Ph.D.	Pennsylvania State University	Physics

Health and Safety

★ Fernando A. Vallecillo	Acting Head	B.S.A.	University of Puerto Rico	Health Physics
★ Ramon E. Ramírez Ledesma	Consultant, Medical Services	M.D.	Southwestern Med. College	General Medicine
★ Roberto Ortiz Muñiz	Senior Scientist I	M.S.E.	University of Michigan	Electrical Engineering
★ Mohyi E.M. Abu Zeid	Scientist I	Ph.D.	University of Tennessee	Physics
★ Porfirio A. Toledo	Scientific Associate III	M.S.	University of Puerto Rico	Radiological Health
Nimia Esther Irizarry	Scientific Associate I	M.S.	University of Puerto Rico	Radiological Health
★ Alice Ortiz de Caraballo	Research Associate I	B.S.	University of Puerto Rico	Biology
Nereida Torres de Cardona	Research Assistant III	R.N.	San Lucas Hospital	Nursing

Joint Radiation Survey Project

★ Michael Gileadi	Scientist I	M.S.	University of Puerto Rico	Sanitary Science

★ Terminated before June 30, 1976

Reactor Operations

Richard Brown Campos	Head	M.S.	University of Puerto Rico	Nuclear Technology
* José E. Rivera-Guzman	Reactor Supervisor	B.S.	University of Puerto Rico	Physics
* Sergio D. Rodriguez	Senior Reactor Operator		University of Puerto Rico	Engineering
Miguel A. Rodriguez	Chief Reactor Operator	Cert.	Puerto Rico Nuclear Center	Nuclear Reactor Operator
Juan Perez Muniz	Reactor Operator	Cert.	Puerto Rico Nuclear Center	Nuclear Reactor Operator

Applied Physical Sciences

José P.A. Castrillón	Head	Ph.D.	University of Buenos Aires	Organic Chemistry
* Rafael Arce-Blanco	Scientist II	M.A.	Harvard University	Physics
* George A. Simpson	Scientist II	Ph.D.	University of Notre Dame	Chemistry
* Rafael Arce-Quintero	Scientist I	Ph.D.	University of Wisconsin	Physical Chemistry
* Manfred Eberhardt	Scientist I	Ph.D.	Universitat Tubingen	Organic Chemistry
* Rosa Santana de Tirado	Research Associate III	M.S.	University of Puerto Rico	Chemistry
* Betzaida Castilla	Research Associate I	B.S.	University of Puerto Rico	Chemistry

* Terminated before June 30, 1976

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2. Block, A. McB. and Clements, R.G. 1975. Structure-activity Correlations for Phenoxyacetic Acids and Indoleacetic Acids Used for Plant Growth Regulation. *Int. J. Quantum Chem.*, Quantum Biol. Symp. **2**, 197.
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47. Wood, E. D. et al. 1975. Cabo Mala Pascua Environmental Studies. *PRNC-188*.
48. Wood, E. D. 1976.Winds for Puerto Rico With Summaries San Juan 1971-1974. Vol.2. *PRNC-192*.
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2. Banus, M.D. 1975. Trace Metals in Mangrove Seedlings from Polluted and Unpolluted Bays in Puerto Rico. Presented at 15th Hanford Life Sci. Symp., Session III. Richland, Washington.
3. Brown, R. A. 1975. The Effect of Radiation Upon Host-Parasite Interactions in *Schistosoma mansoni* Infected Mice. Presented at American Soc. of Tropical Med. and Hygiene 24th Annu. Mtg. New Orleans.
4. Butler, J. M., Ferguson, F. F., Palmer, J. R., and Jobin, W. R. 1975. Displacement of a Colony of *Biomphalaria glabrata* by an Invading Population of *Tarebia granifera* in a Small Stream in Puerto Rico. Presented by (W.R.J.) at Am. Soc. Tropical Med. and Hygiene 24th Annu. Mtg., New Orleans.
5. Carrasco-Canales, J. A. and Colón, J. I. 1976. Study on the Adaptation of Nucleic Acid Hybridization Techniques to the Classification of Fungi Using the *Microsporum gypseum* Complex. Presented by (J.A.C.) at the Annu. Mtg. Assoc. Clinical and Lab. Sci., UPR School of Med., San Juan.
6. Castrillon, J. P. 1976. Thiaxanthen-9-one Carboxylic Acids and Their Corresponding Sulfoxides and Sulfones. Presented at IV Xavier-MBS Biomed. Symp., New Orleans.
7. Chellapan, S., Pedersen, K. B., and Plaza, H. 1975. Mercury and Cadmium Concentrations in Milk in Puerto Rico. Presented by (S.C.) at the Int. Nucl. and Atomic Activation Analysis Conf., Gatlinburg, Tenn.
8. Colón, J. I., Rios-Olivares, E., Rodríguez, M., and Carrasco-Canales, J. A. 1976. Evidence of the Genetic Control of the Synthesis of Interferon in Chick Fibroblast Monolayers. Presented by (J.I.C.) at Annu. Mtg. Am. Assoc. Clinical Lab. Sci., San Juan.

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17. Lanaro, A. E. 1975. Teaching of Nuclear Medicine. Presented at Regional Workshop of Northern Zone of the Latin American Assoc. of Societies of Biol. and Nucl. Med., Mexico.
18. Marcial, V.A. 1976. Carcinoma of the Esophagus; Management of Tumors of the Female Pelvis; Radiation Hepatitis. Presented at Midwinter Radiol. Conf., Los Angeles.
19. Marcial, V.A. 1975. Carcinoma of the Uterine Cervix; Curietherapy of Pelvic Cancer; Current Concepts in the Treatment of Breast Cancer; Therapeutic Associations; Treatment of the Endometrium, Cancer of the Esophagus; Unconventional Fractionation of Doses in Radiotherapy (in Spanish). Presented at Annu. Mtg. of Argentine College of Radiotherapists, Buenos Aires.
20. Marcial, V.A. 1975. Current Policies on Cancer Education of the National Cancer Institute. Presented at Mtg. of Soc. of Chairmen of Academic Radiation Oncology Programs, San Francisco.
21. Marcial, V. A. 1975. Irradiation Treatment of Cancer of the Tongue; Treatment of Ganglear Metastases in Head and Neck Cancer (in Spanish). Presented at Congr. Annu. Mtg. of Argentine Soc. Pathol. of Head and Neck, Buenos Aires.
22. Marcial, V. A. 1976. Management of Invasion Carcinoma of the Cervix. Presented at Am. Cancer. Soc., Natl. Conf. on Radiation Oncology, San Francisco.
23. Montgomery, J. R. 1975. Leaching of Heavy Metals From Secondary Treated Sewage Sludge by Sea Water and Possible Pathways in a Tropical Marine Ecosystem. Presented at Int. Conf. on Heavy Metals in the Environment, Toronto.
24. Ríos-Olivares, E. and Colón, J. I. 1975. The Effect of Gamma Radiation and Actinomycin D on the Multiplication of Sindbis virus. Presented by (E.R.O.) at Annu. Mtg. of Tissue Culture Assoc., Montreal.

25. Sasscer, D. S. and Andrew, C. 1976. Environmental Monitoring of Argon-41. Presented by (D.S.S.) at 9th Midyr. Top. Symp. on Operational Health Phys., Denver.
26. Singh, R. S. 1976. Study of Structural Phase Transition in Crystals Using Light Scattering Techniques. Presented at Am. Assoc. of Phys. Professors Mtg., Ponce, P.R.
27. Vázquez, F. and Gonzalo, J. A. 1975. Brillouin Scattering of DTGS at Room and Through the Transition Temperature. Presented by (F.V.) at Int. Conf. on Low Lying Lattice Vibrational Modes and Their Relationship to Superconductivity and Ferroelectricity, San Juan, P.R.
28. Watters, K. W. 1976. Commercialization of Raft Oyster Culture in Puerto Rico. Presented at 1st. Natl. Fish Culture Workshop, Springfield, MO.

SEMINARS

Rio Piedras

Dr. Lawrence S. Ritchie, Director, PRNC: "Bilharzia in Communist China" (September 19, 1976).

Mr. José C. Pacheco: "Isocentric Dosimetry for 8-mV X-Rays" (October 7, 1975).

Dr. Heriberto Torres: "^{99m}Tc as a Potential Environmental Contaminant" (October 14, 1975).

Dr. E. T. Agard: "Report on Second Latin American Conference in Medical Physics Symposium on the Medical Uses of Linear Accelerators, held in Bello Horizonte, Brazil, July 6-11" (October 21, 1975).

Ms. Heidi Pabón: "Xerography" (October 28, 1975).

Dr. Raymond Seeger, Director, Sigma Xi Bicentennial Lectures: "The Scientist's Responsibility to Society" (November 7, 1975).

Dr. Grafton D. Chase: "Theoretical Versus Empirical Approaches to RIA Data Reduction" (November 24, 1975).

Ms. Cecilia Ramírez: "Field Separation in Multiple Portal Radiation Therapy" (November 4, 1975).

Mr. Michael A. Gribble: "Somatic Effects of Whole-Body Irradiation" (November 11, 1975).

Mr. Karl L. Prado: "A Revision of Dosimetric Properties of LiF and CaF_2 for Clinical and Environmental Monitoring" (November 18, 1975).

Dr. E. T. Agard: "The BEIR Report" (November 25, 1975).

Dr. W. R. Jobin: "The Comparative Ecology of Lakes Cidra and Carite" (April 1976).

Dr. W. R. Jobin: "Socio-Economic Changes in Puerto Rico and the Control of Bilharzia" (May 27, 1976).

Mayagüez

Dr. Grafton D. Chase, Philadelphia College of Pharmacy and Science: "Theoretical Model for Radioimmunoassay" (November 23, 1975).

Dr. Lawrence S. Ritchie: "Contemporary Pictures of the Peoples' Republic of China" (April 8 through May 2, 1975).

Dr. K. Watters and Dr. L. Keow: "Information Exchange Between UPR Marine Science Department and PRNC Marine Ecology Division on the Research in Progress in Both Programs" (February 1976).

Dr. J.B. Cohen, Northwestern University; "Diffuse Scattering" (March 1976).

Dr. Michael Butler, Sandia Corporation: "H_2 Production by Photoelectrolysis of H_2O" (June 11, 1976).

Table 1: Enrollment in PRNC Training and Education Program from July 1, 1975 to June 30, 1976.

Training Activity	Max. Duration (Months)	Enrollment	Student Months
Thesis Research, Ph.D. Degree, Ecology	12	1	12
Thesis Research, M.S. Degree, Biology	12	1	6
Thesis Research, M.S., Degree, Fisheries	12	1	12
Special Training, Marine Ecology	3	8	20
Thesis Research, Ph.D. Degree, Botany	12	1	7
Thesis Research, M.S. Degree, Biology	12	3	27
Special Training, Terrestrial Ecology	3	2	4.5
Thesis Research, Ph.D. Degree, Medical Zoology	12	1	12
Thesis Research, Ph.D. Degree, Microbiology	12	2	15
Thesis Research, M.S. Degree, Microbiology	12	3	33
Thesis Research, M.S. Degree, Biochemistry	12	1	12
Thesis Research, M.S. Degree, Anatomy	12	1	6
Bilharzia Field Control Practice	2	3	3
Special Training, Human Ecology	12	8	49
Thesis Research, M.S. Degree, Biology	12	3	32
Thesis Research, M.S. Degree, Agronomy	12	1	0.5
Special Training, Plant Physiology	12	6	25.5
Graduate Courses, Tropical Agro-Sciences	4	17	68
Thesis Research, M.S. Degree, Physics	12	4	28
Thesis Research, M.S. Degree, Chemistry	12	7	32
Thesis Research, M.S. Degree, Electrical Engineering	12	1	6
Special Training, Material Sciences	3	2	3
Graduate Course, Material Sciences	4	2	8
Thesis Research, M.S. Degree, Nuclear Engineering	12	5	46
Graduate Courses, M.S. Degree, Nuclear Engineering	4	17	68
Special Training, Nuclear Engineering	3	2	3.5
Workshop, Energy and the Environment	.25	30	7.5
Basic Nuclear Medicine	5	8	40
Basic Radioisotope Techniques	1	15	15
Special Training, Nuclear Medicine	2	10	13.25
Nuclear Medicine Residency	4	2	7
Elective Course in Nuclear Medicine	1	1	1
Research , SUBE Program	5	1	5
Orientation Course, Nuclear Medicine	.5	59	29.5
Radiation Therapy Residency	12	1	12
Special Training, Radiation Therapy	12	3	21
Short Term Radiotherapy Training	1	12	12
Special Training, Medical Physics	2	2	4
Refresher Course, MEV XII Linear Accelerator	.25	5	1.25
Summer Training, M.S. Degree, Radiological Health	1	7	7
TOTALS		259	714.5

TRAINING AND INFORMATION

The Training and Information Division provides centralized direction and coordination for the training and information activities of the Center for Energy and Environment Research (formerly Puerto Rico Nuclear Center). The Division Head serves as Educational Officer, Technical Information Officer, and Public Information Officer.

Training responsibilities include registering students; maintaining centralized records on training activities; preparing reports for ERDA; scheduling the utilization of training facilities; providing audiovisual equipment; assisting in the preparation of courses, seminars, symposia, and meetings; administering fellowship programs; and providing personal assistance to students in matters such as housing and immigration. The Division Head represents the Director on the Admissions Committee.

Information responsibilities include preparation of manuscripts for ERDA patent clearance and publication release, maintenance of central files on all manuscripts and publications, preparation of the Annual Report, providing editorial and translation assistance, operation of a Technical Reading Room, operation of an ERDA Film Library, operation of a Reproduction Shop, providing copying services, and assisting visitors.

TRAINING ACTIVITIES

Table 1 provides information on the enrollment in PRNC training activities from July 1, 1975 through June 30, 1976. Of the 259 students enrolled in training courses offered at PRNC, 36 students were engaged in thesis research. Pertinent information on thesis research at PRNC during FY-1976 is provided in Table 2. The geographical distribution of PRNC students from FY-1970 through FY-1976 is shown in Table 3. The total number of students trained at PRNC since its founding in FY-1958 through FY-1976 listed by country of origin is presented in Table 4.

Fellowship Support

The President's Office of the University of Puerto Rico provided financial support for PRNC students through the PRNC Student Economic Aid Program. Table 5 presents information on the eleven trainees who were granted a total of $9,550 from this Program. Students also were supported by the ERDA Laboratory Graduate Participation Program and ERDA Undergraduate Research Trainee Program, both administered by the Oak Ridge Associated Universities. Two students from Venezuela were supported by the Gran Mariscal de Ayacucho Fellowship Program of the Venezuelan Government and four students from Brazil, Mexico and Peru had fellowships from the Organization of American States.

Table 2: PRNC - Thesis Research from July 1, 1975 through June 30, 1976.

1. "Metabolism and Recovery of Coral Reef After an Environmental Stress"	Carolyn Rodgers-Ph.D.-Ecology U. of Florida	Dr. S. Kolehmainen
2. "Effect of Thermal Stress on Selected Aspects of Nitrogen Fixation and Cycling in a Tropical Bay"	Marilyn C. Kimbal-M.S.-Biology U. of Miami	Dr. M. Banus
3. "Transfer of Heavy Metals From Sewage Sludge to Marine Organisms"	Mary Price-M.S.-Fisheries U. of Washington	Dr. K. Watters
4. "The Role of *Palicourea riparia* Bentz. in the Recovery of a Disturbed Tropical Rain Forest in Puerto Rico"	María Lebrón-Ph.D.-Botany U. of North Carolina	Dr. R. Clements
5. "Changes in Selected Water Quality Parameters as Influenced by Land Use Patterns in the Espiritu Santo Watershed"	Elvira Cuevas-M.S.-Biology U. of Puerto Rico	Dr. R. Clements
6. "Limiting Factors Affecting the Distribution of *Caracolus caracolla* in Puerto Rico"	Pedro Cebollero-M.S.-Biology U. of Puerto Rico	Dr. R. Clements
7. "Some Aspects of the Ecology of the Fresh Water Shrimps in the Upper Espíritu Santo River at El Verde, Puerto Rico"	Johnny Villamil-M.S.-Biology U. of Puerto Rico	Dr. R. Clements
8. "*Schistosoma mansoni* Studies on Functional and Structural Changes at the Cercarial to Schistosomule Interface"	Felix Liard-Ph.D.-Medical Zoology U. of Puerto Rico	Dr. L. Otero
9. "Genetic Analysis of *Microsporum gypseum* Complex at the Molecular Level"	José Carrasco-Ph.D.-Microbiology U. of Puerto Rico	Dr. J. Colón
10. "The Effect of Gamma Radiation on Viral Infections, Gamma Radiation and the Synthesis of Macromolecular Infected Cells"	Eddie Ríos-Ph.D.-Microbiology U. of Puerto Rico	Dr. J. Colón
11. "Interferon Production in Viral Induced Mutated L-Cells"	Mercedes Rodríguez-M.S.-Microbiology-U. of Puerto Rico	Dr. J. Colón
12. "Multiplication of Sindbis Virus in L-Cell Monolayers"	Nitza Dávila-M.S.-Microbiology U. of Puerto Rico	Dr. J. Colón
13. "Kinetics of Glycogen Phosphorylase of a Strain of *Saccharomyces cerevisiae* and One of its Glycogen-Deficient Mutants as Determined in Protamine Permeabilized Cells"	Sergio Silva-M.S.-Microbiology U. of Puerto Rico	Dr. J. Colón
14. "Proteolytic Enzymes in *Fasciola hepatica*"	Genaro Ortiz-M.S.-Biochemistry U. of Puerto Rico	Dr. J. Chiriboga
15. "The Effect of Gamma Irradiation on Different Stages of *Fasciola hepatica*"	José Torres-M.S.-Anatomy U. of Puerto Rico	Dr. J. Chiriboga
16. "Phonon Raman Spectra of TGS and its Isomorphic Crystal DTGS"	Osvaldo Matos-M.S.-Physics U. of Puerto Rico	Dr. R. Singh
17. "Phonon Raman Spectra of TGSe and TGFBe"	Fernando Noriega-M.S.-Physics U. of Puerto Rico	Dr. R. Singh
18. "A Study of Phase Transitions in Crystals by Light-Scattering Techniques	Luis Mera-M.S.-Physics U. of Puerto Rico	Dr. R. Singh
19. "Radiolysis of Aqueous Solutions of Sulfur-Containing Amino Acids"	Luz García-M.S.-Chemistry U. of Puerto Rico	Dr. R. Lee
20. "Radiolysis of Aqueous Solutions of Difluorobis (ethylenediamine cobalt III nitrate)"	María Colón-M.S.-Chemistry U. of Puerto Rico	Dr. R. Lee

21. "Triplet Excited States"	Samuel Hernández-M.S.-Chemistry U. of Puerto Rico	Drs. Herrero & Lee
22. "Raman Scattering of Ribosomal RNA and Some Antibiotics"	René Vieta-M.S.-Chemistry U. of Puerto Rico	Dr. T. Jao
23. "The $NaNO_2$ System and its Properties"	Mario Rojas-M.S.-Chemistry U. of Puerto Rico	Dr. T. Jao
24. "I.R. Studies of the Bromine–Benzine Complex"	Roberto Torres-M.S.-Chemistry U. of Puerto Rico	Dr. T. Jao
25. "Raman Scattering of Some Polyamino Acids, Peptides, and Proteins"	Gloria Marquez-M.S.-Chemistry U. of Puerto Rico	Dr. T. Jao
26. "Dielectric Constant in TGS and DTGS with Uniaxial Pressure"	Jorge Ortiz-M.S.-Electrical Engr. U. of Puerto Rico	Dr. F. Vazquez
27. "Feasibility of Qualitative and Quantitative Elastic Scattering Studies Using a 1000-Ci Americium Source"	Dick Carrero-M.S. Nuclear Engr. U. of Puerto Rico	Dr. E. Ortiz
28. "Feasibility of Integrated Ocean Thermal Gradient–Nuclear Plants for the Production of Electrical Power at Several Sites in Puerto Rico"	Frank Ferrer-M.S.-Nuclear Engr. U. of Puerto Rico	Dr. D. Sasscer
29. "Methane Gas Production From Returned Activated Sludge Using the Anaerobic Filter"	Angel Rivera-M.S.-Nuclear Engr. U. of Puerto Rico	Dr. K. Pedersen
30. "Effects of Cadmium on Some Photosynthetic Reactions of Isolated Chloroplasts"	Carmen Asencio-M.S.-Biology U. of Puerto Rico	Dr. A. Cedeño
31. "Cytogenetic Effects of Insulin on Human Chromosomes"	Alice Ortiz-M.S.-Biology U. of Puerto Rico	Dr. J. Ferrer-Monge
32. "Availability of Methionine for Protein Synthesis in Soybean Seeds During Development"	Blanca Riesco-M.S.-Biology U. of Puerto Rico	Dr. F. Koo
33. "Mutagenic Specificity of 5-Bromodeoxyuridine in Germinating Soybean (*Glycine max* (L) Merrill) Seeds"	Federico Cuevas-M.S.-Agronomy U. of Puerto Rico	Dr. F. Koo
34. "Excimeric Properties of Carcinogenic Compounds"	José Lopez-M.S.-Physics U. of Puerto Rico	Dr. Abu-Zeid

Table 3: Geographical Distribution of PRNC Students, FY 1970 through FY 1976.

	Fiscal Years						
Geographical Area	1970	1971	1972	1973	1974	1975	1976
South America	24	50	48	34	24	21	22
Central America & Mexico	7	12	3	10	10	8	6
Caribbean	8	6	6	8	17	3	3
Puerto Rico (USA)	141	110	155	164	297	189	192
Continental (USA)	5	5	12	5	13	24	16
Europe, Asia, Africa	5	2	4	4	4	4	0
	190	185	228	225	265	249	239

Table 4: PRNC Students by Country – FY 1958–FY 1976 *

(A student is counted once each fiscal year he is in training)

	1958–71	72	73	74	75	76	Total
Argentina	30	6	7	2	–	2	47
Bolivia	15	5	2	1	1	3	27
Brazil	1	–	–	1	–	–	2
Chile	23	1	1	1	1	–	27
Colombia	78	12	9	9	5	5	118
Costa Rica	13	2	1	1	1	–	18
Cuba	14	–	2	6	–	–	22
Dominican Republic	41	4	6	9	3	3	66
Ecuador	23	1	2	1	1	1	29
El Salvador	9	–	2	1	–	1	13
Formosa	13	1	–	–	–	–	14
Germany	2	–	–	–	–	–	2
Great Britain	5	–	–	–	–	–	5
Greece	3	–	–	–	–	–	3
Guatemala	9	–	1	3	1	–	15
Haiti	2	–	–	2	–	–	4
Honduras	1	–	–	–	–	–	1
Hungary	1	–	–	–	–	–	1
India	10	1	2	2	1	–	16
Indonesia	0	1	1	–	–	–	2
Israel	3	–	–	1	–	–	4
Jamaica	1	2	–	–	–	–	3
Japan	1	–	–	–	–	–	1
Kenya	0	–	–	–	1	–	1
Korea	2	1	–	–	–	–	3
Lebanon	2	–	–	–	–	–	2
Liberia	3	–	–	–	–	–	3
Malay	0	–	1	–	–	–	1
Mexico	24	1	2	–	–	1	28
Nicaragua	12	–	3	3	2	2	22
Panama	5	–	1	2	4	1	13
Paraguay	13	1	2	1	2	–	19
Peru	19	3	3	3	5	5	38
Philippine Islands	6	–	–	–	–	–	6
South Africa	1	–	–	–	–	–	1
Spain	20	–	–	1	2	–	23
Thailand	2	–	–	–	–	–	2
Turkey	1	–	–	–	–	–	1
United Arab Republic	1	–	–	–	–	–	1
Uruguay	12	2	2	–	–	–	16
Venezuela	38	5	2	2	2	4	53
Total Non-US Citizens	464	51	56	56	36	31	694
Total US Citizens	1800	167	169	309	213	208	2866
Total Students	2264	218	225	365	249	239	3560

* Total number of students trained at PRNC from its first year of operation FY-58 through FY-76.

Table 5: PRNC Student Economic Aid Program FY-1976 – $9,550

NAME	COUNTRY	TRAINING	INCLUSIVE DATES
Carlos A. Spada	Argentina	Radioisotope Techniques, Nuclear Medicine	Aug. 1, 1975 – Nov. 30, 1975
Ambrosio Yapura	Bolivia	Radioisotope Techniques, Nuclear Medicine	July 1, 1975 – Dec. 31, 1975
Hector Flores	Peru	M.S. Degree, Agriculture	Nov. 1, 1975 – Nov. 30, 1975
Angel Laracuente	Puerto Rico	Snail Competition Studies	Nov. 1, 1975 – Feb. 28, 1976
Fernando Noriega	Guatemala	M.S. Degree, Physics, Thesis Research	Jan. 1, 1976 – Jun. 30, 1976
Angela Saavedra	Bolivia	Radioisotope Techniques, Nuclear Medicine	Jan. 1, 1976 – Jan. 31, 1976
Eduardo Brunel	Brazil	Radioisotope Techniques, Nuclear Medicine	Jan. 1, 1976 – Jun. 30, 1976
Yolanda Otero	Colombia	Radioisotope Techniques, Nuclear Medicine	Jan. 1, 1976 – Jun. 30, 1976
Karl Prado	Puerto Rico	Special Course in Computer Science	Apr. 1, 1976 – Apr. 30, 1976
Rafael Urioste	Bolivia	Special Training, Nuclear Medicine	Apr. 19, 1976 – May 14, 1976
Azucena Garzón	Ecuador	Radiotherapy Dosimetry	May 1, 1976 – July 31, 1976

Table 6: PRNC Technical Reference Room Collection – June 30, 1976

Books	4,546
Theses	26
Journals-Periodicals (Volumes)	1,020
Documents (AEC and ERDA)	27,850
Documents (Foreign Countries)	953
Microcards	73,499
Microfiche	105,070
Movies (16 mm)	383

Table 7: PRNC Technical Reference Room Utilization – FY-1976

Staff Consultations	226
Student Consultations	213
Circulation – Staff	275
Circulation – Students	194
Interlibrary Loans	427
Interlibrary Loans	395
Movies Loaned	135

TECHNICAL REFERENCE ROOM

The PRNC Technical Reference Room functions as an autonomous branch of the UPR Mayagüez Campus Library. During FY-1976 Ms. Iraida Oliver de Padovani and Ms. Ivette Lorenzo de Vélez were responsible for operations. Ms. Grace Quiñones, who had been serving as the Librarian-in-charge, was granted a sabbatical leave by the University. Tables 6 and 7 present brief summaries on the Technical Reference Room collection and utilization during FY-1976.

STAFF

Mr. Frederick E. Rushford, Educational Officer and Head of the Training and Information Division, briefed Dr. Arturo Morales Carrión, President of the University of Puerto Rico, on PRNC educational activities during his visit to the laboratory on September 11, 1975. On May 6, 1976, he met with Mr. Harold Young, Dr. James Kellet Jr., and Dr. Lawrence Akers, at the ERDA Office of University Programs in Washington, D.C. to discuss the proposed Education and Training Program for the Center for Energy and Environment Research of the University of Puerto Rico (CEER) scheduled to replace PRNC on July 1, 1976. On June 28-29, 1976, Mr. Rushford participated in the ERDA Laboratory Education and Training Program Workshop held in Germantown, Maryland. At the Workshop Mr. Rushford was invited to serve as chairman of the Administrative Procedures Panel. He also submitted a paper entitled "A Training and Education Program for Puerto Rico's Center for Energy and Environment Research."

RADIATION ONCOLOGY

The Radiation Oncology Division has had as its main objectives both to operate an academic training program and to carry out research on radiation therapy of cancer. Since fiscal year 1975, following a directive from ERDA, increased effort has been given to research. The research activities have been complemented by the training program, which has been oriented towards producing radiation oncologists, giving physicians short-term experience in radiation oncology, and teaching medical students about clinical cancer and its radiation therapy. The purpose of the research effort is to improve present modalities of radiation therapy of cancer.

As in previous years, the Division has operated as the Radiation Oncology Program of the Department of Radiological Sciences of the University of Puerto Rico School of Medicine. It has provided radiation oncology support to patients at the University Hospital and to academic programs of the University of Puerto Rico Medical Sciences Campus. The patients, in turn, have provided the clinical basis for the educational and research projects of the Division.

Funding has been primarily from PRNC ($\sim$40%) and from National Cancer Institute grants channeled through the School of Medicine ($\sim$60%). Special inter-institutional relationships with the San Juan Veterans Administration Hospital and the Metropolitan Hospital in San Juan have permitted inclusion of patients from these institutions in the Division's research projects. Medical physics and radiotherapy consultations have been provided to the Radiotherapy Department of the VA Hospital.

The change in mission of the Center from multidisciplinary to energy oriented, the gradual budget reduction (accentuated by inflation), and the scheduled elimination of National Cancer Institute training grants on June 30, 1976, have handicapped the programs and introduced considerable uncertainty and instability resulting in a reduction of personnel. This has affected both the training and the research objectives of the Division.

RESEARCH ACTIVITIES

A. Residents' Projects

Radiation-induced tumor regression in carcinoma of the esophagus. Dr. Gloria Arroyo continued this study. She entered 32 patients analyzed as to sex, age, survival after treatment, and symptomatic and radiological appraisal of tumor regression with and without carbogen (5% CO_2 + 95% oxygen) breathing. The results will be published.

B. Staff – Intramural Projects

Floor of the mouth project. This previously reported project continues the gradual incorporation of follow-up information on close to 200 patients who have been treated by the staff of the Radiation Oncology Division. The material is pending analysis of factors which affect the survival of these patients.

Effect of therapeutic irradiation of the lung studied by pulmonary function tests and lung scan techniques. This project is being continued at a reduced tempo because of lack of funding. Additional follow-up information on the previously registered patients is gradually being incorporated.

Split-course radiation therapy of cancer. A total of 524 cases have been registered in this project as of June 1976. The patients with largest accrual have been those with base of tongue site, a total of 144. In June 1976 the study group decided to discontinue accession of patients with this site and to proceed with analysis and publication of the results during fiscal year 1976-77. Preliminary results based on the status of the study in June 1974 were published in 1975.

Radiation-induced tumor regression in a mouse chondrosarcoma. Jointly with the Human Ecology Division of the Center, various factors influencing tumor regression after irradiation are being studied in a mouse chondrosarcoma system. A shortage of funds and personnel has resulted in reduced activity, but resumption of work is expected as soon as the Comprehensive Cancer Center of the P. R. School of Medicine recruits the services of a radiobiologist.

Radiation-induced liver damage. A project being done in collaboration with the Surgical Research Laboratory of the School of Medicine, the Nuclear Medicine Division of the Center, and a private veterinarian (Dr. Carlos Gómez) is aimed at determining the factors involved in radiation damage to the liver. Dogs are being subjected to irradiation of the liver to various dose levels ranging from 3000 rads in 3 weeks to 4000 rads in 4 weeks. Before irradiation, biopsy of the liver, liver scan, and chemical blood studies are done. After irradiation these tests are repeated, to determine the extent of liver damage. The information gained should help in preventing radiation hepatitis in humans. A paper on this subject was presented at an IAEA meeting and will be published in the proceedings.

C. Extramural Projects

Carbogen study. As of June 1976 a total of 320 cases were registered, most of them from this Division, and accession of cases was stopped. The preliminary impression is that breathing carbogen (5% CO_2 + 95% oxygen) during radiotherapy does not improve the survival of patients with cancer of the head, neck, and esophagus. Analysis of the results will be finished during fiscal year 1976-77.

Treatment of brain metastases. The objective of this project is to determine optimal ways of treating brain metastases with radiation. As of June 1976, accession of patients was interrupted, and the results are now being analyzed.

Treatment of brain gliomas. The purpose of this project is to determine optimal methods of treating brain gliomas. Various radiation dose levels are being tested, and also combination with chemotherapy (BCNU). In June 1976 more than 100 cases had been registered.

Medulloblastoma. The objective is to compare survivals of medulloblastoma patients treated by cranio-spinal irradiation alone or in combination with chemotherapy, in order to improve survival. Since this is a rare condition the Division has registered only one patient to the study during fiscal year 1975-76.

B. Medical Students'Projects

Bone scan in sarcoma of the prostate – Néstor C. Tirado.
Lymph node metastases in carcinoma of the breast – María C. Cardona.
Carcinoma of the endometrium, stage II – Noel Totti.
Sarcoma of the uterus – Nayda Figueroa.

TRAINING ACTIVITIES

The training program of the Radiation Oncology Division has included a residency program in radiation oncology for physicians, short-term radiotherapy training for persons with previous experience in the specialty, in-service training for medical students (summer fellows) on cancer and radiation therapy, in-service training for radiological physicists and radiotherapy technicians, and a lecture course on radiotherapy and cancer for third-year medical students. Because of a shortage of personnel and the change in mission of the Center, both the amount and the scope of the training activities have been reduced. The training in radiation oncology will be continued for a limited number of residents, but the training of medical students will be interrupted until the Division can acquire sufficient staff. In-service training of physicians and radiological physicists will be continued.

Table 1: Training Acitivities of the Radiation Oncology Division, July 1975 to June 1976.

Name	Dates	Present Position
A. Radiation Oncology Resident		
Dr. Jorge A. Moscol	7/75 - 6/76	2nd yr. resident
B. Training Course for Medical Students		
Luis A. Almodóvar	Jun-Jul 1975	Internship
María M. Cardona	"	"
Antonio G. Sotomayor	"	"
Néstor C. Tirado	"	"
Noel Totti III	"	"
Francisco J. Vizcarrondo	"	"
Carmen D. Zorrilla	"	4th yr. medical student
María E. Vélez	"	Internship
Nayda Figueroa	"	"
C. Short-Term Radiotherapy Course		
Dr. Guillermo Guerrra	10/75 - 3/76	Returned to Colombia
Dr. Arturo Ydrach	2/76 - 4/76	Comprehensive Cancer Center

MEDICAL SERVICES

In fiscal year 1975-76 service was continued at the University Hospital for patients who required radiation therapy. This was necessary to provide the basis for the teaching of medical students, residents, and short-term trainees in the Medical School and the Radiotherapy Division. The staff of the Division participated in combined treatment planning conferences at the Medical School lasting at least 1 1/2 hr twice a week, to choose the cancer patient's plan of therapy and to select cases suitable for research protocols.

STAFF ACTIVITIES

A. Scientific Meetings and Courses Attended

Dr. José M. Tomé – Annual Mtg.Puerto Rico Medical Assoc., Nov. 1975, San Juan; 3rd Ann. Cancer Course for Physicians, P.R. Div. of Am. Cancer Soc., Jan. 1976, San Juan.

Dr. Jeanne Ubiñas – Annual Mtg. Puerto Rico Medical Assoc., Nov. 1975, San Juan; 3rd Ann. Cancer Course for Physicians, P.R. Div. of Am. Cancer Soc., Jan. 1976, San Juan.

Dr. Juan Reusche – Semi-Ann. Mtg. Radiation Therapy Oncology Group, San Diego, CA, Jan. 1976; 3rd Ann. Cancer Course for Physicians, P.R. Div. of Am. Cancer Soc., Jan. 1976, San Juan.

Dr. Victor A. Marcial – Cancer Ed. Committee Mtg. Nat. Cancer Inst., Jan. 1976, Bethesda, MD; Midwinter Radiological Conf., Jan. 1976, Los Angeles; 2nd Plenary Mtg. Scientific Program Committee 12th Int. Cancer Congr., May 1976, Toronto; Ann. Mtg. Am. Radium Soc., May 1976, Vancouver; Am. Cancer Soc. Nat. Conf. Radiation Oncology, May 1976, San Francisco; Cancer Ed. Committee Mtg. Nat. Cancer Inst., June 1976, Bethesda MD; Semi-Ann. Mtg. Radiation Therapy Oncology Group, June 1976, Hyannis, MA.

B. Distinguished Visitors

Dr. James A. Belli, Harvard Medical School, Boston, Massachusetts.
Mr. Thomas Ulmer, President Board of Directors, American Cancer Society.

Table 2: Case Load of the Radiation Oncology Division July 1, 1975 to June 30, 1976.

Site	No. of cases	Site	No. of cases
Buccal Cavity and Pharynx		**Bone, Connective and Soft Tissue, Skin, and Breast**	
Lip	3	Bone	2
Base of tongue	16	Leiomyosarcoma	1
Anterior two-thirds	3	Kaposis sarcoma	2
Parotid gland	4	Dermatofibrosarcoma	1
Salivary gland	1	Skin	50
Submaxillary gland	1	Breast	38
Lower gum	2		
Floor of mouth	9	**Urinary and Genital Organs**	
Oral mucosa	3	Cervix uteri	21
Palate	2	Endometrium	4
Retromolar angle	4	Ovary	5
Uvula	1	Prostate	2
Oropharynx	3	Penis	1
Tonsil	2	Bladder	5
Tonsilar fossa	9	Kidney	1
Faucial arch	6	Wilms' tumor	1
Nasopharynx	4		
Hypopharynx	5	**Other and Unspecified Sites**	
Pyriform sinus	4	Eye	1
Pharyngeal wall	1	Brain	16
		Neuroblastoma	3
Digestive Organs and Peritoneum		Chordoma	1
Esophagus	20	Meningioma	1
Stomach	2	Malignant paraganglioma	1
Rectum	4	Thyroid	2
Liver	1	Pituitary	6
		Primary unknown	3
Respiratory System			
		Lymphatic and Hematopoietic System	
Maxillary antrum	5	Reticulum cell sarcoma	3
Larynx	1	Lymphosarcoma	1
Vocal cords	8	Hodgkin's disease	12
Lungs	12	Eosinophilic granuloma	1
Mediastinum	1	Malignant lymphoma	8
		Multiple myeloma	4
		Leukemia	15
		Total New Cases	356
Teletherapy Applications (^{60}Co), Mev. XII, Superficial			17,045
Follow-up			1,964
Curietherapy Applications			26

Table 1: Nuclear Medicine Division Training Activities, July 1975 – June 1976
(Institutions given in parentheses are sponsors)

1. BASIC RADIOISOTOPE TECHNIQUE COURSE

June 30 – July 31, 1975

Angel F. Avilés Ramos, P.R. (Cayey U. College)
Antonia Benítez, P.R. (VA Hospital)
Carmen C. Caballero, P.R. (VA Hospital)
Elsa Cora, P.R. (UPR)
José N. Crespo Caruci, Venezuela (PRNC)
Manuel A. Marcial Seoanne, P.R. (UPR)
Frieda Silva de Roldán, P.R. (University Hospital)
Rubén L. Vélez, P.R. (UPR)
Ambrosio Yapura, Bolivia (PRNC)

Jan. 7 – Feb. 3, 1976

María C. Ballesteros, P.R. (UPR)
Yolanda Otero Castro, Colombia (PRNC)
Eduardo Brunel Ludwig, Brazil (PRNC)
Alba Nydia Cappas, P.R. (PRNC employee)

2. BASIC NUCLEAR MEDICINE COURSE

Aug. 4 – Dec. 31, 1975

Carlos Spada, Argentina (PRNC)
Ambrosio Yapura, Bolivia (PRNC)
José N. Crespo Caruci, Venezuela (PRNC)
José L. Molinaris, P.R. (PRNC)

Feb. 4 – June 30, 1976

Yolanda Otero Castro, Colombia (PRNC)
Eduardo Brunel Ludwig, Brazil (PRNC)
Diana Calderón Rodríguez, P.R. (observer)
Carmen Alicia Pérez, P.R. (PRNC employee; observer)

3. SPECIAL TRAINING

Orientation in Nuclear Medicine

Queenland Morales, M.D., P.R., Radiology resident – Sept. – Oct. 1975
Magali de Mari, M.D., P.R., Radiology resident – Jan. – Feb. 1976
Marcela de la Torre, M.D., Argentina – Feb. 23-27, 1976
María J. Baño, M.D., P.R., Radiology resident – Mar. 1-31, 1976
Gloria Arroyo, M.D., P.R., – Mar. 29 – May 31, 1976

Nuclear Medicine in Hematology

Feb. 4-27, 1976

José M. Sobrino, M.D., P.R.
Juan Javier, M.D., P.R.

Nuclear Medicine in Endocrinology

Feb. 4-27, 1976

Harry Jiménez, M.D., P.R.

4. NUCLEAR MEDICINE RESIDENCY

Frieda S. de Roldán, M.D., P.R. – 7/75; 4-7/76
Carmen C. Caballero, M.D., P.R. – 7/75; 1-2/76

5. NUCLEAR MEDICINE 100 (Elective)

Luis A. de Jesus Vargas, P.R. – June 6-18, 1975

6. ORIENTATION IN NUCLEAR MEDICINE FOR TECHNOLOGISTS

8 Lectures + 8 Demonstrations for 54 students – Oct. 20 - Nov. 3, 1975

7. HUMAN BIOLOGY I: Endocrinology

1 Lecture with demonstrations for 150 medical students – April 12, 1976

NUCLEAR MEDICINE

The Nuclear Medicine Division conducts clinical research in nuclear medicine and offers training in the medical applications of radioisotopes for physicians and technicians principally from Puerto Rico (USA) and Latin America. Diagnostic and therapeutic services are offered for patients from University Hospital in order to ensure an adequate patient load for research and training.

RESEARCH ACTIVITIES

A. Work Completed

Vitamin B_{12} Absorption in Pregnancy Followed Via a Whole-Body Counter — A. E. Lanaro and J. J. Corcino. The data have been analyzed and a paper is in preparation. See PRNC-198, p.50.

Use of ^{99m}Tc-DMSA for the Diagnosis of Myocardial Infarction — A. H. Sarmiento, A. E. Lanaro, and A. Suárez. The results have been written up and submitted for publication. See PRNC-198, p.50.

Evaluation of Liver Detoxification with ^{14}C Phenobarbital — A. Rodríguez-Olleros, R. Dietrich, E. Taveras, and A. E. Lanaro. The data have been analyzed, and a paper has been submitted for publication. See PRNC-198, p.50.

B. Work in Progress

Use and Usefulness of ^{67}Ga in Tumor Localization — E. Vélez Garcia and A. E. Lanaro. Data were collected on $\sim$150 patients with different malignant and inflammatory diseases. Evaluation of the data is now in progress. See PRNC-198, p.5l.

Effects of External Irradiation on the Normal Thyroid and Pituitary Gland — A. E. Lanaro. This study is an extension of the evaluation of thyroid uptake tests that was done at PRNC several years ago. The purpose was to compare different laboratory methods for measuring variation of thyroid function after irradiation. Only a few patients were studied during this period because of budget restriction, and no conclusions have been reached. See PRNC-198, p.51.

Effects of External Irradiation on the Normal Lung — A. E. Lanaro. This study is an extension of work begun with special funds from the AEC program RX 0103. Follow-up with perfusion scans is being done on patients seen during 1973-74 in order to determine late effects on lung tissue.

Follow-up on Hyperthyroid Patients Treated With Iodine-131 — A. E. Lanaro. Hyperthyroid patients treated with ^{131}I at PRNC were again asked to come in for an annual check-up. Of the 104 patients given clinical examinations and thyroid uptake tests, 61 were authyroid, 34 hypothyroid, and 9 hyperthyroid. See PRNC-198, p. 51.

Follow-up on Thyroid Carcinoma Patients Treated With ^{131}I — A. E. Lanaro. Patients treated for thyroid carcinoma were also requested to come in for a check-up. Of the 22 cases seen, 16 were positive and 6 negative. The positive cases will continue to receive treatment.

Radiation Injury to the Liver — E. Santiago Delpín, V. Marcial, and A. E. Lanaro. A group of dogs was tested with sulfocolloid ^{99m}Tc and Rose Bengal ^{131}I liver scans, ^{99m}Tc kidney scans,and Rose Bengal ^{131}I clearance. They were then irradiated with various doses to the liver. Some of them died, but the tests were repeated on the survivors. Many problems were encountered, particularly distemper and worm contamination of the dogs. These problems are being worked on so that the study can continue. See PRNC-198, p.50.

Biological and Effective Half-Life of Radionuclides in Children — A. E. Lanaro and J. Sifontes. A protocol was prepared and presented to the National Institutes of Health. The study plan includes the determination of biological and effective half-lives of different radionuclides in children submitted to routine nuclear medicine tests in the Division in order to establish the relation, if any, between these half-lives and other parameters such as sex, age, size, and biological situation. No radioactive material will be administered to any child solely for this study; only children referred for specific tests will be studied. The decay of the radioactive material will be followed in the whole-body counter through at least two half-lives. For normal controls, the data from children with normal results in the tests requested and without pathology in the studied organ will be used.

Study of Hepatic Tumors in Women Taking Oral Contraceptives — A. Fuertes de la Haba, A. E. Lanaro, and C. Rubio. The objective of this study is to determine the frequency of hepatic tumors in humans taking the pill for a long period. The maternal health program of the University of Puerto Rico School of Medicine has a large group of women who have used contraceptives for a long time, and also good controls. These women will be studied by Tc sulfocolloid scans in the Anger camera.

Digoxin Levels in Patients Submitted to Closed Cardiovascular Surgery — A. Martínez Picó, J. Sánchez, A. E. Lanaro, and J. M. Caamaño. The plan is to determine digoxin levels in patients with congenital heart disease who undergo cardiac surgery without extracorporeal circulation. Samples will be taken one day before and at least one and two days after surgery. The effects of such surgery on digoxin levels and tolerance will be studied.

TRAINING ACTIVITIES

The training activities of the Division are summarized in Table 1. In addition, Dr. Lanaro presented a seminar on nuclear medicine to 24 nursing students from Sacred Heart University College in August 1975.

MEDICAL SERVICES

From July 1975 through June 1976 a total of 4517 diagnostic and therapeutic procedures were carried out in the Nuclear Medicine Division. This is a smaller number than for the preceding fiscal year because of limitation of the service exclusively to the University District Hospital. This limitation saves money and results in better scientific work. A close relationship is maintained with the University District Hospital, which produces good clinical information and more complete studies. Even so, for some tests appointments are being given with a two-week delay.

Table 2: Teaching and Service Procedures Carried Out July 1975 to June 1976

	Teaching	Clinical Teaching	Service
Thyroid studies	89	272	706
Absorption studies	10	15	33
Hematology studies	24	4	9
Circulation studies	21	1	32
Total body water	2	0	1
Liver studies	9	2	11
Renal studies	11	6	28
Organ and tumor localization	46	296	859
Camara studies	71	691	1268
Subtotal	283	1287	2947
	Total 4517		

STAFF ACTIVITIES

A. Attendance at Scientific Meetings

Dr. A. E. Lanaro – First Regional Workshop of North Area of Latin Am. Assoc. of Societies of Biology and Nuclear Medicine, Aug. 1975, Mexico; Second Latin Am. Regional Mtg. of Nuclear Biology and Medicine, Caxias do Sul, Brazil, Sept. 1975; Seminar on Endocrinology, Children's Hospital, Buenos Aires, Oct. 1975; Lectures on Nuclear Medicine at VA Hosp. and at P.R. Soc. of Nuclear Medicine, Dec. 1975; Lectures on Ultrasound at VA Hosp., Feb. 1976; Symposium on the Thyroid (Bayamon Committee of Continuing Medical Education and Hospital Meléndez, Inc.), San Juan, Feb. 1976; Lectures on Immunobiology at Medical Sciences Campus and at P.R. Med. Assoc., Feb. 1976; P.R. Soc. of Nuclear Medicine Ann. Convention, San Juan, May 1976; Planning Committee of Second Congr. of World Federation of Biology and Nuclear Medicine (attended as representative of Latin Am. Assoc. of Societies of Biology and Nuclear Medicine), Dallas, June 1976; 23rd Ann. Mtg. of Soc. of Nuclear Medicine, Dallas, June 1976.

A. H. Sarmiento – Lectures on Ultrasound at VA Hosp., Feb. 1976.

B. Changes in Staff

Appointment: Mr. Víctor Serrano, Nuclear Medicine Technician, Feb. 5, 1976.

Resignations: Mrs. Aida Avila de Medina, Nuclear Medicine Technician, Jan. 16, 1976;
Dr. Arístides H. Sarmiento, Senior Scientist I, April 30, 1976;
Mrs. Olga Aponte, Research Assistant II, June 30, 1976.

Ad Honorem Appointees: See PRNC-198, p.55.

C. Distinguished Visitor

On November 23 and 24, 1975, Dr. Grafton D. Chase, from the Philadelphia College of Pharmacy and Science, who was in Puerto Rico as a guest of PRNC and the P.R. Society of Nuclear Medicine, visited the Nuclear Medicine Division.

Medical Physics

The Medical Physics Section is concerned mainly with the solution of physical problems and the development of new techniques associated with the medical applications of ionizing radiations. It provides the physics support necessary for efficient functioning of the Radiation Oncology Division, including staff training, and also offers limited technical assistance to the Nuclear Medicine Division.

RESEARCH ACTIVITIES

A Nomogram for the Estimation of an Average Tissue-Air Ratio for Rotation Therapy Planning — A. M. Thompson and E. T. Agard. This work (see PRNC-198, p. 57) has been published.

Isocentric Dosimetry for 8-MV Photons — J. C. Pacheco and E. T. Agard. This work (see PRNC-198, p.57) has been written up and submitted for publication.

Electron Dosimetry at 3, 7, and 11 MeV — E. T. Agard and J. C. Pacheco. This work (see PRNC-198, p.57) is being published.

Solution of a Dosimetry Problem Caused by a Mercury Shutter — A. T. Agard, M. A. Gribble, J. C. Pacheco, and S. Gómez F. A paper on this incident, involving the malfunction and subsequent repair of the mercury shutter system of the PRNC Eldorado-A cobalt unit, has been accepted for publication.

A Technique for Contrast Enhancement in Portal Radiographs — M. A. Gribble, E. T. Agard, and J. Reusche. At the radiation energies used in treatment of radiotherapy patients, one of the serious drawbacks in the use of portal radiographs (check-radiographs exposed to the radiation of the treatment unit with the patient in the treatment position) is the lack of definition of anatomical structures. Lead filters inserted into the radiation beam have been able to increase the radiographic image contrast by as much as 50%. A paper describing this research has been submitted for publication.

Calibration of 3-MeV Electrons with Thimble Ionization Chambers — J. C. Pacheco and E. T. Agard. A paper on this research is being prepared for presentation.

TRAINING ACTIVITIES

1. In-service Training

Dr. Alfredo Moscol, Radiation oncology resident — Oct.-Nov. 1975.
Ms. A. Caraballo, X-ray technician, PRNC — Oct. 1975.
Ms. E. Colon, X-ray technician, PRNC — Nov. 1975.

2. Special Training in Medical Physics and Radiation Dosimetry

Ms. Azucena Garzón-Quiróz, Ecuador Atomic Energy Commission — May-July 1976.

3. M.S. Course in Radiological Health

This course was placed "in moratorium" because of a lack of funding.

4. Physics Seminars

From October 1975 to June 1976, weekly open seminars were held in the Medical Physics Section. Informal papers and discussions were presented by staff members of the Section and of the Health and Safety Division, on a wide range of physics-related topics. Average attendance was 6 to 10 persons.

STAFF

Dr. E. T. Agard, Head of the Medical Physics Section, attended the Second Latin American Conference on Medical Physics and Radiological Protection in Belo Horizonte, Brazil, in July 1975 and presented a paper. In February 1976, he was elected President of the Puerto Rico Chapter of the Health Physics Society for 1976-1977. To the regret of many people at PRNC, on June 30, 1976,Dr. Agard resigned both as Section Head and as Chapter President; he will head a department in a Medical Center in Dayton, Ohio.

Mr. José C. Pacheco attended the International Conference on Computerized Transaxial Tomography in San Juan in March 1976.

Mr. Michael A. Gribble, a medical physicist with four years' experience, from the Poole General Hospital in England, joined the staff of the Medical Physics Section in August 1975. Mr. Gribble has B.Sc. Honours in Physics from the University of Aston, Birmingham, England, 1971; and an M.Sc. in Radiation Biology from London University, 1974.

HUMAN ECOLOGY

The Division of Human Ecology conducts research related to the impact on man's health of energy production and subsequent ecological alterations, in the tropics. The program also includes work on the tropical disease schistosomiasis, supported by outside agencies. The juxtaposition of nuclear technology and tropical diseases affords a unique opportunity to apply advanced methodologies to classical endemic diseases which have been difficult to control with traditional techniques. At the same time, the rapid industrialization of Puerto Rico and several Latin American and Caribbean nations makes it necessary to find ways of minimizing the health impact of expanding energy production in the tropical environment. Utilization of such advanced technology in the tropical Americas requires training of scientists and students as methods are developed; therefore, the Division maintains its emphasis on local and international education and training in the Caribbean and Latin America.

RESEARCH ACTIVITIES

Hydroelectric Reservoir Project (M. Bhajan, R. A. Brown, M. Caballero, W. Jobin, and V. Lopez)

The purpose of this project is to assess the environmental health impacts of proposed hydroelectric reservoirs and to develop methods of minimizing them. The ecology of existing hydroelectric reservoirs in Puerto Rico is being studied in order to determine the factors that cause or prevent health problems related to them. The major health problem being investigated is schistosomiasis. Methods will be developed for predicting the extent of disease transmission from new reservoirs being designed but not yet constructed. Alternative designs and other preventive or control measures will be studied.

In this first year of the project, major emphasis was on an ecological survey of all reservoirs in Puerto Rico prior to selection of six for continued study in the next two years. A joint team from the Health Department and PRNC surveyed 28 reservoirs, two of which (Lakes Carite and Cidra) were intensively studied with additional help from the University College at Cayey.

Lake Carite was very low in algal productivity (0.7 mg/liter per day). The lake was turbid but contained low populations of coliform bacteria and possible viruses. The high turbidity contributed to the low algal populations and reduced photosynthesis. Consequently, the population of primary herbivores such as mollusks was low, and the lake was generally low in biota. *Biomphalaria glabrata* were found in the emergency spillway, but they were not infected with schistosomes. The surrounding human population was very sparse and had little contact with the water.

In sharp contrast, the Cidra Reservoir had floating masses of water hyacinth, large snail populations including *Lymnaea* infected with *Fasciola*, and gross sewage pollution including coliform bacteria and viruses, probably Coxsackie. The lake was surrounded by

Table 1: Snails and Vegetation in Major Lakes of Puerto Rico, 1976

Lake No.	Name	Bg*	Mc	Tg	Pa	Ph	Ly	Tr	Water Hyacinth	General Vegetation
1	Adjuntas	-				X			-	Sparse
2	Caonillas	-							-	Sparse
3	Carite	X			X				-	Sparse
4	Carraizo	X			X				X	Abundant
5	Cartagena								-	Sparse
6	Cidra	-	X		X				X	Moderate
7	Coamo								X	Abundant
8	Comerio #1	-	X	X		X	X		X	Moderate
9	Comerio #2	-	X	X					X	Moderate
10	Dos Bocas	X	X	X					X	Moderate
11	Garzas	X	X	X		X			-	Sparse
12	Guajataca	-	X	X				X	-	Sparse
13	Guayabal	-	X	X				X	-	
14	Guayo	-	X						-	Sparse
15	Guineo	-	X	X		X		X	-	
16	Jordan	-	X						-	
17	La Plata	-	X	X					X	Moderate
18	Las Curias	-	X	X					-	Sparse
19	Loco	-	X	X					-	
20	Luchetti	-	X	X				X		
21	Matrullas	-				X			-	Sparse
22	Patillas	-	X	X					-	Sparse
23	Pellejas	-							-	
24	Prieto	-	X						-	Sparse
25	Rio Blanco	-							-	
26	Toa Vaca	-	X	X				X	-	Sparse
27	Toro	-								
28	Tortuguero	X	X	X						
29	Vivi	-				X				
30	Yahuecas	-								

* Bg= *Biomphalaria glabrata*

Mc= *Marisa cornuarietis*

Tg= *Tarebia granifera*

Pa= *Pomacea australis*

Ph= *Physa* sp.

Ly= *Lymnaea* sp.

Tr= *Tropicorbis* sp.

housing developments and pasture containing horses and cattle. Algal populations were high, as were insect and bird populations.

In the other 26 surveys the primary emphasis was on water chemistry and snail populations. All reservoirs contained aquatic snails except four, which were extremely clear lakes of low productivity. *Biomphalaria glabrata*, the intermediate snail host of schistosomiasis, was found in five (Table 1), all of which are hydroelectric reservoirs except Tortuguero Lagoon.

The other predominant snail species were *Marisa cornuarietis* (in 18 reservoirs), *Tarebia granifera* (in 14), and *Physa cubensis* (in 6). All the reservoirs that contained *Biomphalaria glabrata* had at least one and usually two of these other species. A large ampullarid snail, probably a species of *Pomacea*, was found in three lakes, two of which also contained large masses of floating water hyacinth and showed gross evidence of eutrophication such as algal blooms and anaerobic bottom sludges. However, one lake (Dos Bocas) showed eutrophication with water hyacinth but no *Pomacea*.

The lakes in general tended to be clean with low levels of phosphates and nitrates (Table 2). It is interesting that Cidra Lake, which is known to be heavily contaminated and whose shore is overgrown with water hyacinths, has barely detectable phosphates and about 0.2 mg/liter nitrates. This tends to support reports suggesting that the water hycinth is very efficient in removing nutrients from the water. Cidra Lake has more chlorides than most of the others; perhaps chlorides serve as an indicator of contamination. The iron content in samples taken from lakes early in the year was very low but in samples taken from other lakes during the winter it was much higher; this may reflect overturn of previously stratified lakes.

Methods for Detecting Schistosome Cercariae and Miracidia in Hydroelectric Reservoirs

The filtration method often used to concentrate and detect cercariae in the field is being used in the reservoir study program and has been quantitatively tested in the laboratory. It is essential that a pump with a good vaccuum be used for the filtration or most of the cercariae are lost under the filter paper, and there are unavoidable losses of cercariae on surfaces. The recovery rate in laboratory studies closely simulating field conditions was a rather consistent 25%.

The results of using sentinel snails for detecting schistosome miracidia was compared with the results of coliform bacteria sampling in the Carraizo Reservoir and its tributaries on two occassions, and in Carite and Cidra Lakes. Twelve stations on Carraizo Lake were found to have high coliform levels (10^4 to 10^6 per 100 ml) but no miracidia. Low numbers of coliform bacteria were found in Lake Carite (200 per 100 ml) and no miracidia. In Lake Cidra, despite high concentrations of coliform (10^6 per 100 ml) and the presence of enteroviruses, no miracidia were found. Although the sentinel snail technique was satisfactory from the practical standpoint, it must be tested during the dry summer transmission season when miracidia are more common. The preliminary testing this year was done with extremely high reservoir levels due to heavy rainfall.

Methods for Schistosome Control in Hydroelectric Reservoirs

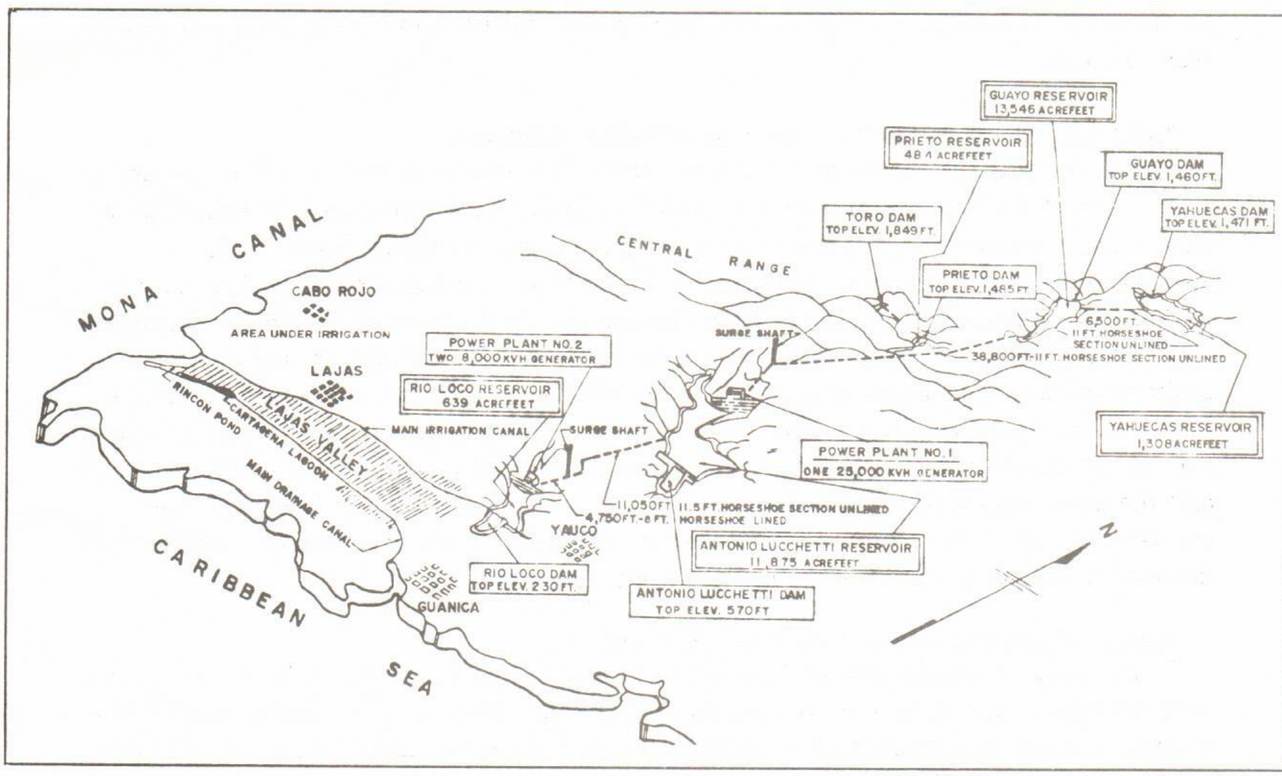
Whenever feasible, biological control methods are highly desirable because they are in general inexpensive and environmentally safe. This is especially true for schistosomiasis control in Puerto Rico's hydroelectric reservoirs because many of them are used also for human water supply. Data from several sources have established that the *S. mansoni*

Table 2: Water Quality in Major Reservoirs of Puerto Rico, 1976

	Lake	No. of samples	(standard units)	Turbidity (standard units)	Chlorides (mg/liter)	Total phosphates (mg P/liter)	Iron (mg/liter)	Nitrite and nitrate (mg N/liter)	Hardness ($mg\ MgSO_4$/liter)
1	Adjuntas	3	6.7±2.1	1.1±0.4	10.7±5.9	0.25±0	0.23±0.15	0.22	144.5±17.3
2	Caonillas	21	8.9±2.0	19.9±2.9	10.8±2.8	0.04±0.04		0.18±0.16	95.7±21.1
3	Carite	5	7.8±2.7	8.0±7.2	7.7±0.5	0.04±0.03	0.78±0.39	0.09±0.05	49.8± 1.2
4	Carraizo	6	21.7±11.7	30.5±58.8	29.3±9.2	0.18±0.10		0.95±0.73	101.1±52.5
5	Cartagena								
6	Cidra	6	8.6±2.0	2.8±2.6	14.1±0.4	0.02±0.02	0.56±0.27	0.17±0.11	76.3± 2.6
7	Coamo								
8	Comerio #1								
9	Comerio #2								
10	Dos Bocas	6	11.3±2.9	6.9±6.7	11.5±3.2	0.08±0.20*		0.54±0.70	127.0±67.7
11	Garzas	16	7.3±2.4	2.2±2.2	4.1±0.7	0.02±0.01	0.31±0.24	0.03±0.02	64.2± 8.5
12	Guajataca								
13	Guayabal	6	11.7±6.1	5.2±5.2	7.8±2.2	0.06±0.02		0.13±0.13	21.4± 4.4
14	Guayo	10	10.0±0	2.7±1.8	4.9±1.8	0.02±0.01	0.17±0.09	0.16±0.14	92.5±18.6
15	Guineo	6	5.0±0	1.6±1.3	2.9±0.5		0.04±0.01	0.03±0.01	
16	Jordan	2	6.0	12	13.6	0.01	0.1	0.02	156.9
17	La Plata								
18	Las Curias								
19	Loco	6	5.3±0.8	5.3±4.7	8.3±3.7	0.04±0.02	0.03±0.01	0.12±0.10	
20	Luchetti	23	5.3±0.8	3.0±2.1	7.7±0.5	0.04±0.05	0.23±0.21	0.30±0.31	156.7±10.4
21	Matrullas	8	5.0±0	2.2±0.7	5.6±2.9		0.03±0	0.04±0.03	
22	Patillas								
23	Pellejas	2	6.5	15.3	9.8	0.01	0.5	0.02	138.3
24	Prieto	1	12	0.4	8.0	0.01	0.4	0.27	203.2
25	Rio Blanco								
26	Toa Vaca	13	6.1±1.7	1.8±1.0	10.1±2.0	0.09±0.08	0.04±0.01	0.04±0.03	30.2±11.0
27	Toro	1	5	10.6	9.9			0.44	138.3
28	Tortuguero								
29	Vivi	3	6.3±0.6	1.9±1.6	10.2±2.4	0.01±0	0.40±0.40	0.08±0.10	127.9±36.2
30	Yahuecas	4	10.5±4.2	75.0±10.8	8.6±2.4	0.04	0.24	1.03±0.45	120.9±14.2

* From 25 samples.

Kariba Dam on the Zambesi River in Central Africa.



Lajas Valley Irrigation and hydroelectric power system.

miracidium is attracted to its host by a simple chemical or chemicals. The attractant is not specific, and many classes of organisms including other snails attract the miracidia in competition with the host snail. This finding can be utilized for schistosomiasis control by introducing another snail species into reservoirs where transmission occurs and thus decreasing the probability of successful snail infections. Four snail species, *Marisa*, *Pomacea*, *Tarebia*, and *Helisoma* were tested as competitors in laboratory experiments in plastic pools with ratios of decoy snails to *B. glabrata* of 0, 2, 5, and 10. All the controls were >90% infected; the highest ratio of decoys reduced infection rates in the *B. glabrata* to zero in two cases and to 20% in the third. This result is highly significant since the method is ideal for use in hydroelectric reservoirs in Puerto Rico and may make it possible to open many of them for recreation in the near future.

Epidemiological Modeling Project (H. Negrón and C. M. Nazario)

In the development of new energy production facilities and in programs to reduce pollution from existing facilities, planners need tools for predicting the environmental and health impact of these changes. Since PRNC is in the tropics, a subject of special concern is the relationship of tropical diseases to hydroelectric impoundments, which in Latin America and Africa have had considerable impact in spreading schistosomiasis, malaria, onchocerciasis, and other parasitic diseases. More subtle diseases caused by air pollution from oil-fired steam plants also occur in tropical areas, especially in those undergoing rapid industrial development, and these also merit attention. The purpose of this project is to develop epidemiological models that can be used to predict the changes in disease prevalence and incidence related to power facilities in Puerto Rico and other tropical areas.

Epidemiological Data for African and Brazilian Reservoirs

During the year site visits were made to Volta Reservoir in Ghana and Trés Marias, Furna, and Volta Grande Reservoirs in Brazil to gather engineering and epidemiological data. Data summaries were also obtained for Lake Nasser in Egypt, Lake Kariba in Rhodesia and Zambia, Kossou Lake in the Ivory Coast, and Lake Kainji in Nigeria. Of these 10 hydroelectric reservoirs, the one having the most complete information available was Volta Reservoir in Ghana. Preliminary modeling was completed on one phase of schistosomiasis transmission in the Afram arm of Volta Reservoir, where an epidemic of *Schistosoma haematobium* occurred soon after filling. Field and laboratory data on dispersion of schistosome miracidia and cercariae were analyzed and related to snail populations, and the effectiveness of a chemotherapy program was compared with that of a snail control program. The latter was shown, by simple model analysis, to cause a much greater decrease in incidence rates for local inhabitants.

Survey of Schistosomiasis Prevalence in Puerto Rico

As the basis for epidemiological modeling of schistosomiasis in Puerto Rico, an Island-wide prevalence survey was conducted by skin-testing a 25% random sample of all fifth-graders. Antigen was prepared from adult schistosome worms, standardized for nitrogen content, and sterilized. Public Health nurses skin-tested >18,000 children by the same procedure used in the surveys of 1963 and 1969, which provided reference data. In the area of eastern Puerto Rico where bilharzia is endemic, a serious increase was found in the

Table 3: Prevalence of Bilharzia in Eastern Puerto Rico Among Fifth-Graders, May 1976

Municipality		Total children			Urban				Rural			
		No. pos.	No. tested	% pos.	No. schools	No. pos.	No. tested	% pos.	No. schools	No. pos.	No. tested	% pos.
Aibonito	1	40	443	9.0	1	16	124	12.9	7	24	319	7.5
Arroyo	2	27	236	11.4	1	16	96	16.7	3	11	140	7.8
Caguas	3	31	251	12.4	4	16	129	12.4	5	15	122	12.3
Canovanas	4	38	84	45.3	1	14	27	51.9	2	24	57	42.1
Carolina-P	5	81	170	47.7	1	27	58	46.5	3	54	112	48.2
Guayama	6	91	648	14.1	3	27	226	12.0	10	64	422	15.2
Gurabo	7	33	327	10.1	1	16	119	13.5	8	17	208	8.2
Humacao	8	228	730	31.2	3	88	263	33.5	14	140	467	30.0
Juncos	9	120	464	25.9	1	49	146	33.6	9	86	318	27.0
Las Piedras	10	125	390	32.1	1	64	138	46.3	7	61	252	24.2
Loiza	11	8	51	15.7	1	5	21	23.8	1	3	30	10.0
Luquillo	12	120	237	50.1	1	44	65	67.7	4	76	172	44.1
Maunabo	13	35	258	9.7	1	10	103	9.7	4	15	155	9.7
Naguabo	14	63	241	26.2	1	38	94	40.4	7	25	147	17.0
Patillas	15	42	444	9.5	1	5	103	4.8	11	37	341	10.8
Rio Grande	16	196	526	37.2	1	88	191	46.1	8	108	335	33.2
Salinas	17	43	426	10.1	2	5	92	5.4	9	38	334	11.4
San Lorenzo	18	9	132	6.8	1	2	35	5.7	3	7	97	7.2
Trujillo Alto	19	22	87	25.3	1	17	38	44.8	2	5	49	10.2
Yabucoa	20	214	708	30.2	1	54	117	46.2	18	160	591	27.1
Vieques	21	30	156	19.3	1	7	55	12.7	3	23	101	22.8

Table 4: Comparison of Bilharzia Prevalence in Eastern Puerto Rico in Areas With and Without Control Effort, May 1976

	Pos.	Total	% Prev.
Original Control Programs 1954–1976			
Aibonito	40	443	9.0
Arroyo	27	236	11.4
Guayama	91	648	14.1
Naguabo	63	241	26.2
Patillas	42	444	9.5
Vieques	30	156	19.3
Total	293	2168	13.5
New Control Programs 1969–1976			
Gurabo	33	327	10.1
Humacao	228	730	31.2
Juncos	120	464	25.9
Las Piedras	125	390	32.1
Maunabo	35	258	9.7
Salinas	43	426	10.1
Yabucoa	214	708	30.2
Total	798	3303	24.2
Areas Not Controlled (Samples)			
Caguas			12.4
Canovanas			45.3
Carolina			47.7
Loiza			15.7
Luquillo-Total			50.1
Rio Grande-Total			37.2
San Lorenzo			6.8
Trujillo Alto			25.3
Weighted mean			28.1

municipalities directly downstream and east of Lake Carraizo (Canóvanas, Carolina, Rio Grande, and Luquillo), and the prevalence was generally higher in rural than in urban areas (Table 3). Preliminary analysis of the results of control efforts showed a significant drop in the prevalence rate in the areas of the original control programs compared with that in untreated areas (Table 4).

Schistosomiasis Control Project (W. Jobin, F. Liard, and M. Bhajan)

This project, jointly sponsored by ERDA and the Edna McConnell Clark Foundation, was aimed at making a global survey of the best available methods for schistosomiasis control in the tropics (see Figures 1 and 2); it was completed in 12 months. The conclusions reached after review and analysis of 41 projects on schistosomiasis control throughout the tropics included the following.

1. Schistosomiasis control programs should combine chemotherapy, snail control, and provision of domestic water in that order of priority. Although chemotherapy is expensive, it provides greater benefit than the other methods per unit cost.

2. Chemotherapy with Hycanthone for *S. mansoni* and Ambilhar for *S. haematobium* is effective and costs \$3.50 to \$10.00 annually (1972 prices) per person in the endemic zone. Two newer drugs, Oxamniquine and Metrifonate may soon replace Hycanthone and Ambilhar, respectively.

3. For snail control the universally accepted chemical is Bayluscide, and annual costs per 100 cubic meters of treated habitat are ∿\$20 in natural drainage systems and ∿\$3 in irrigation systems (1972 prices). Per capita costs have limited meaning in relation to snail control, but were estimated as \$0.40 to 7.40 per year.

4. Provision of adequate domestic water will be as effective as snail control if adequate health education is included in the program. Such a program, with high effectiveness, will cost ∿\$10 per capita per year.

5. Of six major control projects, only one encountered a problem in meeting its initial objectives, and a change in strategy corrected it. This shows that the means and ability to control schistosomiasis are generally available.

6. Projects have been initiated in 23 countries, but successful national programs have been carried out only in Iran, Japan, Puerto Rico, and Venezuela, all relatively wealthy countries.

7. Global control of schistosomiasis, defined as prevalence of <1% in any nation, would cost about \$3 billion, the major costs being \$1 billion each for Brazil and Egypt, and would take ∿20 years. (See Table 5.)

8. Because of international market considerations it is doubtful that cheaper drugs or cheaper chemicals for snail control will be found.

9. The most promising approach to reducing costs is to develop biological methods for controlling snails and transmission, and environmental methods for controlling snail habitats and human contact with infected water. Such methods involve costs generally outside the international market structure, and they depend primarily on local materials and unskilled labor.

10. The areas for most cost-effective control operations are the ones with the highest intensity of infection and the highest prevalence rates; these are Brazil for *S. mansoni* and Egypt for *S. haematobium*.

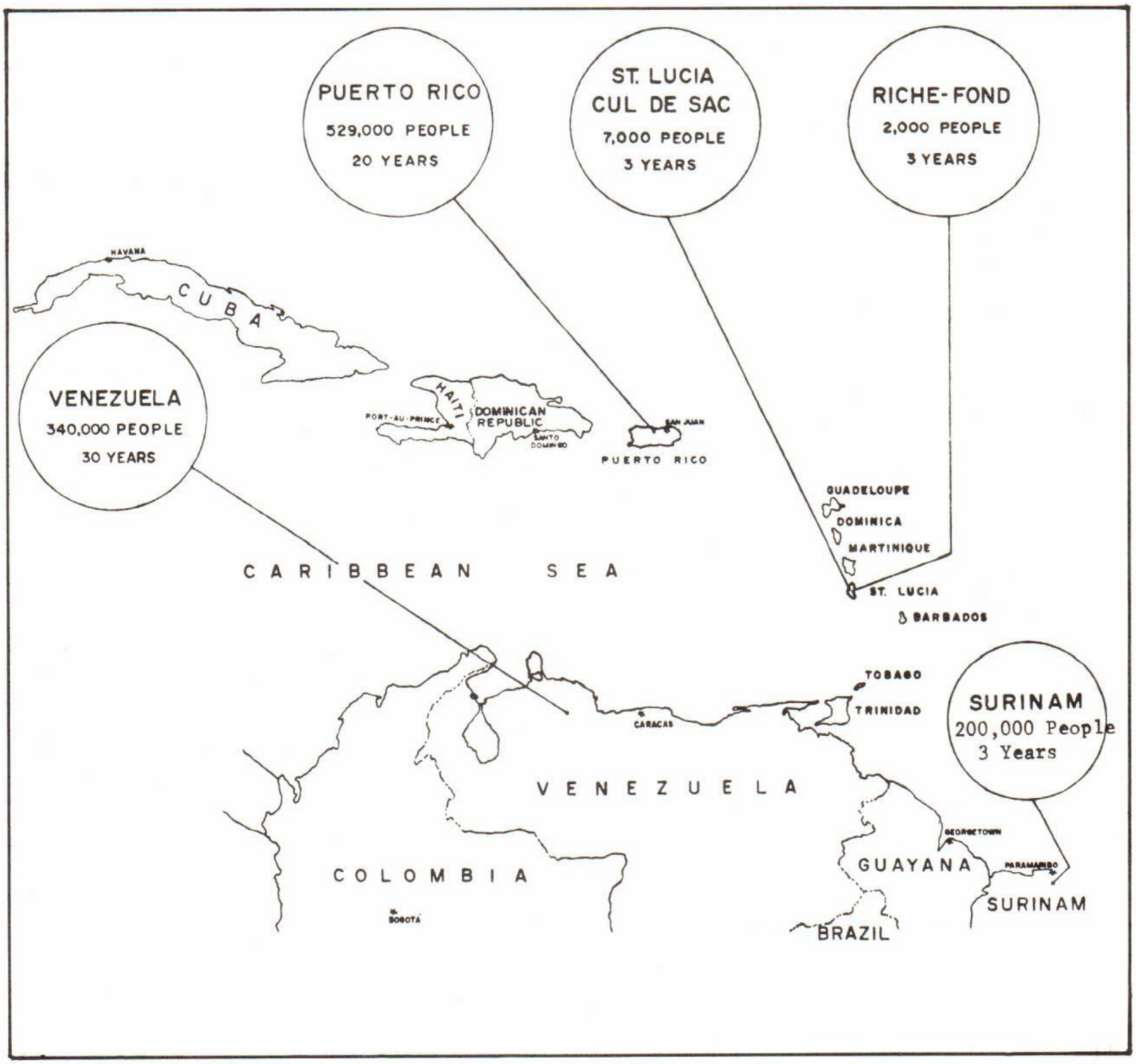


Figure 1: Programs for control of *Schistosoma mansoni* in the Caribbean.

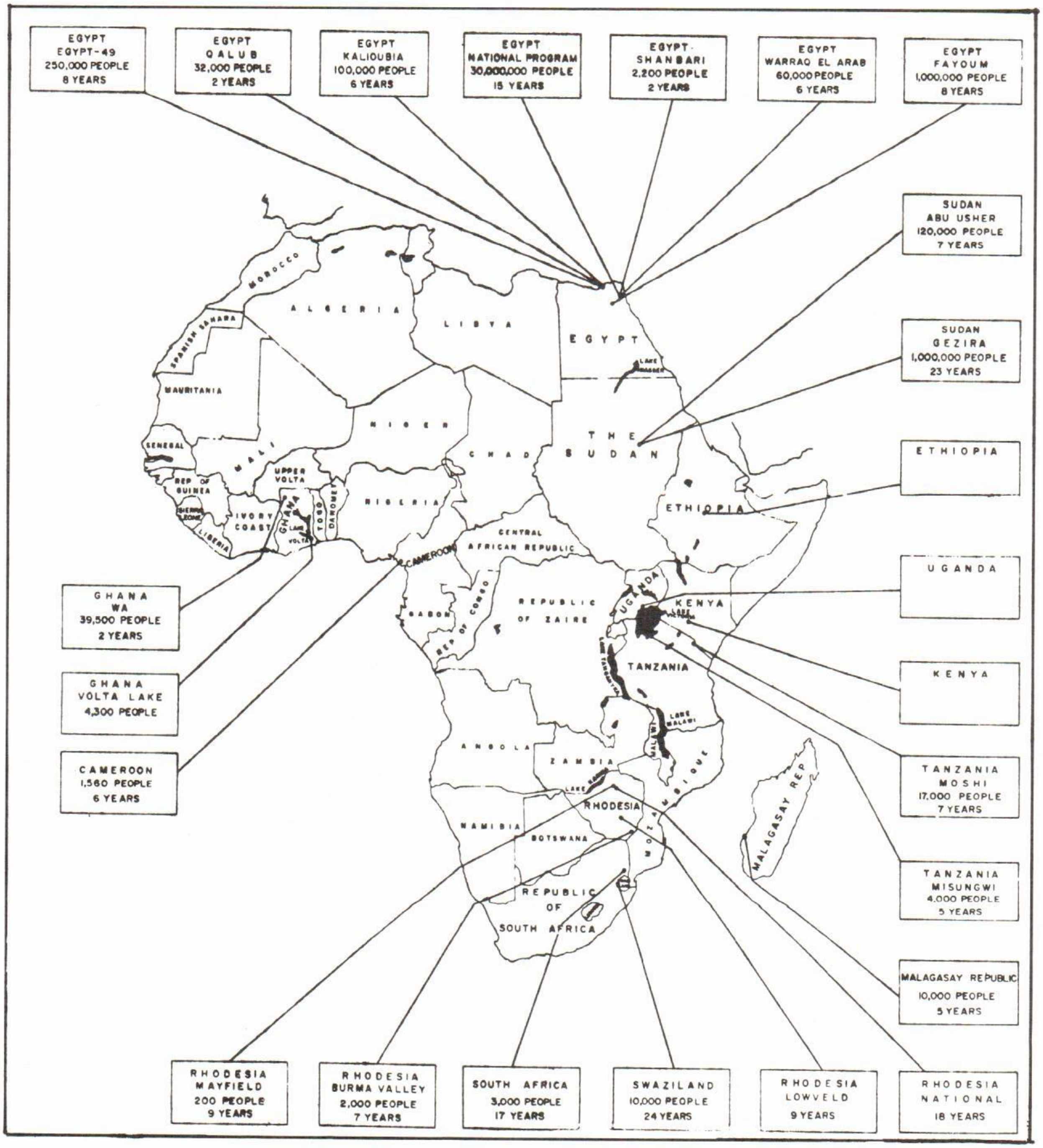


Figure 2: Programs for control of schistosomiasis in Africa.

Table 5: Comparison of Molluscicide Program Costs for Eleven Recent Schistosomiasis Control Projects.

COUNTRY	PUERTO RICO			ST. LUCIA	BRAZIL			EGYPT	IRAN	TANZANIA	MALAGASY
LOCALITY	Vieques	Patillas	Guayama Arroyo	Cul de Sac	São Lourenco	Belo Horizonte	Taquarendi	Kom El Birka	Dez Scheme	Misungwi	Mangoky
HYDROLOGY	Natural	Natural and Irrigation	Natural and Irrigation	Natural	Natural	Natural and Irrigation	Irrigation	Irrigation	Irrigation	Natural	Irrigation
Annual Rainfall (cm)	115	179	140	250	150	160	50	30	30	100	61
Controlled Area (Km^2)	130	122	207	18	80	200	2.5	52	220	100	100
Population	8,400	17,100	47,000	6,000	4,280	20,000	1,500	17,000	18,000	4,300	11,000
Annual Volume of Snail Habitat treated (m^3)	65,000	89,000	106,400	182,000	80,000	39,000	15,000	1,354,000	500,000	200,000	554,000
Habitat Volume per Surface Area (m^3/km^2)	500	739	514	10,000	1,000	195	6,000	16,000	2,300	2,000	5,540
Population Density (persons/km^2)	64	140	227	333	54	100	600	330	82	43	110
Habitat Volume per person (m^3)	7.8	5.2	2.3	30	18.5	2.0	10	80	28	46	50
Molluscicide	NaPCP	NaPCP	NaPCP	Bayer	Bayer	Bayer	Bayer	NaPCP and Bayer	Bayer	Bayer	Frescon
Cost Period (years)	10	7	1	1.1	10	4	5	1	1	1	5
Currency	U.S.$	U.S.$	U.S.$	U.S.$	U.S.$	U.S.$	U.S.$	Egyptian £	U.S.$	Shillings	Swiss Franc
Total Cost of Program	$63,600	$60,380	$8,298	$27,000	$316,800	$34,000	$6,800	20,700	$17,000	TS 30,000	SF 270,000
Base year for Costs	1960	1960	1955	1972	1972	1968	1968	1963	1972	1972	1972
Annual Cost in 1972 U.S. Dollars	$13,000	$17,000	$20,000	$25,000	$ 32,000	$10,000	$1,500	$58,600	$17,000	$4,178	$18,000
Annual Cost per 100 m^3 treated	$ 20	$ 19	$ 19	$ 14	$ 40	$ 26	$ 10	$ 1.40	$ 3.40	$ 2.10	$ 3.25
Annual Cost per Km^2	$ 100	$ 139	$ 97	$ 1,400	$ 400	$ 50	$ 600	$ 1,130	$ 77	$ 42	$ 180
Annual Cost per person	$ 1.50	$ 1.00	$ 0.43	$ 4.17	$ 7.40	$ 0.50	$ 0.70	$ 3.45	$ 0.94	$ 0.75	$ 1.65
Program Cost Breakdown											
Labor	65%	61%		50%	80%	50%	36%	5%	6%		17%
Molluscicide	3%	6%	11%	12%	10%	11%	40%	85%	19%	25%	21%
Transport and Equipment	7%			16%	5%	15%	24%		21%		18%
Supervision	22%			16%		24%			54%		15%
Others	3%	33%	89%	6%	5%			10%		75%	29%

Air Pollution Project (J. M. Chiriboga and V. A. López)

This project is concerned with the effect of pollution due to utilization of oil for energy and other purposes in Puerto Rico. Several approaches are used to correlate air pollution levels with human and animal health. Epidemiological studies seek links between morbidity and mortality in populations with high and low risk. A small epidemiological study in Cataño and Guayanilla uses the Espíritu Santo area as a control.The Cataño area has the Palo Seco plant, one of the major producers of both gaseous and particulate pollutants in Puerto Rico. A recent change in the combustion system has reduced its particulate output by a factor of ten, and a correlation is being sought between this dramatic change and local health data. The incidence of respiratory disease and asthma encountered in the emergency room at Cataño has been extraordinarily high (Table 6).

Biological Test System for Pollutants That Damage DNA

Biological test systems are being developed in the laboratory for detecting substances in the atmosphere that can damage DNA. In one system, the growth of an *E. coli* mutant deficient in DNA polymerase is inhibited by mutagens because the mutant cannot repair the damage to the DNA. The response of this mutant to benzopyrene and hydroxyurethane is being quantitated. In another system, cells are exposed to the toxicant and then examined for micronuclei. The sensitivity of the method is not very high, and an attempt has been made to enhance it by using irradiation (Table 7).

TRAINING ACTIVITIES

Participants in the Division's educational activities are listed in Table 8.

Thesis work is summarized below. An asterisk indicates that the work has been completed. All degrees were from UPR School of Medicine.

The Effects of Gamma Irradiation on Different Stages of *Fasciola hepatica*. José Luis Torres (for M.S. in Anatomy* under Dr. J. Chiriboga). Study of the alteration in viability of normal *Fasciola hepatica* metacercariae as a function of storage time at 4°C showed a significant decrease only after 100 days. Comparison of the *in vitro* viability of normal metacercariae with that of those exposed to increasing radiation doses revealed two opposite effects: (a) activation of the excystation process by the lower radiation doses (1.5 and 2.5 kR) persisting up to the 14th day post-radiation and (b) impairment of the process starting on the 14th day by doses of 3.5 and 5.0 kR. Rats were used to study correlation between liver damage and radiation dose to metacercariae, up to 34 days after oral inoculation. Hepatic parenchymal destruction was measured in terms of serum glutamic pyruvic transaminase (SGPT) levels. Rats infected with 1.5-kR-irradiated metacercariae showed a greater increase in SGPT level than normally infected rats, which has been tentatively associated with inability of the developing worms to find the liver ducts. Metacercariae irradiated with 2.5 and 5.0 kR produced only a slight elevation of SGPT. Correlation was good between SGPT level and macroscopic and microscopic liver lesions in rats infected with unirradiated and irradiated worms.

Adult *F. hepatica* incubated in Hedon-Bleig solution for 6 hr release many types of proteins, some of which are neoformed judging by the incorporation of ^{75}Se-methionine. These proteins were purified by Sephadex G-100 and gel electrophoresis. The Sephadex elution curve had two peaks, A and B. Peak B precipitates specifically with *Fasciola*-

Table 6: Respiratory Ailments Among ∿2000 Patients Seen in Emergency Room of Cataño Health Center, January 1976

Asthma	9.8 %
Other Respiratory	16
Allergy	2
Cardiovascular	2

Table 7: Effect of Benzopyrene and Radiation on the Percent of Micronuclei in Bone Marrow of Mice (For each group 1500 bone marrow cells were counted from 3 mice)

Group	% Micronuclei
Control	0.12
Benzopyrene (2 mg)	0.13
Benzopyrene + radiation (200 R)	1.00
Radiation (200 R)	0.20

Table 8: Participants in Educational Activities of Human Ecology Division
(From Puerto Rico unless otherwise noted)

Project	Participants	Date
Fasciola hepatica	Dr. Rene Cardona	15Jun75 – 20Jul 75
Schistosoimiasis	15 Inspectors, Health Dept.	1Sep75 – 5Sep75
	Michael G. Uhrin (PA)	1Jul75 – 30Aug75
	Angel Laracuente	1Jul75 – 30Jun76
Hydroelectric Reservoirs	Martha Caballero (Peru)	1Jul75 – 31Dec75
	4 Students, UPR-Cayey	1Dec75 – 31Jan76
	Ada L. Irizarry	1Jun76 – 30Jun76
	Luz E. Torres	1Jun76 – 30Jun76
	Amarilis Silva	1Jun76 – 30Jun76
Parasitology	Iván Carrión	1Jul75 – 30Jun76
Fossil Fuel	Ana L. Rodrĭguez	1Jul75 – 30Jun76

positive rat serum but not with normal rat serum, and ammonium sulfate precipitation showed a high specific binding. Each peak obtained was found to be a mixture of proteins. The electrophoresis pattern showed 4 bands in peak A and 3 bands in peak B. Protein synthesis in adult parasites irradiated with 1.5 and 2.5 kR increased; in those irradiated with 5.0 kR it decreased slightly.

It was concluded that (1) metacercarial excystation is not hindered appreciably by storing at 4°C for <3 months but is greatly reduced by longer storage; (2) radiation doses of up to 2.5 kR do not impair metacercarial excystation within 2 weeks post-irradiation; (3) inocula of 2.5-kR-irradiated metacercariae are capable of excystation in rats, some of the flukes reaching the liver and a few completing the normal trajectory through its parenchyma but never developing into normal adults; (4) protein synthesis by adult flukes is not significantly affected by radiation doses as high as 5.0 kR.

Genetic Analysis of *Microsporum gypseum* Complex at the Molecular Level. José A. Carrasco (for Ph.D. in Microbiology,* under Dr. J. Colón). A new procedure for the isolation and purification of fungal DNA yields a highly purified and polymerized product. During development of the procedure a protamine-like protein, or nonhistone chromosomal protein, was discovered, tightly bound to the fungal DNA, which could have important implications in the genetic control of the fungus. The DNA was labeled with tritiated uridine, giving counts of 1700 dis/min per μg DNA when the label was on carbon-5 and 4000 when it was on carbon-6. The incorporation of radioactive pyrimidines suggests that *M. gypseum* contains thymidine phosphorylase, a *trans*-N-deoxyribosyl transferase, and thymidine kinase. These enzymes have been reported in *Escherichia coli* but not in *Neurospora crassa*. Qualitative analysis of the DNA showed the usual purine and pyrimidine bases. The mole percent guanine cytosine found for the *Microsporum gypseum* complex was 44.6 in *gypsea* (+), 46.8 in *gypsea* (-), 46 in *incurvata* (-), 44 in *fulva* (+), and 40.8 in *fulva* (-). DNA hybridization on nitrocellulose filters showed a marked difference between species and between donor and recipient strains. A high degree of homology found between *N. gypsea* and *N. fulva* suggests that they are closely related. *N. incurvata* gave less hybridization with *gypsea* than with *fulva*, even though *incurvata* and *gypsea* are supposed to be more closely related. The technique developed will be useful for classification studies in mycology.

Multiplication of Sindbis Virus in L-Cell Monolayers. Nitza Magali Dávila (for M.S. in Microbiology,* under Dr. J. Colón). Chronic Sindbis virus infection in L-cells was established in 14-day-old monolayers by changing the medium every 2 hr after virus inoculation, and in 24-hr monolayers by changing it every 2 or 3 days. The 14-day-old L-cell monolayers were "cured" of Sindbis virus primary infection by changing the medium every 2 or 3 days. Chronically infected L-cell monolayers were cured by adding 220 units of interferon per ml to the system. L-cells produced a small amount of interferon on primary infection with Sindbis virus, and none or undetectable amounts once chronically infected. Chronically infected L-cells were resistant to superinfection with homologous virus, and with the heterologous viruses NDV and influenza A PR_8. Doses of 1,000 and 10,000 rads of gamma radiation had no effect on the state of chronicity or on virus production. Spontaneously "cured" L-cells behaved the same as previously uninfected L-cells. A review of the literature on interferons and their importance in persistence infections is included.

Interferon Production in Viral Mutated L-cells. Mercedes Rodríguez (for M.S. in Microbiology,* under Dr. J. Colón). Interferon was isolated from irradiated chick embryo monolayers derived from hens grown in Puerto Rico. Chick interferon was shown to be synthesized very early in the growth cycle of Sindbis virus. A substance of protein nature that stimulates virus growth was also isolated in these monolayers. Monolayers prepared from embryos from imported eggs were shown to be very poor producers of interferon and virus-stimulating protein. A rapid and efficient method was described for obtaining interferon antiserum in rabbits. Evidence was presented for the presence of two proteins with interferon activity in chick embryo monolayers infected with Sindbis virus. The anti-interferon serum was used to demonstrate the presence of interferon in irradiated monolayers from imported eggs. Timing experiments with gamma radiation and exogenous interferon supported the proposed model for interferon synthesis and action. A review of the literature from the discovery of interferon in 1957 to 1976 was included.

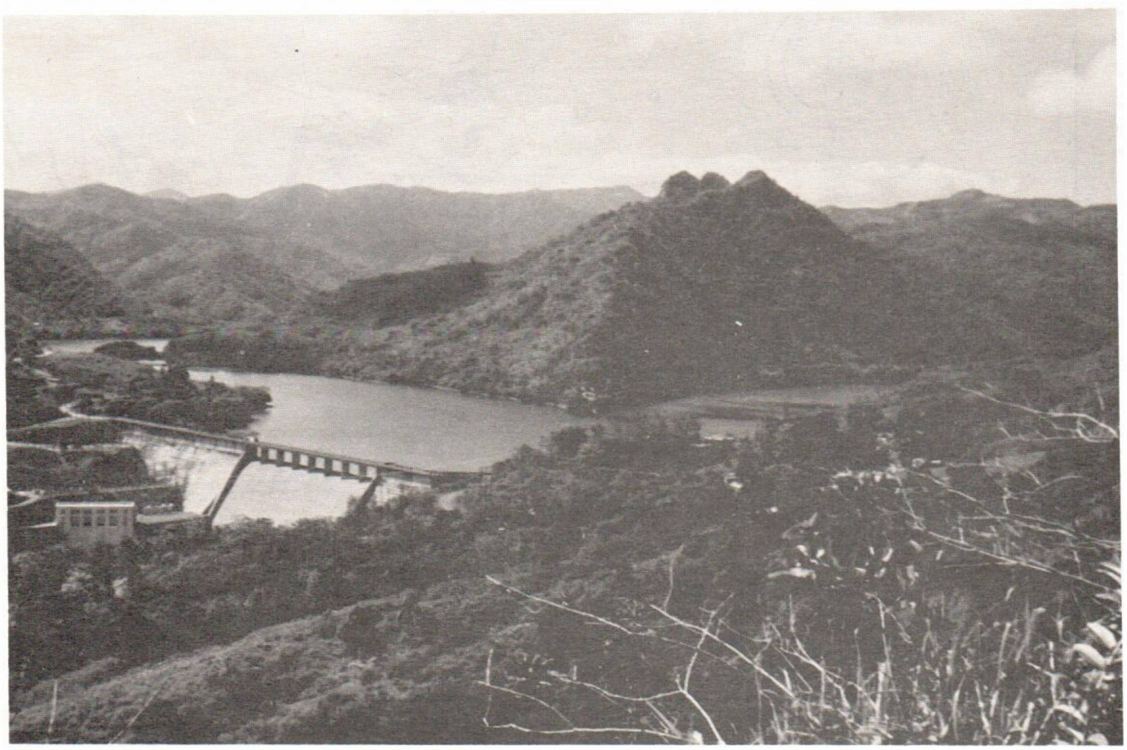
Gamma Radiation and Virus Multiplication: Evidence for the Genetic Control of Interferon Synthesis in Chick Embryo Fibroblast Monolayers Infected With Sindbis Virus. Eddy O. Ríos-Olivares (for Ph.D. in Microbiology,* under Dr. J. Colón). The effect of gamma radiation and actinomycin D on Sindbis virus reproduction was studied in chick embryo fibroblast monolayers. Radiation doses of 1,000 rads or >25,000 rads, given 1 hr before infection, markedly inhibited viral reproduction, whereas a dose of 10,000 rads significantly stimulated it. The increase after radiation was greater when a complex medium was used rather than one deficient in amino acids. The number of cells forming the monolayer and the multiplicity of infection had no effect on the enhancement of virus growth. Treatment of monolayers, 2 hr before virus infection, with 2 μg/ml actinomycin D, also stimulated viral production at the early stages of the growth cycle. Treatment of normal cells with actinomycin D reduced uridine incorporation by 98%, whereas radiation (10,000 rads) slightly inhibited it. During the first 6 hr of infection, cells treated with 10,000 rads showed an increase in uridine and cells treated with actinomycin D showed a significant decrease. Although not at the same rate, both 10,000 rads and actinomycin D decreased normal cellular RNA synthesis and consequently protein synthesis. These results suggest that both agents may act by inhibiting a cellular constituent, perhaps a protein (interferon-like), which regulates viral synthesis. The results indicate that changes in the capacity of chick embryo monolayers to support Sindbis virus growth after being exposed to different doses of radiation are mediated by the presence or absence of a protein similar to interferon.

A model for genetic control of the interferon system has been proposed, in which the interfering activity of the cell on viral growth is probably regulated genetically by the action of four structural genes and their respective controls, operating through a combined negative and positive regulatory mechanism. Normally, when an exogenous inducer acts on the control region of the interferon gene, interferon is produced and stimulates the transcription of the translation-inhibiting protein, which creates the antiviral refractory state in the cell. When sufficient protein has been transcribed this process is stopped. Production of interferon and of this protein is terminated by a blocking protein coded by a gene, which could act as superrepressor or interferon gene repressor or at the level of translation of the interferon gene mRNA.

Proteolytic Enzymes in *F. hepatica.* Genaro Ortiz (for Ph.D. in Biochemistry, under Dr. J. Chiriboga).

Biological Methods for Testing Environmental Hazards. Ivette Ramos (for M.S. in Biochemistry, under Dr. J. Chiriboga).

Loading Jon-boat for photosynthesis studies in hydroelectric reservoirs.



Lake Dos Bocas in the Arecibo River below Utuado.

Table 1: Monthly Mean of Daily Maximum and Minimum Temperatures at Sites Downstream From Power Plant Discharge

	Site D		Site 3A		Site 5		Site 6	
Mo.-Yr.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
May 75	35.9	37.8	34.2	35.9	30.8	32.2		
Jun 75	35.6	37.0	33.0	35.5	31.8	33.2		
Jul 75	36.3	37.9	39.2	36.4	31.6	32.8		
Aug 75	37.4	39.0	35.9	37.5	31.6	32.8		
Sep 75 (Hurricane)	36.8	38.4	35.4	37.2	31.9	38.6		
Oct 75	37.7	38.6	35.1	37.0	31.2	33.0		
Nov 75	36.0	37.7	33.9	35.5	30.9	32.4		
Dec 75	33.9	34.7	31.4	32.6	28.4	29.3		
Jan 76	30.9	32.3	30.3	32.4	27.3	29.0		
Feb 76	32.0	33.2	30.3	32.6	26.9	28.0	26.9	28.3
Mar 76	31.8	33.1	30.0	31.6	26.2	27.2	26.5	28.8
Apr 76	33.6	35.2	31.9	33.5	29.9	31.6	29.1	30.5
May 76	36.0	37.5	33.5	35.2	29.4	30.8	29.3	30.8
Jun 76	34.6	36.1	32.8	34.7	30.1	31.3	29.1	30.5

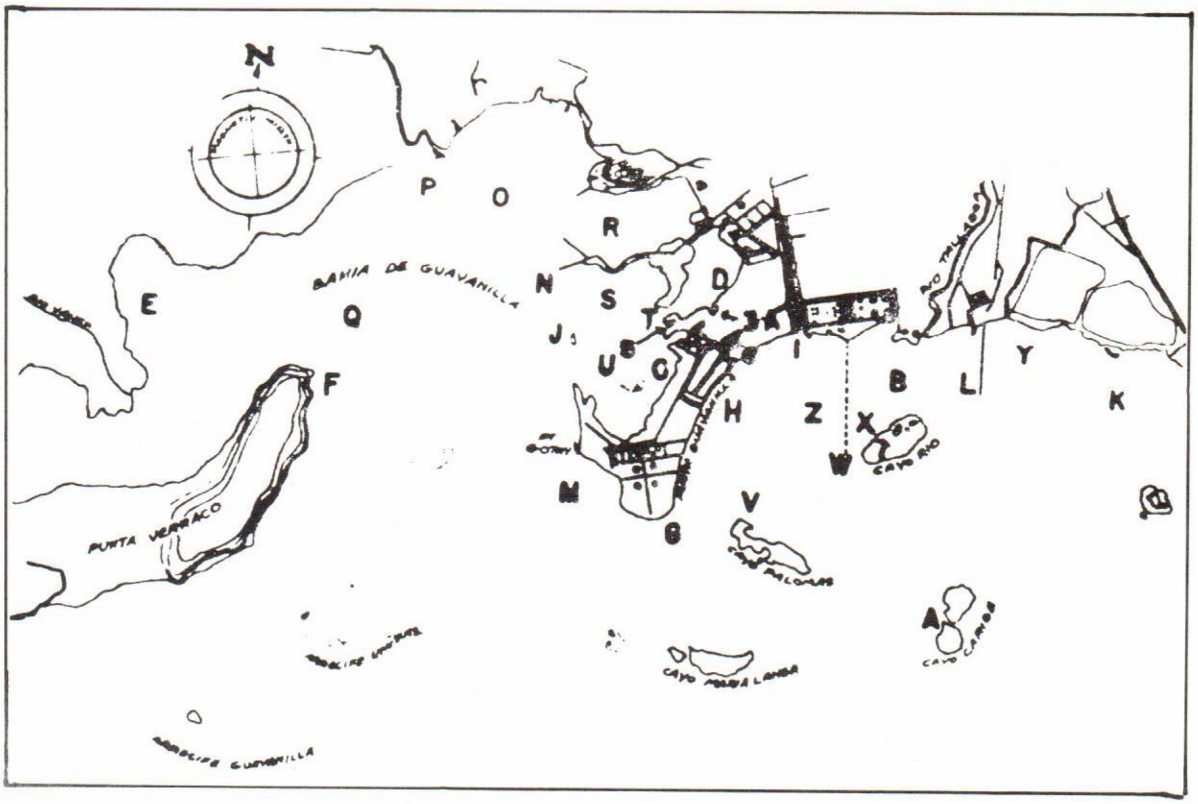


Figure 1: Guayanilla and Tallaboa Bays.

MARINE ECOLOGY

Marine Pollution Studies

The purpose of the marine pollution studies is twofold: (1) to investigate and evaluate the effects of stresses on the coastal marine environment associated with the continuing development of the largest energy-producing and petrochemical complex in Puerto Rico and (2) to determine the management alternatives for the wise utilization of energy and marine resources.

The energy complex (an oil refinery, a fossil-fuel power plant, and downstream petrochemical plants) lines the shores of Guayanilla and Tallaboa Bays, which are protected by offshore reefs and cays (Figure 1). The dominant current is from east to west, and it carries pollutants through Tallaboa Bay into Guayanilla Bay and then out to sea. Tallaboa Bay is fairly open to the sea, but water movement in Guayanilla Bay is restricted by a narrow channel, which favors the accumulation of pollutants from the energy complex on the eastern side of the bay.

Many independent studies have been conducted in this area; but an integrated research approach is needed to investigate and evaluate the effects and fates of pollutants introduced into Guayanilla Bay.

An integrated team approach will be used to investigate the interaction of physical, chemical, and biological systems in the Guayanilla-Tallaboa Bay area. The pollutants will be identified and characterized, and their transport within and through the bay ecosystem will be determined. The stresses they impose on the biological systems will be measured and evaluated. Research programs for the next five years are the subject of a comprehensive plan now being developed. The work done from July 1975 to June 1976 was primarily on the effects of the power plant's thermal discharge on the local marine community, and on surveying the trace metal contents of some of the organisms.

RESEARCH PROGRAMS

A. Physical and Chemical Oceanography (M. D. Banus)

Extensive physical and chemical oceanographic data will be required for an understanding of water movements and transport of heated effluents and pollutants in Guayanilla and Tallaboa Bays. The program to obtain such data was not initiated during the past year because of a lack of equipment and personnel, but some temperature monitoring was done as part of the study on the effect of thermal enrichment on mangrove survival and growth. The thermal monitoring program had two parts. (1) The surface water temperatue was measured about once every two weeks for ten months at 12 to 18 sites (see Figure 1) located in both Tallaboa and Guayanilla Bays and including the discharge both from the CORCO canals and from the 1100-MW(e) fossil-fuel plant. Additional measurements were made during fish and benthic sampling periods. Because the power plant discharge was

Table 2: Percentage Breakdown of Monthly Zooplankton Counts at Guayanilla Power Station

	Sept. 1975		Jan. 1976		Feb. 1976		Mar. 1976		Apr. 1976		June 1976	
	In.[a]	T.C.[a]	In.	T.C.	In.	T.C.	In.	T.C.	In.	T.C.	In.	T.C.
Holoplankton[b]												
Total	83	85	84	91	80	44	83	46	67	26	75	76
Copepods	79	83	82	86	72	41	67	40	48	21	72	72
Chaetognaths	4	1	1	4	<1	<1	2	<1	2	<1	–	–
Larvaceans	–	–	1	–	6	<1	11	3	8	1	2	1
Meroplankton[c]												
Total	17	15	16	9	20	56	17	54	32	74	25	24
Larvae	4	2	8	4	13	9	9	12	10	6	10	5
Cirripede nauplii	12	13	8	5	7	46	7	42	22	68	14	19
Fish eggs	1	–	<1	–	1	1	1	<1	<1	<1	1	1

[a]In. = Intake; T.C. = Thermal Cove.

[b]Holoplankton = copepods, chaetognaths, larvaceans, pteropods, ostracods, cladocorans, medusae, siphonophores, ctenephores, salps, and doliolids.

[c]Meroplankton larvae = annelid, cirripede nauplii, cirripede, cypris echinoderm, eetoproct, bivalve, gastropod veligers, brachyuran, shrimplike, and fish.

Table 3: Total Standing Crop Values of *Thalassia testudinum*, 1976

Numbers are average dry weight of crop (including rhizomes, roots, and shoots) and standard deviation, per 0.02 square meter, for 5 samples at each station.

Station	Date	Crop
Guayanilla		
7	2/11	9.2±6.4
10	2/11	4.2±1.3
1	2/11	3.9±2.9
8	2/11	1.7±1.2
7 deep	3/18	3.3±0.9
Jobos		
M	4/29	12.1±4.6
X	4/29	16.1±6.3
IV	4/29	27.1±0.6
3	4/29	25.9±6.1

expected to have a large effect on the mangroves, four sites were continuously monitored with recording thermographs installed about 20 cm below mean low water.

Table 1 lists the monthly means of daily maximum and minimum temperatures. The drop in June 1976 resulted from shutdown of one 440-MW unit from 13 June until about 6 July 1976. At each site the diurnal variation is 1.5° to 2°C, probably due to decreased power plant operation at night and to solar heating. Between Sites D and 3A is a ΔT of -2°C, with a ΔT of -3°C to Site 5.

Biweekly temperature measurements showed that the temperature of the plant intake (Site R) was about 1° above the ambient in Guayanilla and Tallaboa Bays, and that ΔT through the plant varied between 8° and 12°C. The maximum temperature of discharge was 41°C. The entire cove receiving the discharge had temperatures within ±0.2°C of the values recorded at Site D. A few vertical temperature profiles showed no variation from surface to bottom within the cove. An intrusion of cold water along the bottom appears at the lagoon entrance (Site T) on some tides. The enclosed high temperature body of water is called the thermal lagoon (or cove) in the studies described below.

Temperature measurements in Tallaboa Bay showed a moderate thermal discharge from the canal (Site I) flowing shouthwest along Pta. Guayanilla and having a ΔT that varies from 1.4° to 7.2°C with most values at 6°C. At night and in winter, weak N to NE winds let this warm effluent spread into the zone between H and Z, but in the daytime, strong E to SE winds compress it so that it stays within ∿100 m of the shoreline. At H, in the daytime, ΔT is ∿1°C, but at G (closer to shore) ΔT is higher, 1.5° to 2.0°C. A transect from H to the shore showed an increase from 29.3°C (ΔT = 1°C) to 32.5°C by ∿25 m from the beach. At the same time, G was 30.5°C. This warm water goes around Pta. Guayanilla, with Site M being 0.5° to 1.0°C above the ambient in Tallaboa Bay, and it transports hydrocarbons from the canal and possibly heavy metals and other pollutants.

B. Plankton Project in Guayanilla Bay 1975-1976 (Mary Nutt, Hilda Rojas, and J. Suarez-Caabro)

The research on thermal tolerance of plankton started by Youngbluth (PRNC-179, p.125) was continued. *Acartia* sp. was chosen for study because it is the most common species of copepod in Guayanilla Bay. It was found that the live copepods in the thermal cove were not introduced by the cooling water of the Guayanilla Bay power plant.

The question remains as to whether the *Acartia* sp. in the cove is tolerant to thermal stress or whether a separate population of *Acartia* sp. is undergoing thermal adaptation in the cove. The thermal cove *Acartia* sp. population collected in the winter (30° to 34°C) could not survive *in vitro* at 37°C and above, but the summer population (exposed to at least 37°C in the cove) could survive *in vitro* at 39°C for 2 hr and at 41°C for 10 min.

Monthly sampling of the plankton population in Guayanilla Bay, begun by Youngbluth (PRNC—179a), was continued. Table 2 presents the results for the thermal cove and intake. Monthly sampling was also done in the shore and offshore areas.

Future research will include further tests of the thermal tolerance of *Acartia* sp. and measurement of parameters affecting their physiology, both in the laboratory and in the field. The qualitative and quantitative distribution of plankton, especially *Acartia* sp., in the thermal cove will be determined. The results of all these studies will help clarify the physiological ecology of this copepod.

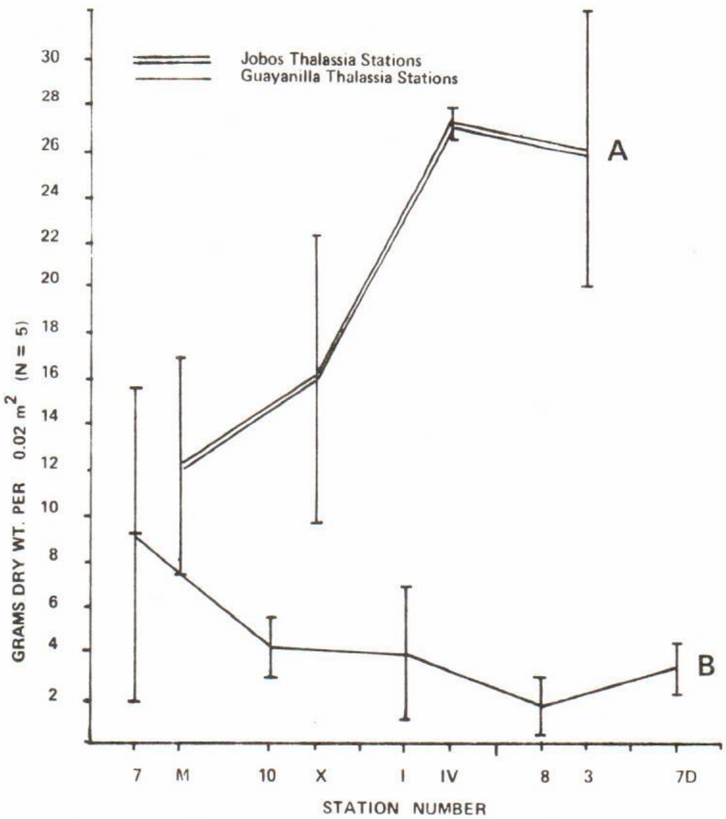


Figure 2: Total standing crop of *Thalassia* at Jobos (A) and Guayanilla (B) stations.

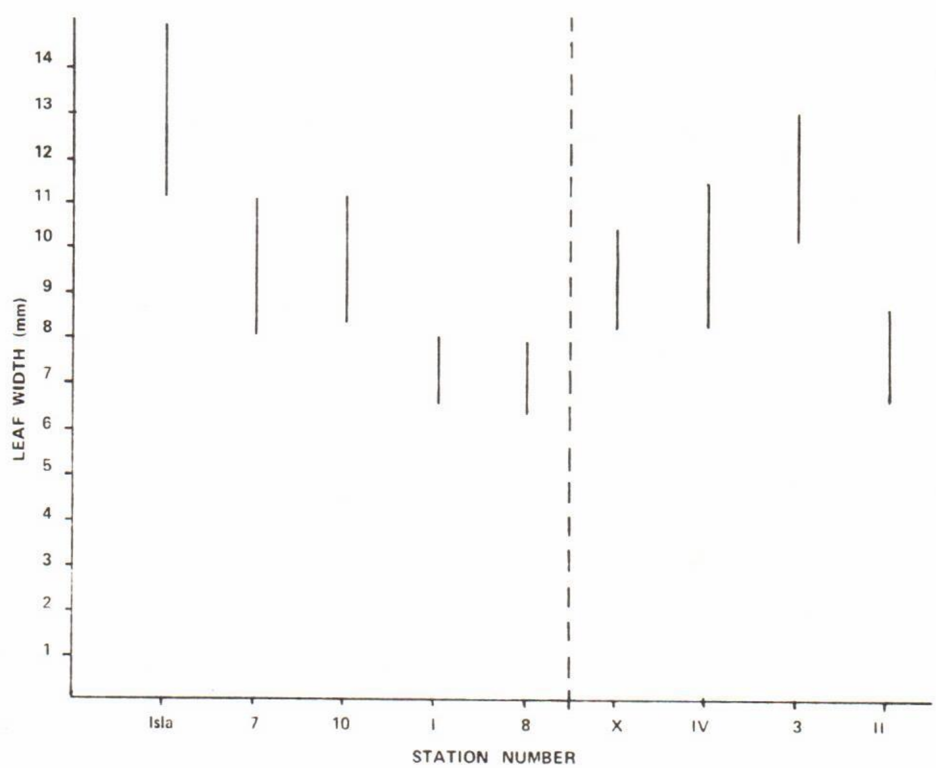


Figure 3: Leaf width of *Thalassia* at Jobos (right) and Guayanilla stations.

C. Ecological Evaluation of Tropical Seagrass Ecosystems in Industrially Disturbed and Undisturbed Environments (Vance P. Vicente)

Guayanilla Bay is an industrially disturbed marine environment. Many of its seagrass meadows (which are fragile tropical marine ecosystems) have not been studied; those that have, have not been compared with undisturbed meadows in Puerto Rico. A comparative study was therefore initiated in February 1976. Of the eight *Thalassia* beds being studied, four are in the industrially disturbed bay, two being continuously exposed to higher than ambient temperatures due to thermal effluents from power plants and two being at ambient temperatures but subject to other aspects of the industrial environment. The other four beds are in Jobos Bay, under natural environmental conditions. Visits were made to several additional *Thalassia* meadows around Puerto Rico to obtain data for comparison of specific ecological parameters.

Thalassia beds in Guayanilla Bay at higher than ambient temperatures have suffered more deleterious effects than other beds, as shown by their low standing crop (SC) values, which include weight of roots, rhizomes, and shoots (Figure 2 and Table 3). The beds in undisturbed habitats in Jobos Bay have much higher SC values (up to about 25 g dry wt. per 0.02 m^2), and Station 8, located close to the thermal effluents, showed the lowest values (less than 2 g). Low SC values have serious implications, since the SC value largely determines the physical and biological stability of a *Thalassia* bed ecosystem. The roots and rhizomes provide physical stability by preventing soil erosion, and the amount of leaf material is the major factor in the amount of energy going to support upper trophic levels.

Thalassia in Guayanilla Bay have shown other effects also. The two beds exposed to thermal effluents do not form sexual reproductive bodies, and the two at ambient temperature are practically inhibited from formation of buds, flowers, or seeds, probably by some type of pollution other than thermal; whereas the four beds under natural conditions in Jobos Bay showed prolific formation of reproductive bodies, seen on up to half of the shoots. Other beds around Puerto Rico were prolific also (see Table 4). Both the leaves and the rhizomes of *Thalassia* exposed to effluents are thinner than those of undisturbed *Thalassia* (see Tables 5 and 6 and Figure 3).

Other biological parameters measured for *Thalassia* seemed to be determined by genetic factors or biotic factors such as grazing pressure and did not correlate with physical parameters. These are being investigated further.

Besides the damage to the seagrasses due to thermal effluents and probably to other pollutants in Guayanilla Bay, effects are seen on the macroalgae and invertebrates of the floral and faunal assemblages. Table 7 shows that the macroalgae have a lower species diversity at Station 8 (exposed to thermal effluents) than at Station 7 (not so exposed). Reductions have been seen also in the typical *Thalassia* faunal assemblages at Stations 1 and 8. The urchin *Lytechinus*, the gastropod *Tegula fasciata*, many bivalves such as *Chione cancellata* and *Codakia*, corals such as *Manicina areolata*, and many other species normally forming part of a *Thalassia* faunal composition have been killed, only recent fossils remaining.

Temperature, visibility, salinity, and oxygen values for the *Thalassia* beds studied are presented in Tables 8 and 9.

Table 4: Percentage of *Thalassia* Shoots With Reproductive Bodies (Buds, Flowers, or Fruits) in Seagrass Beds Around Puerto Rico, 1976

Site	Location	Date	Collected	Shoots with reproductive bodies	
				No.	%
Luquillo	NE Coast	5/22/76	50	10	20
Luquillo Estuarine	NE Coast	5/22/76	50	10	20
P. Las Marias	N Coast	5/22/76	50	0	0
P. Arenas	W Coast	5/27/76	46	15	33
Las Croabas	E Coast	5/23/76	47	14	30
Las Croabas(middle)	E Coast	5/23/76	50	2	4
Sta. 3 Jobos	SE Coast	5/19/76	46	13	27
Sta. X Jobos	SE Coast	5/19/76	50	9	18
Sta. M Jobos	SE Coast	5/19/76	50	7	14
Sta. IV Jobos	SE Coast	5/19/76	50	12	24
Sta. 11 Jobos	SE Coast	5/19/76	50	27	54
Sta. 10 Guayanilla	SW Coast	5/14/76	50	2	4
Sta. 8 Guayanilla	SW Coast	5/14/76	50	0	0
Sta. 7 Guayanilla	SW Coast	5/14/76	50	0	0
Sta. 1 Guayanilla	SW Coast	5/14/76	50	0	0

Table 5: Leaf Diameter Measurements of *Thalassia* Leaves, 1976

Station	Date	Diameter ± S.D., mm
Guayanilla		(average of 24)
Island	2/5	13.1±1.8
7	2/5	9.6±1.5
10	2/5	9.7±1.4
1	2/5	7.3±0.7
8	2/5	7.1±0.8
Jobos		(average of 25)
X	3/26	9.3±1.1
IV	3/26	9.8±1.6
3	3/26	11.4±1.3
11	3/26	7.6±1.0

Table 6: **Rhizome Diameters of *Thalassia testudinum*, 1976**

Station	Date	No. measured	Diameter ± S.D., mm
Guayanilla			
7	2/11	39	4.4±0.6
10	2/11	50	3.9±0.8
1	2/11	40	2.7±0.5
8	2/11	33	2.8±0.4
7 deep	2/11	52	3.2±0.6
Island	3/18	10	6.0±0.4
7	3/18	10	3.9±0.4
10	3/18	10	4.6±0.4
1	3/18	10	3.2±0.2
8	3/18	10	3.2±0.3
7 deep	3/18	10	3.2±0.4
Jobos			
11	3/26	10	3.8±0.6
X	3/26	10	3.9±0.6
IV	3/26	10	4.2±0.5
3	3/26	10	5.4±0.8
M	4/29	50	4.1±0.7
IV	4/29	50	4.3±0.6
3	4/29	46	4.5±0.6

Table 7: Common Macroalgae (Including Seagrasses) in *Thalassia* Beds in Guayanilla Bay Exposed to Thermal Effluents (Sta.1) and at Ambient Temperature (Sta.7).

Station 7	Station 1
Hypnea spinella	*Thalassia testudinum*
Halophila baillonis	*Halophila baillonis*
Caulerpa verticillata	*Acanthophora spicifera*
Chondria sp.	*Caulerpa verticillata*
Ceramium sp.	*Cyanophyta* (unid. sp.)
Acanthophora spicifera	*Gracilaria* sp.
Halimeda opuntia	*Enteromorpha*
Gracilaria sp.	
Caulerpa sertularioides	
Caulerpa mexicana	
Cludophora sp.	
Dictyota bartayxesii	
Caulerpa verticillata	
Thalassia testudinum	

Table 8: Monthly Average Values, With Standard Deviation, of Temperature, Salinity, and Visibility February to June 1976

Station	No. measured	Temp., °C	No. measured	Salinity ‰	No. measured	Visibility (ft)
Guayanilla						
Island	1	24.5	1	34.5	1	20
7	16	26.9±1.3	16	34.3±0.5		
10	9	28.9±1.5	9	34.4±0.4	9	8 ±2.8
1	12	30.1±1.6	12	34.2±0.5	12	3.2±1.0
8	12	30.6±1.4	12	34.2±0.7	12	2.4±0.8
Jobos						
M	5	26.7±2	5		5	
X	5	27.4±3				
IV	5	27.8±2.5				
3	5	27.7±1.7				

Table 9: Temperature, Salinity, Visibility, and Oxygen Content in Guayanilla Bay During a 24–Hour Period, August 11-12, 1976 (TC = Thermal Cove)

Station	Temp. °C	Salinity %	Visibility (ft)	0_2 ppm	0_2 ppm	Time
1	34.0	34	2	4.9	4.8	4 pm
	33.8	34	1.5	4.6	4.5	8 pm
	33.5	34	2.5	4.6	4.5	12 pm
	33.0	34	2.5	4.5	4.2	4 am
	32.8	34	3.0	4.6	4.5	8 am
	33.8	34	2.5	5.1	4.9	12 am
	34.2	34	2.0	4.7	4.7	4 pm
	33.6±.5	34	2.3±.5	4.7±.2	4.5±.2	
8	34.5	34	3	5.0	4.6	4 pm
	34.1	34	2	4.8	4.4	8 pm
	34.2	34	2	4.6	4.2	12 pm
	34.0	34	1.5	4.7	4.2	4 am
	33.0	34	2	4.6	4.2	8 am
	35.0	34.5	1.5	4.7	4.8	12 am
	34.0	34.0	2.0	4.7	4.8	4 pm
	34.1±.6	34.1±.2	2.0±.5	4.7±.1	4.4±.3	
7	29.8	34	2	5.1	4.7	4 pm
	29.8	34	2.5	4.7	4.6	8 pm
	29.8	34	1.5	4.7	4.2	12 pm
	29.2	34	2.5	4.7	4.5	4 am
	29.5	34.5	4.0	4.8	4.8	8 am
	29.8	34.0	3.0	5.1	5.3	12 am
	29.8	34.0	3.0	4.8	5.0	4 pm
	29.7±.2	34.1±.2	2.6±.8	4.8±.2	4.7±.4	
10	31.8	34	2.5	5.2	4.9	4 pm
	30.8	34	2.0	4.3	4.2	8 pm
	30.8	34	2.5	3.9	3.9	12 pm
	30.0	34	2.0	3.5	3.3	4 am
	30.5	34.5	4.5	4.2	4.1	8 am
	31.5	34.0	2.5	6.4	5.0	12 am
	30.5	34.5	3.5	5.1	4.9	4 pm
	30.8±.6	34.1±.2	2.8±.9	4.6±.1	4.3±.6	
TC	39.2	33.5	3	4.7	4.8	4 pm
	39.2	32.0	2.2	4.7	4.6	8 pm
	38.2	33.5	2.4	4.4	4.6	12 pm
	37.2	32.0	2	4.5	4.5	4 am
	36.0	33.0	3.5	4.6	4.4	8 am
	37.8	34.0	3.0	4.7	4.8	12 am
	38.5	34.0	3.0	5.1	5.2	4 pm
	38.0±1.1	33.1±.8	2.7±.5	4.7±.2	4.7±.3	

D. Mangroves (M.D. Banus)

1. *Survival and Growth of Seedlings and Small Trees Under Thermal Stress*

In western and southern Puerto Rico most new mangrove seedling settlement is taking place in shallow water *Thalassia* beds protected by coastal coral reefs. The survival, rooting, and growth of mangrove seedlings has been studied and reported (PRNC-198, p.92). Current research shows a survival from seedling to small tree of 54% after two years for 100 seedlings put in a 4 X 4-ft net cage with mud bottom in a moderately sheltered cove at Pta. Ostiones. Thirty-four of the trees had one or more prop-roots. These seedlings were subjected to natural conditions (including a severe storm), but were protected from direct contact with boats, floating palm branches, and logs. The survival of another batch was only 35% because some seedlings were swept out of the net at eight months. Both batches are now overcrowded.

Seedlings are used in thermal stress studies both because they provide the means to regenerate the mangal and because often the juvenile form of an organism is more sensitive to stress than the adult. Seedlings from trees in the thermal lagoon at Guayanilla were found to be significantly shorter (20.6±4.1; 21.5±4.2 cm) than those from trees in other parts of Guayanilla Bay (29.4±5.9 cm), in Boqueron Bay (30.7±5.0 cm), and in Pta. Ostiones (31.9±5.9 cm), and the differences were shown not to be related to tree height. They are probably due to thermal, not to other, stresses. The smaller seedlings have much less chance of finding a location of the optimum water depth to survive and grow. The seedlings from thermally stressed trees, when held in a control area, were also found to have slower leaf formation but slightly faster root formation than the seedlings native to that area.

The effect of thermal stress was studied by comparing sub-batches of 100 seedlings each: those from Site D and Site 3A being held either in the thermally enriched water or at the control site at Pta. Ostiones; those from the control site being held either there or at Sites D and 3A (see Table 10). The seedlings from the thermally stressed trees did not survive as well in the heated water as they did in ambient water. Seedlings from trees in ambient water did very poorly in the heated water. The seedlings (local and control) at Sites D and 3A, placed in mud substrate on 12 September, showed little further growth, although many formed roots. By December at Site D and by February at Site 3A, even though the temperatures had decreased, all the seedlings were dead except 16 of the control seedlings at Site 3A, which, starting in December, grew rapidly and well. The results show that temperatures >37°C even for part of the day are eventually lethal for seedlings, and those between 35° and 37°C drastically inhibit root and leaf formation and survival, but some seedlings from non-stressed trees can survive in the 35° to 37°C range and then grow when the range drops to 31° to 34°C.

Small trees raised in water at ambient temperatures were planted in June 1975 at Site D, 25 with their roots always subtidal and 25 with roots bared at low tide. All were leafless in two weeks and dead in three weeks. The mean maximum daily water temperature was 37.5°C. The experiment was repeated in December 1975 with 33 trees planted at each site (D, 3A, and control), of which 20 were from seedlings picked from Site D and rooted at the control site and 13 were from seedlings from Boqueron Bay (Table 11). At Site D all but two survived and most grew within two months. At Site 3A, all survived and all were growing well at three months, more vigorously than those at the control site.

New sub-batches of 20 trees were planted at each site on 1 June 1976 (Table 12).

Table 10: Water Temperature and Seedling Growth, June 12 to September 12, 1976
(R=small roots; L=leaves; D=dead)

	At Site D		At Site 3A		At Pta. O. (Control)
T, °C, mean (range)					
Day	38.1	(36.1->40)	36.7	(34.3-39.2)	(26.8-30.9)
Night	36.5	(34.4-39.1)	34.2	(32.2-38.1)	
Seedlings					
From Site D	19%R; 9%D				100%R; 27%L
From Site 3A			68%R; 12%L; 2%D		100%R; 50%L
From Control	3%R; 9%D		31%R; 3%L; 5%D		100%R; 37%L

Table 11: Survival and Growth of Small Trees Planted in December 1975

	At Site D (Guayanilla)				At Site 3A (Guayanilla)			
	From Site D		From Boqueron		From Site D		From Boqueron	
	Total	Grow	Total	Grow	Total	Grow	Total	Grow
16 Dec	20		13		20		13	
22 Dec	20	0	13	0	20	0	13	0
8 Jan	20	0	13	0	20	3	13	1
4 Feb	20	14	13	10	20	17	13	12
10 Mar	20	16	13	11	20	20	13	13
26 Apr	19	17	12	12	14*	14	11*	11

*Eight trees destroyed by floating tire.

Table 12: Small Trees Planted 1 June 1976

	At Site D (Guayanilla)			At Site 3A (Guayanilla)		
	Total	Growing	Dead	Total	Growing	Dead
1 Jun	20			20		
8 Jun	20	0	0	20	0	0
15 Jun	20	0	1	20	1	1
22 Jun	20	0	2	20	4	3 (all deep)
8 Jul	20	3	4	20	12	5 (all deep)
20 Jul	20	3	6	20	15	5 (all deep)
Mean Temp., °C	Max.	Min.		Max.	Min.	
1-14 Jun	37.8	36.7		35.6	33.9	
15-30 Jun	∿ 35			∿ 33		
1-20 Jul	37.7			35.8	33.1	

The survival at Site D was higher than the previous year, perhaps because of lower temperatures in mid-June. During the 1 June to 20 July period, most of the December trees planted at Site D continued to grow
established small trees if they are acclimated gradually. The loss of five trees at Site 3A was due to planting in water that covered them during part of every tide; growth of the small trees is not inhibited at 35° to 36°C.

2. Uptake of Trace Metals by Mangrove Seedlings

Mangal sediments and pore-water are the source of nitrogen, phosphorus, and the many trace metals essential for growth of the trees. These metals can be toxic if present at higher concentration (e.g., B, Cu, and Cr.), and other metals such as Cd and Hg are of no known benefit to plants. The availability of trace metals to plants depends on their concentrations in the sediments and on the presence of compounds such as sulfides or chelators that make them more or less soluble in the pore-water.

The absorption of trace metals from sewage sludge by mangove seedlings has been under study for two years at PRNC as part of a larger EPA study (J. R. Montgomery et al., presented at 3rd ERDA Environmental Protection Conference, Chicago, September 1975). Rooted seedlings were grown to small trees in flowing seawater tanks, one containing sewage sludge and the other being a control. The roots, bottoms, growing shoots, and leaves from trees in both tanks were analyzed for Cd, Cr, Cu, Ni, Pb, and Zn. In the first experiment, the roots of the experimental trees had Cr and Cu concentrations double those of the control trees after 125 days; they also had significantly high concentrations of Ni, Pb, and Zn at 50 and 125 days; and the concentrations of both groups of metals increased with time. The data on the other portions of the trees show no significant increases for any metals.

Roots can act as a barrier to the movement of some trace metals into growing shoots, but this was not demonstrated for mangrove trees by the present study because the experiment was not run long enough.

3. Trace Metals in Mangrove Leaves and Seedlings

The leaves and seedlings from trees at several locations in the Guayanilla-Tallaboa area and from trees in Boqueron Bay and Pta. Ostiones have been analyzed for the trace metals Fe, Mn, Cu, Zn, Cd, Pb, and Ni (Table 13). All sites have been sampled a second time but analyses are not yet complete. An unusual feature of the data is the very high Mn values for the Guayanilla leaves, the highest being for the leaves from apparently unstressed trees. The very high Fe and Cu values for the Guayanilla heated leaves may be due to stress or to a higher metals content in the sediment. Agreement between results for different sampling batches is within the standard deviation for most elements and locations.

Typical batches of seedlings from all locations (Table 13) have a manganese concentration 3 to 4 times as high in the top as in the bottom, probably because of the photosynthetic processes in the growing shoot, and Mn content is significantly higher in seedlings from the three Guayanilla sites than in those from the other sites. Iron content is not significantly different in tops and bottoms, and is lower in the seedlings from Pta. Ostiones and Tallaboa, probably because these locations have the lowest agricultural and/or industrial inputs. The copper content is similar in tops and bottoms, and is significantly higher in the seedlings from the Guayanilla mangal inside and outside the thermal lagoon. The zinc content is higher in tops than in bottoms of seedlings except those from Tallaboa, and is lower in those from Tallaboa and Pta. Ostiones than in those from Boqueron and Guayanilla.

le 13: Trace Metals in Mangrove (ppm dry wt.), Mean ± S.D. of 10 Replicates (5 tops and 5 bottoms for seedlings)

	Mn	Fe	Cu	Zn	Cd	Pb	Ni
ves							
. Ost. trol	88 ± 6	23 ± 2	2.0 ± 0.2	4.1 ± 0.7	0.39 ± 0.02	1.6 ± 0.3	2.5 ± 0.1
. Cont.	74 ± 7	17 ± 3	4.0 ± 0.3	5.8 ± 1.0	0.29 ± 0.03	3.3 ± 0.6	2.8 ± 0.3
	99 ± 10		3.3 ± 0.3		0.5 ± 0.08	1.1 ± 0.03	2.8 ± 0.4
llaboa /o te A	65 ± 4	40 ± 3	3.1 ± 0.2	2.3 ± 0.6	0.4 ± 0.04	3.2 ± 0.7	2.4 ± 0.2
ay-AMB te E	372 ± 29	28 ± 3	3.3 ± 0.2	2.7 ± 1.1	0.23 ± 0.1		2.6 ± 0.4
	248 ± 3	40 ± 3	3.4 ± 0.4	2.3 ± 0.4	0.27 ± 0.3	2.3 ± 0.2	2.3 ± 0.2
ay-Int. te E	169 ± 15	25 ± 3	4.3 ± 0.9		0.46 ± .05		4.4 ± 0.5
		24 ± 1	4.8 ± 0.2	4.4 ± 0.2	0.31 ± 0.5	2.5 ± 0.2	3.5 ± 0.3
ay-Heat te D	162 ± 14	88 ± 8	9.4 ± 0.7	4.0 ± 0.3		2.1 ± 0.4	3.8 ± 0.3
edlings							
a. Ostiones Control)							
Tops	23 ± 3	7.8 ± 1.9	2.4 ± 0.6	2.1 ± 0.5	0.13 ± 0.04	0.88 ± 0.14	0.95 ± 0.1
Bottoms	5.5 ± 1.6	7.5 ± 2.3	2.1 ± 0.6	1.7 ± 0.4	0.08 ± 0.03	0.73 ± 0.05	0.59 ± 0.2
queron Control)							
Tops	17 ± 3	16 ± 5	2.6 ± 0.4	3.1 ± 0.9	<.06	<0.35	0.51 ± 0.15
Bottoms	3.7 ± 0.6	16 ± 2	2.2 ± 0.2	1.5 ± 0.1	<.06	0.25 ± 0.4	0.33 ± 0.08
allaboa Cayo							
Tops	10 ± 3	8.6 ± 3.7	2.4 ± 0.6	2.1 ± 0.9			1.3 ± 0.6
Bottoms	3.7 ± 0.9	11 ± 4	2.8 ± 0.7	2.4 ± 0.9			
uay-AMB							
Tops	42 ± 9	15 ± 6	2.7 ± 0.4	3.6 ± 1.6	0.10 ± 0.03	1.6 ± 0.5	0.75 ± 0.13
Bottoms	10 ± 2	16 ± 5	3.4 ± 0.4	2.2 ± 0.3	0.08 ± 0.01	0.66 ± 0.15	1.3 ± 0.1
uay-Int.							
Tops	38 ± 7	16 ± 3	5.2 ± 0.6	3.1 ± 0.6	0.05 ± 0.08	<1.0	0.77 ± 0.08
Bottoms	13 ± 2	12 ± 3	5.1 ± 0.6	2.3 ± 0.6	0.08 ± 0.06	<0.7	0.61 ± 0.08
uay-Heat							
Tops	36 ± 11	20 ± 4	4.8 ± 0.7	3.4 ± 0.6	0.14 ± 0.04	1.4 ± 0.4	1.3 ± 0.3
Bottoms	13 ± 3	15 ± 3	5.5 ± 0.5	2.4 ± 0.3	0.07 ± 0.03	1.1 ± 0.4	0.9 ± 0.2

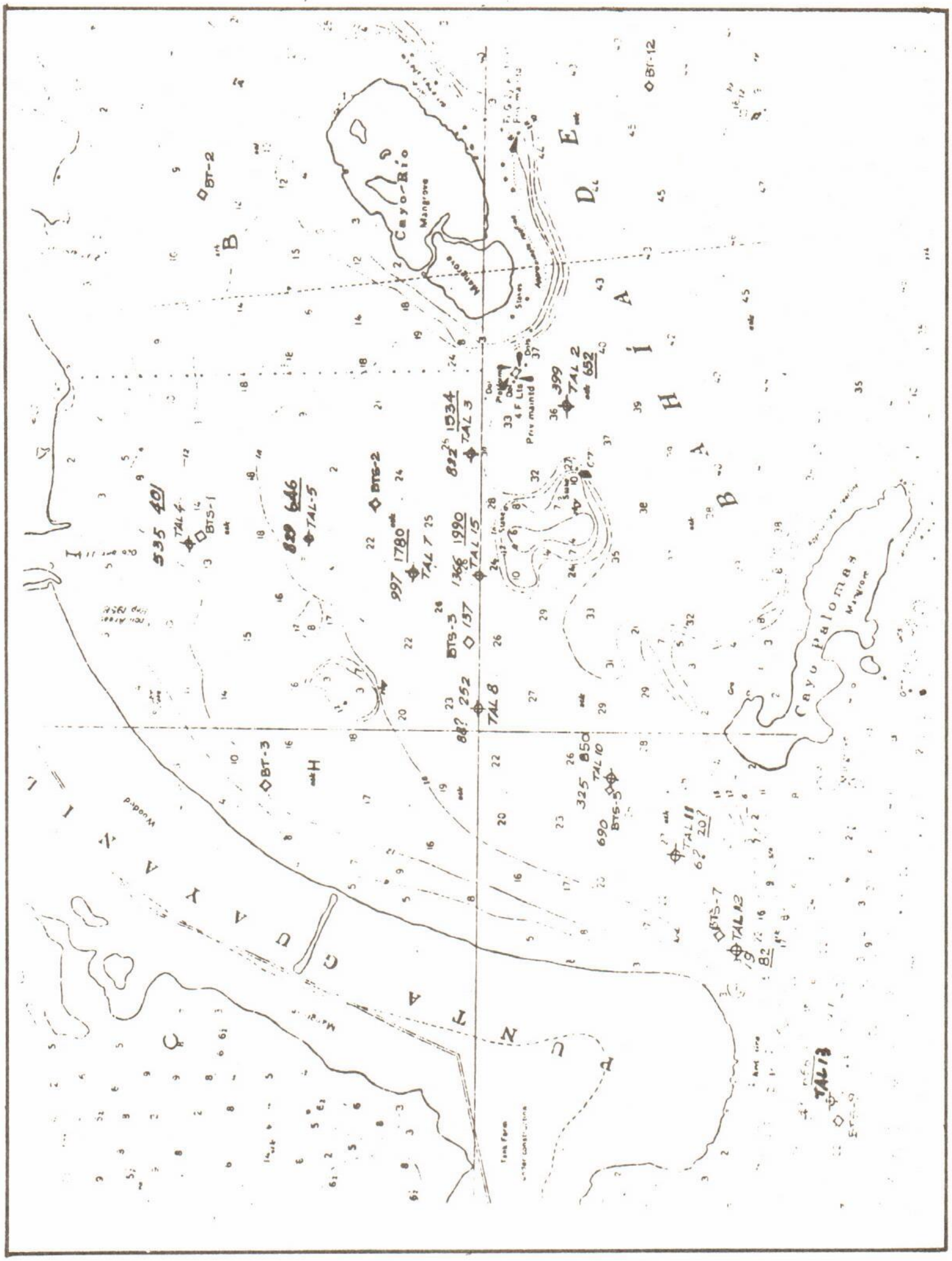


Figure 4: Italic numbers are foraminifers per sample; underlined numbers are individuals in the meiofauna other than foraminifers.

The differences in trace metal content of leaves and seedlings from various locations may be due to different levels of the metals in the sediment, and evaluation of this factor will require sediment and pore-water analyses. Another possibility is that in some locations the metals are in forms more available to the mangrove roots. For example, the leaves from the small trees in the sewage-sludge experiment (both control and treated) had much higher levels of Cd (1 to 2 ppm), Cu (6 to 7 ppm), Ni (3 to 4 ppm), and Pb (4 to 6 ppm) than leaves from the trees in Pta. Ostiones from which these small trees originated. Alternatively, the various amounts of thermal enrichment to the trees in some areas of Guayanilla Bay may affect the transport of metals to fruit and leaves. Zn, Fe, and Mn are all involved in various metabolic processes in plants; thermal enrichment may change the process rates and therefore the metal concentrations.

E. Foraminifers of Guayanilla and Tallaboa Bays (George A. Seiglie)

The purpose of this work is to study the foraminiferal assemblages in Tallaboa and Guayanilla Bays in relation to the environmental effects of the effluents from the petrochemical and power plants. The foraminiferal assemblages of Guayanilla Bay have been described by Seiglie (*Rev. Esp. Micropaleontol.* 7, 453-88, 1975). The dominant foraminifers are *Ammonia catesbyana* in the shallower parts and *Fursenkoina punctata* in the deeper parts; in the latter,in an area 10 cm^2 with a depth of 1 cm, the number of foraminifers was higher than the number of nematodes. Nematodes were far more abundant in Jobos and Mayagüez Bays. The length/width ratio of *Fursenkoina punctata* appears to be related to pollution.

Methods of Study

A modified Shipeck grab was used to take samples of the undisturbed surface of sediment, 10 cm^2 and 1 or 2 cm deep, which were preserved in 30% ethyl alcohol and stained in the laboratory with Rose Bengal for about 8 hr and then washed in an 0.0625-mm-mesh sieve. The various species of living and dead foraminifers were counted and their precentages computed.

Tallaboa Bay

Tallaboa Bay is limited on the south by Palomas and Rio Cays. The longshore current transports part of the petrochemical plant effluents into the shallow waters (up to $\sim$6 m) near the coast where the sediments are sandy. In the deepest part of the bay (6 to 9 m), between the shallow area and the cays, the sediments are sandy clays and clayey sands, and the water quality is affected by clean oceanic waters and by petrochemical effluents according to the pattern of currents indicated by M.D. Lair et al. (*EPA Tech. Study* TS-03-71-208-02, pp. 1-45, 1971). At the stations shown in Figure 4 in Tallaboa Bay, 23 samples were taken.

P. González was the first to study the foraminiferal assemblages of Tallaboa Bay, (UPR Master's Thesis, 1969). He found the dominant foraminifer in the deepest area to be *Fursenkoina punctata* ($\cong$ *F. pontoni*), with living specimens occurring in silty clays containing visible amounts of oil; and he found no specimen of *Buliminella elegantissima.*

In samples taken in 1975 and 1976, the dominant foraminifer was *Fursenkoina punctata* in the deepest part of the bay and *Ammonia catesbyana* in the shallowest part, and 59 species were found (see Table 14). The individuals in the samples were counted according to the major taxonomic units that occur in Tallaboa Bay: Foraminiferida, Gasteropoda,

Table 14: Living Foraminifers in Tallaboa Bay

Ammobaculites cf. directus	Nouria polymorphinoides
A. salsus	Parvigenerina textularioides
Ammonia catesbyana	Protelphidium cf. delicatulum
Angulogerina angulosa	Pseunodosaria torrida
Astrononion sp.	Quinqueloculina bosciana
Brizalina lowmani	Q. candei
B. striatula	Q. cf. lamarckiana
B. cf. variabilis	Q. rhodiensis
B. sp. 1	Q. seminulum
Cancris sagra	Q. subpoeyana
Critroelphidium poeyanum	Q. sp. 1
C. sp. 1	Q. sp. 2
Cyclogyra involvens	Q. sp. 3
Discorbis? bulbosa	Reophax caribensis
Eggerella aff. advena	R. nana
Elphidium advenum	R. scotti
Fissurina pellucida	Rosalina floridana
Florilus grateloupii	Sagrina cubana
Fursenkoina complanata	S. pulchella
F. punctata	Sigmoilopsis arenata
Globocassilina subglobosa	Spirillina densepunctata
Glomospira gordialis	Spiroloculina communis
Haplophragmoides canariensis	S. sp.
Hopkinsina pacifica	Textularia earlandi
Lagena laevis	Triloculina oblonga
Loxostomum lanceolatum	T. trigonula
Miliolinella subrotunda	T. sp.
Nonionella fragilis	Trochammina advena
N. "opima"	T. quadriloba
N. fragilis	

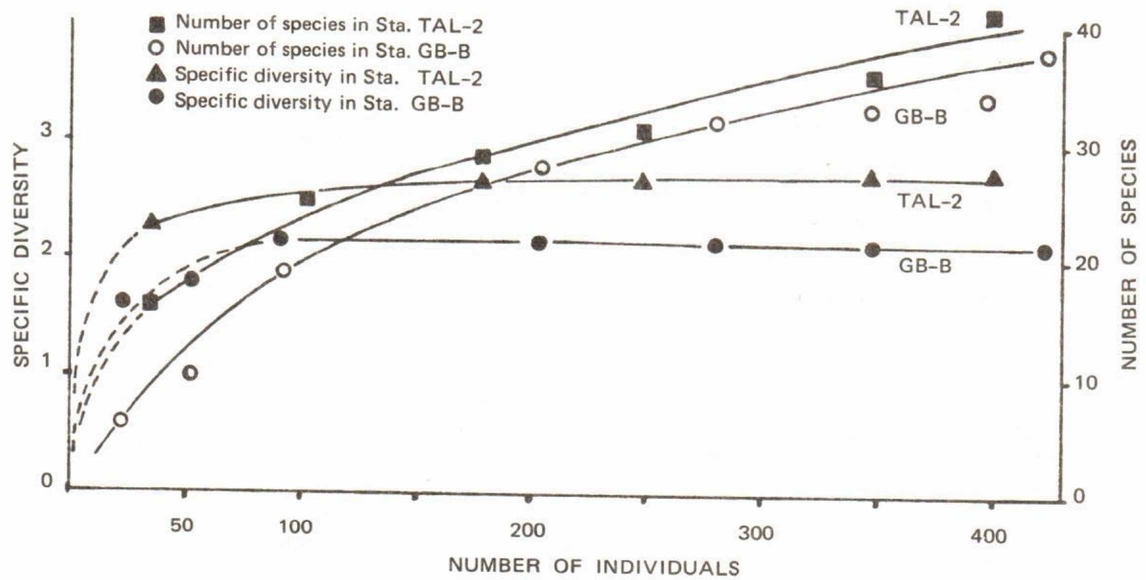


Figure 5: Specific diversity.

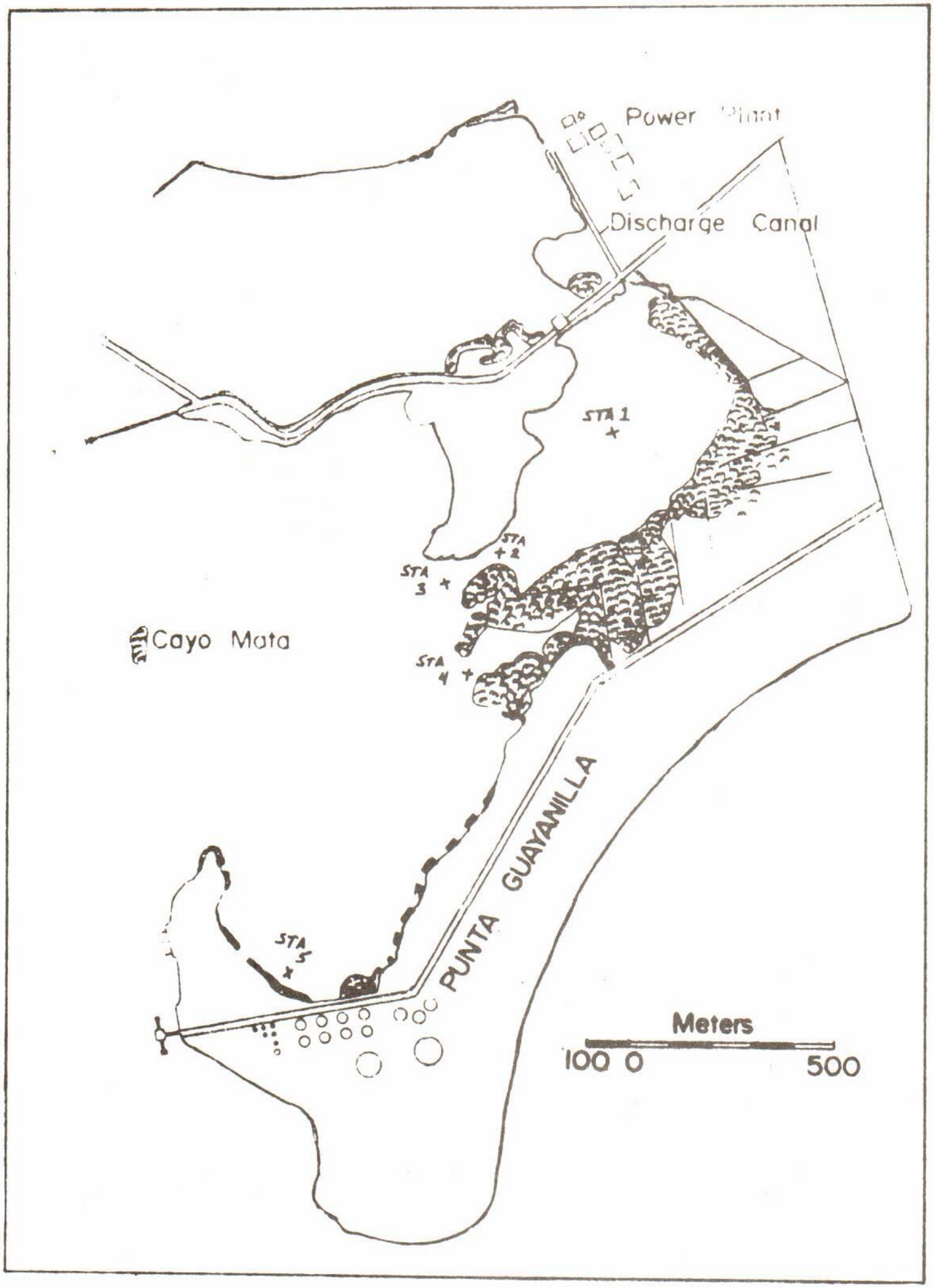


Figure 6: Location of fish gill-net stations (distribution of mangroves is also shown).

Bivalvia, Amphipoda, Copepoda, Ostracoda, Nematoda, Polychaeta, and other worms. The numbers of foraminifers and other meiofauna are given in Figure 4. The specific diversities of the foraminiferal assemblages of Stations B and TAL-2 were calculated with different numbers of individuals counted (see Figure 5). If 80 or more individuals are counted, the specific diversity is the same because the number of species increases with the number of individuals per sample.

The most significant characteristics of the foraminiferal assemblages are as follows: (1) The mean diameter of *Ammonia catesbyana* in Tallaboa Bay is smaller than in Mayagüez, Jobos, and San Juan. (2) The living foraminiferal assemblages in the deep part of the Bay are larger than those in other previously described areas of Puerto Rico (Seiglie, *op. cit.;* in *Aguirre Power Project Environmental Studies 1971 Ann. Rept.*, pp. 54-7; *Carib. J. Sci.* **14**, No. 1-2, 1-68, 1974). (3) The total number per sample is larger for foraminifers than for nematodes at four stations in a line N-S of the CORCO outfall, but the reverse is found in other parts of the Bay (see Figure 4). (4) *Buliminella elegantissima* is relatively abundant in Tallaboa Bay.

B. elegantissima occurs in the waters off Southern California (O.L. Bandy et al., *Limnol. Oceanog.* **9**, 112-23, 124-37, 1964; **10**, 314-32, 1965; *Geol. Soc. Am. Bull.* **75**, 403-24, 1964; in *Ocean Sci. Eng.: Joint Conf. Marine Technol. Soc. and Am. Soc. Limnol. Oceanogr. Trans.*, pp. 55-76, 1965), off Central America, and in the Gulf of Carioco (Seiglie and Bermúdez, *Univ. Oriente Bol. Oceanogr.* **2**, No. 1, 1-88, 1961), all of which have upwelling waters and abundant nutrients. It is found in large numbers also in lagoons of the Gulf Coast and in the Mississippi Delta (W. R. Walton, in *Approaches to Paleoecology*, pp. 151-237, Imbrie and Newell, eds., Wiley, 1964), where, again, nutrients are abundant. Since González found no *B. elegantissima* in Tallaboa Bay in 1968, its presence - and the large foriminiferal populations - are probably due to the increased nutrients from the CORCO outfall.

F. Fish Studies in Guayanilla Bay (Joseph J. Kimmel).

During the past year fish sampling in Guayanilla Bay was initiated, with the following objectives:

1. Survey the fish quantitatively for not less than 12 months and observe seasonal changes and effects of temperature changes due to power plant effluents.
2. Compare condition of fishes in thermally stressed and unstressed zones.
3. Determine spawning time of fishes in thermally stressed and unstressed areas.
4. Examine food habits of fishes in and near thermally stressed areas
5. Compare species diversity with that found in other studies.
6. Record incidence of fish parasitism in fishing areas.
7. Determine thermal tolerances, including critical thermal maxima and preferred temperatures, of several species of fishes.
8. Analyze fish muscle and viscera for heavy metal and possibly for hydrocarbon content.
9. Investigate life history and ecology of *Lupinoblennius dispar* Herre, a fish collected from Guayanilla not previously reported from Puerto Rico.

Methods

Monthly gill-net samples were taken in and near the termal cove in the eastern sector of Guayanilla Bay (Figure 6). At each of the five stations a bottom-rigged monofilament gill net, 40 X 2.5 m with a 5-cm stretched mesh, was set for a period averaging 2.2 hr. Half the sampling was done during the day, between sunrise and sunset. Except for the artificial temperature and chemical stresses, the stations are very similar.

Table 15: Most Abundant Fishes in Gill Net Samples From Guayanilla Bay.
(Upper number shows number; lower number shows weight in grams)

Family	JUL	AUG	SEP	DEC	JAN	FEB	MAR	MAY	JUN	JUL	Total #/wt(g)	% #/wt(g)
Gerridae	2 24.1	1 159.0	19 1148.1	36 9656.5	6 1453.0	48 6973.0	27 5195.8	23 4204.6	21 5210.7	24 5609.8	207 39639.6	26.4 21.3
Carangidae	-	-	3 177.6	25 5308.7	12 6553.7	31 11205.2	34 8206.6	28 4879.2	11292.2	11 2001.9	208 49625.1	26.5 26.7
Sciaenidae	-	-	23 1651.9	6 374.6	-	26 2914.4	11 2291.4	3 740.9	11 2666.4	11 2652.8	91 13292.1	11.6 7.1
Sparidae	-	2 440.4	-	-	-	13 2299.3	26 3057.7	6 614.9	15 2140.2	8 1070.7	70 9623.2	9.0 5.2
Elopidae	-	18 -	18 10835.8	8 3316.3	-	5 2448.9	1 477.9	6 3551.1	15 7156.5	8 3956.7	61 31749.2	7.7 17.0
Mugilidae	-	-	4 528.6	1 462.2	-	7 2930.3	3 1186.7	6 2759.1	17 7976.1	3 -1554.4	41 17397.4	5.5 9.3
TOTAL #/wt.	2 24.1	3 599.4	67 14342.0	76 19116.3	18 8006.7	130 28776.8	102 20416.1	72 16745.8	143 36453.1	65 16846.3	678 161315.6	

Description of Stations

The eastern part of Guayanilla Bay is bordered almost entirely by the red mangrove *Rhizophora mangle*, with minor populations of the black mangrove *Avicennia nitida* and the white mangrove *Laguncularia racemosa.* Aquatic plant material is sparse compared with that in unstressed areas, and no turtle grass, *Thalassia testudinum*, grows at Stations 1, 2, or 3. Another marine phanerogram, *Halophila* sp. is present at Stations 3, 4, and 5, but in low abundance. Inside the thermal cove the only plant able to survive is an unidentified bule-green alga, although during the cooler winter a green alga, *Enteromorpha* sp. may appear for a month or two. Within the thermal cove, mangrove root communities consist only of barnacles, isopods, a few crabs, and the above algae, but outside it they are normal, as described by Kolehmainen and Morgan (at 34th Ann. Mtg. Am. Soc. Limnol. Oceanogr., Tallahassee, Mar. 1972).

Water depths from station to station vary from 1.7 to 3.8 m. The bottom sediment at all stations is grey to black muds with small percentages of sand. Stations 2 and 3 have strong currents, approaching 2 knots at times; Station 1 has bottom currents of varying directions and velocities; Stations 4 and 5 have only low velocity wind-driven currents. Water temperature in the thermal cove (Station 1) ranged from 29.0° to 39.4°C with a yearly mean of 35.3°C; since the cove is well-mixed, it varied no more than 0.4°C from surface to bottom. At Stations 2 and 3, surface-bottom temperature variations as great as 8.8°C have been measured; Stations 4 and 5 show no temperature stratification. Dissolved oxygen measurements show complete oxygen saturation at all stations, due primarily to turbulence caused by consistently strong winds and/or prevailing currents.

The Catch

To date, 786 fishes (186.5 kg) have been gill-netted from the five stations in Guayanilla Bay. They represent 21 families and 43 species. The most abundant are listed in Table 15. Five species of mojarras (Fam. Gerridae) and four species of jacks (Fam. Carangidae) numerically represent 26.4 and 26.5% of the catch respectively. Among mojarra, the most abundant species is *Gerres cinereus;* among jacks, they are *Caranx latus* and *C. hippos.* The families Sciaenidae (croakers), Sparidae (represented by a single species, *Archosargus rhomboidalis*), Elopidae (ladyfishes and tarpon), and Mugilidae (mullets) numerically represent 11.6, 9.0, 7.7, and 5.5% of the total catch respectively. If the fishes are ranked by biomass, the order is Carangidae (26.7%), Gerridae (21.3%), Elopidae (17.0%), Mugilidae (9.3%), Sciaenidae (7.1%), and Sparidae (5.2%).

Although the gill-net survey is not complete, inferences about seasonal frequency of occurrence can be made for several families. Gerridae and Carangidae are present throughout the year, with peak occurrence between December and July. Sciaenidae are present throughout the year, but with varying species composition, the snake croaker, *Ophioscion adustus*, being abundant from March to July, and the croaker *Bairdiella rhonchu* from September to February, with much overlap in occurrence. *Archosargus rhomboidalis*, Fam. Sparidae, is abundant from February through July but virtually absent the rest of the year. Elopidae and Mugilidae are less abundant but are present throughout the year.

Catch/Unit Effort (C/E)

Because of uncontrollable variables such as inclement weather, sickness, equipment failure, etc., the field sampling efforts in studies such as these may vary from sample period to sample period. A catch per unit effort (C/E) was therefore calculated for each sampling trip at each station:

Table 16: Nocturnal (N) and Diurnal (D) Catch/Unit Effort (C/E), July 1975 to July 1976

(Upper number represents number caught per unit time (hr); bottom number represents biomas obtained per unit time (g/hr)

DATE	STATION 1 # / wt D*	STATION 1 # / wt N**	STATION 2 # / wt D*	STATION 2 # / wt N**	STATION 3 # / wt D*	STATION 3 # / wt N**	STATION 4 # / wt D*	STATION 4 # / wt N**	STATION 5 # / wt D*	STATION 5 # / wt N**
7/23/75	0 / 0	-	-	-	-	-	1.000 / 48.67	-	-	-
7/31/75	-	-	-	-	0 / 0	-	-	-	-	-
8/14/75	-	-	-	-	-	-	1.000 / 607.70	-	-	-
8/21/75	0 / 0	-	0 / 0	-	-	-	-	-	-	-
9/26/76	-	.333 / 2.14	-	-	-	7.692 / 2083.19	-	9.787 / 1054.91	-	-
11/7/75	-	-	-	-	.800 / 149.60	-	-	-	-	-
12/3/75	0 / 0	-	1.019 / 350.12	-	.794 / 263.66	-	-	-	-	-
12/17/75	-	1.145 / 414.53	-	3.077 / 646.91	-	4.643 / 1202.70	-	-	-	-
1/22/76	.151 / 606.62	-	1.266 / 282.71	-	1.889 / 526.63	-	-	-	-	-
2/12/76	0 / 0	-	.907 / 369.69	-	.750 / 151.53	-	4.000 / 1353.23	-	-	-
2/19/76	-	2.176 / 783.56	-	8.182 / 1728.50	-	11.558 / 1716.17	-	3.000 / 709.64	-	-
3/25/76	1.000 / 309.53	1.000 / 292.63	2.615 / 651.29	5.750 / 1178.30	1.910 / 721.21	7.500 / 1618.70	1.522 / 2898.76	2.727 / 385.65	.476 / 103.21	1.309 / 265.70
5/20/76	.476 / 92.60	1.250 / 267.68	.910 / 329.00	7.857 / 2048.48	0 / 0	2.176 / 490.67	1.597 / 256.73	4.3478 / 764.76	1.000 / 212.55	.400 / 59.10
6/17/76	3.095 / 653.24	3.000 / 739.45	2.273 / 654.0	7.545 / 2191.16	4.565 / 1292.10	9.545 / 2173.98	.227 / 75.56	2.176 / 480.26	.625 / 105.70	1.600 / 405.54
7/22/76	1.500 / 345.45	0 / 0	3.500 / 944.65	2.3870 / 521.61	.500 / 137.22	9.416 / 1335.00	1.500 / 404.50	2.143 / 374.69	0 / 0	.625 / 116.98
AV. C/E	.692 / 223.648	1.106 / 357.141	1.561 / 447.682	6.056 / 1385.826	1.407 / 360.616	6.775 / 1517.201	1.545 / 805.592	4.036 / 628.518	.525 / 105.565	.984 / 211.63

*D - Diurnal

**N - Nocturnal

$$\frac{C}{E} = \frac{\text{Number or Weight of fishes sampled}}{\text{Number of gill net sets X Average sampling time}}$$

The C/E values discussed below are in units of number of fish/hr; with few exceptions, C/E values as biomass/hr show similar trends. On a monthly basis C/E for all stations was highest from December 1975 through June 1976, which indicates a positive correlation between high C/E and lower average temperatures.

The data from individual stations show some interesting trends (Table 16). Station 1, which is the hottest because of proximity to the thermal effluent source, has the lowest average C/E, as expected. Station 5, one of the two "control" stations with consistently low temperatures, has the second lowest C/E according to the sparse data available. Station 4, the other "control," has a C/E that is third lowest but is an order of magnitude higher than that of Station 5, primarily because of the greater development of mangroves, which provide more protective cover and more potential food for fish. Stations 2 and 3 are both located in the mouth of the thermal cove and have water temperatures not greatly different from Station 1, but C/E values in some cases are higher by many orders of magnitude.

Temperature Effects

Table 17 lists temperature and C/E at each station. The data for Stations 1, 4, and 5, show that C/E values in the heavily thermally stressed area are similar to those in unstressed areas; however, species composition is quite different. The Shannon-Weaver species diversity index within the thermal cove is much lower (3.66) than in outside areas nearby (4.86) (Kolehmainen and Morgan, *op. cit.;* F. D. Martin and J. W. Patus, in *Proc. 27th Ann. Conf. SE Assoc. Game and Fish Commissioners*, pp. 675-88, 1973).

Elevated C/E values at Stations 2 and 3 can be interpreted as indicating that fish are attracted to the hot water areas in large numbers but hesitate to venture into such areas for any distance or length of time. A possible attraction might be an abundance of nutrients, due to death of small organisms passing through the hot water, which may serve as a direct or indirect food source for the fish. The data for Station 1 indicate that temperatures >38°C exclude all fish.

Diurnal-Nocturnal

The C/E values at all five stations show diurnal-nocturnal differences (Table 16), a greater abundance of fishes being captured at night
during the day (between sunrise and sunset). This trend is not uncommon and is the basis for the timing of the field efforts.

Limitation of Data

As seen from Tables 15 to 17, the data for July 1975 to February 1976 are incomplete. During the early stages, certain planning decisions had to be made regarding station locations, type of equipment, time of sampling, etc., that required preliminary data. The initial data are, however, important in interpreting the overall results.

Work in Progress

Other studies of the Guayanilla population of fishes include evaluation of spawning in and around the thermal cove and correlation with temperature; observation of food habits; and planned work on temperature tolerance.

Table 17: Temperature (°C) and C/E (No. of fish/hr) for Each Station, July 1975 to July 1976 (Through February 1976 temperatures were measured at the surface; starting in March, at the bottom)

	STATION 1		STATION 2		STATION 3		STATION 4		STATION 5	
DATE	Temp	C/E	Temp	C/E	Temp	C/E	Temp	C/E	Temp	C/E
7/23/75	39.4	0.000	-	-	-	-	32.5	1.000	-	-
7/31/75	-	-	-	-	36.6	0.000	-	-	-	-
8/14/75	-	-	-	-	-	-	33.0	1.000	-	-
8/21/75	38.3	0.000	37.9	0.000	-	-	-	-	-	-
9/26/75	39.0	0.333	-	-	37.5	7.692		9.787	-	-
11/7/75	-	-	-	-	38.2	0.800	-	-	-	-
12/3/75		0.00	32.6	1.020	32.6	0.794	-	-	-	-
12/17/75	34.7	1.145	34.6	3.077	34.5	4.643	-	-	-	-
1/22/76	31.6	0.152	31.7	1.266	31.5	1.889	-	-	-	-
2/12/76	33.1	0.000	33.5	0.907	33.4	0.750	28.5	4.000	-	-
2/19/76	32.8	2.176	32.8	8.182	32.2	11.559	26.5	3.000	-	-
3/25/76	29.0	1.000	29.1	4.183	28.9	4.710	26.8	2.1295	26.3	.893
5/20/76	37.4	0.863	37.4	4.385	37.1	1.088	29.9	2.972	30.0	.700
6/17/76	34.7	3.047	34.5	4.905	34.6	7.055	29.7	1.202	28.7	.813
7/22/76	35.5	0.000	36.1	2.9455	34.1	2.406	29.8	1.821	29.3	.308

G. Aquarium Laboratory (M. D. Banus).

An aquarium laboratory equipped with running seawater was completed. It has an ambient-light experimental area of about 850 sq ft, a controlled-light room, an office, a large office-laboratory, and a sample preparation and study area. A dual pumping system supplies seawater to a 10,000-gal tank from which the dual supply lines feed the various experimental areas. A system provided with titanium heat exchangers and control valves circulates 50°C seawater through the experimental area to various microcosmsm of which sixteen 1-m^2 and two 2-m^2 are available. Control and measuring circuits are currently being installed.

This laboratory is now ready for experiments on the effects of elevated temperatures on single species of fish, benthic organisms, plants such as *Thalassia* and mangrove seedlings, and communities of organisms. Long-term experiments on optimum growth temperatures and on effects of temperature on reproductive cycles and on survival of juveniles will be possible. Also, the effects of added trace metals and hydrocarbons can be studied either with or without elevated temperatures.

EDUCATIONAL ACTIVITIES

A. Dr. Gary W. Smith of Furman University, Greenville, S.C., spent the summer studying fishes at CEER. He investigated the effects of elevated temperature in combination with cadmium uptake for two species (*Sphoeroides testudineus* and *Lutjanus apodus*). He completed his field and laboratory investigations but is still interpreting his results.

B. Theses

Osmotic Behavior of *Acanthophora spicifera*. Hilda M. Rojas de Morales (for M.S., UPR Mayagüez, under Drs. T. R. Tosteson and L. R. Almodóvar) – *Acanthophora spicifera* (Rhodophyceae) is a red alga associated with the roots of mangroves in shallow water along the southwest coast of Puerto Rico, and its habitat is subject to sharp changes in tonicity due to rainfall, runoff, and evaporation. To study its osmotic behavior, the alga was incubated in isotonic seawater and in seawater solutions ranging in tonicity from 700 to 1300 mOsmol /kg H_2O for periods of 15 min to 18 hr at constant temperature (28°C) in the light and in the dark. The isotonic water content of *A. spicifera* was 10.886±0.3 g H_2O/g dry wt, remaining constant over 18 hr of incubation and independent of the light regime. During osmotic equilibration for up to 18 hr, in both the light and dark, in tonicities of 700 to 1300 mOsmol /kg H_2O, the mean fraction of the total water that was osmotically responsive (43.1±1%) remained constant. The Cl^- content of the alga remained constant through all periods of incubation in the light, and the estimated Cl^- concentration (675±6.8 μmole/g H_2O) in the algal water remained constant through 18 hr of incubation in isotonic media in the light, as did the Na^+ content and estimated concentration (204±6.1 μmole/g H_2O). The K^+ content of the alga increased with incubation time in the light and the estimated average K^+ concentration in the algal water after 4 hr was 27±1.9 μmole/g H_2O. This alga was found to have a higher Cl^- and K^+ and a lower Na^+ concentration than seawater, with the Cl^- and K^+ contents of incubated algae being dependent on light but not the Na^+ content. On the basis of the Na^+, Cl^-, and K^+ contents, *A. spicifera* appeared to be in a state of incipient plasmolysis. The data were consistent with the idea that this alga equilibrates osmotically by gaining or losing water. The experimental conditions did not affect the alga's subsequent viability.

Effect of Thermal Stress on Nitrogen Fixation in Guayanilla Bay. Marilyn C. Kimball (for M.S., U. of Miami, under M. D. Banus) – The objectives of this study are (1) to estimate the contribution of combined nitrogen from biological nitrogen fixation in the sediments along a thermal gradient, (2) to characterize the nature of this fixation, and (3) to describe the distribution of nitrogen chemical species in a thermally enriched portion of Guayanilla Bay. Nitrogen fixation is a widespread occurrence in the sediments of Guayanilla Bay, most of it from March to August apparently being due to non-photosynthetic bacterial activity. Rates of fixation by microflora inhabiting surface sediments were about the same at all *in situ* incubation temperatures during each month, but the rates increased from March to June and subsequently decreased. The mean monthly rates ranged from $\sim$10 to 20 ng N_2/g dry wt sediment/hr in April to 40 to 177 in June; the highest rates were found in the thermal cove in a mat composed predominantly of *Microcoleus chonotoplastes*, a non-heterocystous blue-green alga. Rates of fixation were correlated with development of the mat along a depth gradient. Mean monthly maximum rates ranged from 893 μg N_2/m^2/hr in May to 1725 in August, with a maximum mean of 2065 in June in the intertidal and most developed portion of the mat; the rates in the least developed portions at depths of 2 m ranged from 46 in May to 29 in August, with a maximum mean of 230 in July. The data collected to August did not indicate a direct relationship between temperature and nitrogen fixation. Nitrogen-fixing microbial populations appeared to be selectively stimulated because of thermal tolerance and/or elimination of less tolerant competitors. Synergistic effects with seasonal changes in light were also seen.

C. Oak Ridge Associated Universities

The Effect of Thermal Stress on the Photosynthetic Potential of Mangrove Leaves. Luisa Ferrara, College of Mt. St. Vincent, New York (for summer project under M. D. Banus).

Comparative Ecology of Seagrass Bed Communities. William Allan Flynn, St. John's University, Minnesota (for summer project under V. P. Vicente).

BIKINI ATOLL PROJECT (Rosa J. Santiago, Fausto Muñoz-Ribadeneira, M. Pérez-Padró, and G. Arocho)

The purpose of this project is to determine the distribution patterns of plutonium and americium in the marine waters, sediments, and organisms of Bikini Atoll and the influence of physical, chemical, and biological parameters on their movements through the marine biogeochemical systems. The scope of the project includes clarification of the physical, chemical, and biological processes determining the movement of ^{238}Pu. ^{239} ^{240}Pu, and ^{241}Am from the sediments of the weapons craters at Bikini into the waters, plants, and animals, and also the distribution patterns of these radionuclides in the components of the system. This involves transfer rates and distribution patterns of Pu and Am from water and sediments through specific planktonic, pelagic, and benthic ecosystems. The project was started in 1973 (see PRNC-176, pp. 124-9, pp. 106-11).

During this reporting period the 44 sediment samples (coarse and fine fractions) collected during the October-November 1974 resurvey of Bikini Atoll and the C#2 core from bravo Crater were analyzed for plutonium content. Determination of ^{241}Am, ^{155}Eu, ^{125}Sb, ^{102}Rh, ^{137}Cs, ^{207}Bi, and ^{60}Co in the sediment and core samples was carried out by gamma counting. A computer program for calculation of gamma analysis results was developed. The ten water samples collected in the 1974 resurvey were analyzed for Pu and Am. Taxonomic classification of the 47 plankton samples collected at 38 different stations in the Bikini Lagoon was completed.

RESEARCH COMPLETED

Plutonium Analysis

Sediment Samples. Sediment samples collected during the October-November 1974 resurvey of Bikini Atoll have been analyzed for plutonium content. The samples were collected with a pipe dredge at 44 different stations (see Figure 1) and brought to the PRNC laboratory for grinding, sieving, and separation into fine and coarse fractions. For analysis, 500 mg of sediment was spiked with ^{242}Pu, dissolved in acid, and passed through two AG1-X8 anion exchange columns in nitrate form. The Pu eluate of the second column was repeatedly evaporated to dryness with a mixture of HNO_3 and HCl; the residue was dissolved in 1 $\underline{M}$ HNO_3; and TTA extraction was done to purify the plutonium, which was then electroplated for 0.5 hr on a stainless steel disc at a current density of 1 amp/cm^2. The results are given in Tables 1 and 2.

Core Samples. The bottom half of the core (C#2) was analyzed for plutonium content from depth 105 to 207 cm. The 306-cm-long core, taken from the Bravo Crater in 1972, was cut into 3-cm sections which were oven-dried and ground, and 500-mg portions were taken for Pu analysis by the same procedure as that used for the sediments. Table 3 shows the results. The first half of this core, 3 to 105 cm, had been analyzed previously.

Gamma Analysis

The contents of ^{241}Am, ^{155}Eu, ^{125}Sb, ^{102}Rh, ^{137}Cs, ^{207}Bi, and ^{60}Co in the sediment and core samples were determined by gamma counting. Homogenized and ground 50-g samples were placed in 125-ml, 2-in.-diam plastic jars and counted for 1000 min on a 30-cc coaxial Ge-Li detector housed in a lead cage to reduce background. All samples were counted at the same position relative to the center of the crystal with <5% dead time, and all spectra were read out on paper tape. The efficiency of the detector at different energies was determined by counting standards of known activity at the same geometry as the sample and plotting calibration curves. Spectra obtained from counting the standards for 1000 min were inspected to find the principal gamma peaks for each nuclide of interest. Peaks that were free of interference (where possible) and containing sufficient counts to give reasonable statistics were chosen. The so designated channels from the spectrum of each standard were processed by the GAMMA computer program to find the area of each peak. The areas, or observed counts/1000 min, for each peak were averaged across the four standards.

A graph plotting efficiency as a function of energy was made. Also plotted were previous results obtained from liquid standards prepared in an earlier attempt to determine detector efficiency. Although not directly comparable because of the slightly different self-absorbtion and geometry characteristics of the samples, the curves are in good agreement at high energies, and give some idea of the reproducibility of the system. Two points on the efficiency curve do not fit exactly: the ^{125}Sb peak at 463.5 keV and the ^{207}Bi, peak at 1063.7 keV. The first discrepancy can probably be attributed to poor statistics and to an unidentified interfering peak or peaks; the second has not been explained. Since a standard for ^{102}Rh was not available, the counting efficiency was read from the graph and taken as 0.45 ± 0.02%. There is some question whether this peak has been properly identified in the samples.

The standard activities and observed counts (interpolated in the case of ^{102}Rh) were suplied to the GAMMA program along with appropriate portions of the spectrum of each experimental sample. GAMMA then calculated the areas of the specified peaks and the activities of the associated nuclides in picocuries/gram for each sample. The results for the sediments and core C#2 are shown in Tables 4, 5, and 6.

Plutonium and Americium Analyses of Sea Water Samples

The 10 water samples collected during the October-November 1974 resurvey of Bikini Atoll have been analyzed for Pu and Am content.

About 20 liters of filtered water were collected at different stations (see Figure 1) and brought to PRNC, where each sample was acidified and spiked with ^{242}Pu and ^{243}Am to check the chemical yield, and the transuranium elements were coprecipitated with ferric hydroxide. The precipitate was dissolved; iron was removed by ether extraction; and Pu and Am were separated by ion exchange. The purified radioelements were electroplated on stainless steel discs for alpha spectrometry. The alpha spectrometer system consists of four 300-mm^2 diode detectors, each sample is counted for 1000 to 2000 min to collect enough counts for acceptable statistics. The results are presented in Table 7.

RESEARCH IN PROGRESS

Analysis of fish samples for ^{238}Pu, ^{239}Pu, and ^{241}Am is continuing in order to obtain additional information needed for defining the mechanisms causing the difference between uptake of ^{238}Pu and of ^{239}Pu by marine organisms. The 45 plankton samples collected in

1974 will be analyzed for the three radionuclides. The results will be related to the patterns (1) in Bikini Lagoon at present, (2) in the plankton samples collected in 1972, (3) in the 1974 water samples, and (4) in the bottom sediments.

Analysis of the remaining sediment core samples from the Bravo, Tewa, and Zuni Craters for radionuclides will be continued.

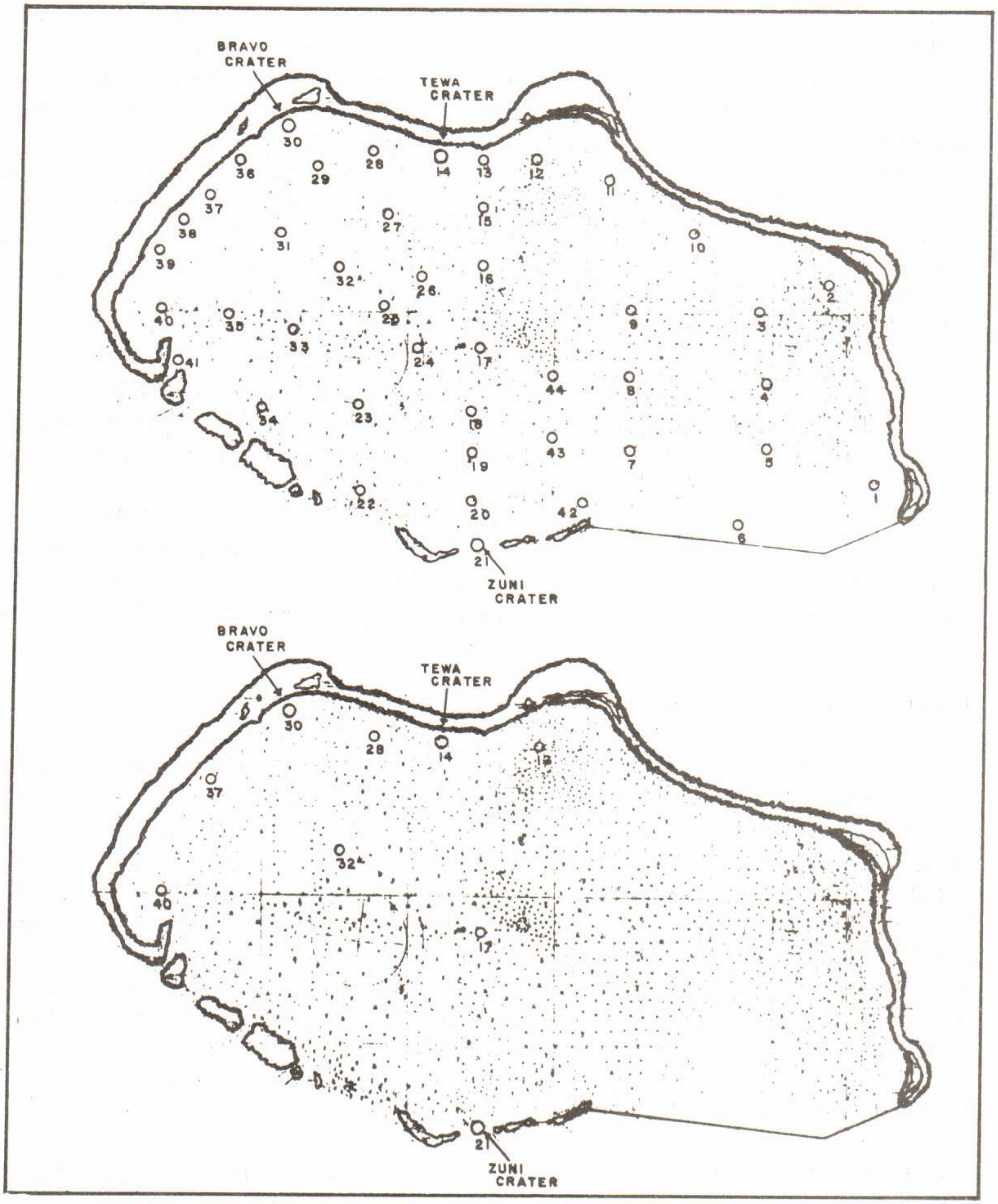


Figure 1: Chart of Bikini Atoll showing stations where samples were collected during October and November 1974. Top: sediment; bottom: seawater.

Table 1: Plutonium Analysis (disintegrations/minute per gram) of Course Fractions (G) of Sediment Samples

STATION NO.	$Pu^{239-240}$ dpm/gm	Pu^{238} dpm/gm	Ratio $Pu^{238}/Pu^{239-240}$
1G	7.3713 ± 1.1548	0.2891 ± 0.2076	0.0392 ± 0.0288
2G	14.1636 ± 10.9665	0.5665 ± 0.2623	0.0400 ± 0.0361
3G	18.1098 ± 3.8459	0.4895 ± 0.4939	0.0270 ± 0.0278
4G	40.1904 ± 2.8419	0.5283 ± 0.1635	0.0131 ± 0.0042
5G	72.2332 ± 11.1073	2.5395 ± 0.9181	0.0352 ± 0.0138
6G	3.4017 ± 0.6837	0.2430 ± 0.1744	0.0714 ± 0.0532
7G	29.9600 ± 2.1200	0.8640 ± 0.2230	0.2880 ± 0.0077
8G	29.8214 ± 2.7655	2.8401 ± 1.6848	0.1604 ± 0.0963
9G	25.4227 ± 1.9194	0.6396 ± 0.3268	0.0252 ± 0.0130
10G	12.9094 ± 0.8705	0.3542 ± 0.1121	0.0274 ± 0.0089
12G	135.0490 ± 2.7010	1.0610 ± 0.2732	0.2575 ± 0.0665
13G	84.2736 ± 6.7944	1.5713 ± 0.3765	0.0186 ± 0.0047
15G	69.3562 ± 23.3865	0.3930 ± 0.1797	0.0010 ± 0.0006
16G	74.5528 ± 5.3813	0.3855 ± 0.1563	0.0052 ± 0.0021
17G	155.2756 ± 6.9441	3.9631 ± 1.0846	0.0255 ± 0.0071
18G	26.3135 ± 2.7723	0.5139 ± 0.2376	0.0195 ± 0.0092
20G	8.2090 ± 1.1551	1.2826 ± 0.4094	0.1562 ± 0.0545
21G	62.3575 ± 7.0549	31.4785 ± 3.8809	0.5048 ± 0.0845
22G	8.9573 ± 1.1679	0.5598 ± 0.2571	0.0625 ± 0.0298
23G	15.3166 ± 1.7730	0.5106 ± 0.2578	0.0333 ± 0.0173
25G	102.4396 ± 6.8719	0.9672 ± 0.2992	0.0094 ± 0.0030
26G	142.8147 ± 9.9970	0.9593 ± 0.2541	0.0672 ± 0.0184
28G	46.8263 ± 2.3877	9.6378 ± 1.8413	0.2058 ± 0.0407
29G	591.2430 ± 66.1030	3.9882 ± 1.4890	0.0067 ± 0.0026
30G	33.9286 ± 3.4434	2.9773 ± 0.6584	0.0877 ± 0.0213
31G	112.5392 ± 15.8756	6.0598 ± 1.8088	0.0538 ± 0.0178
32G	59.1597 ± 5.5811	0.5330 ± 0.2466	0.0090 ± 0.0042
33G	149.7731 ± 13.1425	1.9578 ± 0.9879	0.0131 ± 0.0067
34G	56.0797 ± 3.8853	0.3894 ± 0.2300	0.0069 ± 0.0041
35G	49.8061 ± 2.5422	1.4390 ± 0.2488	0.0289 ± 0.0052
36G	408.6425 ± 23.4747	8.3528 ± 0.9450	0.0204 ± 0.0026
37G	19.4733 ± 1.6524	1.2887 ± 0.3200	0.0662 ± 0.0173
39G	27.5617 ± 2.4958	0.7566 ± 0.2952	0.0275 ± 0.0110
40G	12.0692 ± 1.6592	0.5305 ± 0.2694	0.0440 ± 0.0231
41G	44.3635 ± 2.8515	1.5657 ± 0.2543	0.0352 ± 0.0061
42G	5.0011 ± 0.5340	0.1936 ± 0.1145	0.0387 ± 0.0233
43G	31.3968 ± 4.7619	3.9246 ± 1.5801	0.1250 ± 0.0538
44G	49.7116 ± 5.3310	0.7849 ± 0.3355	0.0158 ± 0.0070
45G	17.4780 ± 1.9928	0.1170 ± 0.1174	0.0067 ± 0.0068
46G	37.1834 ± 3.6621	0.4201 ± 0.2131	0.0113 ± 0.0053

Table 2: Plutonium Analysis (disintegrations/minutes per gram) of Fine Fractions (F) of Sediment Samples.

STATION NO.	$Pu^{239-240}$ dpm/gm	Pu^{238} dpm/gm	Ratio $Pu^{238}/Pu^{239-240}$
1F	7.2313 ± 1.6170	Not detected	
2F	19.3059 ± 1.6037	0.3171 ± 0.1586	0.0164 ± 0.0083
3F	41.2690 ± 2.3740	0.6681 ± 0.1886	0.0162 ± 0.0047
4F	39.5119 ± 1.3105	0.4650 ± 0.0750	0.0118 ± 0.0020
5F	15.6142 ± 1.0590	0.2798 ± 0.1009	0.0179 ± 0.0066
6F	5.5912 ± 0.4906	0.2673 ± 0.1121	0.0478 ± 0.0205
7F	26.0884 ± 1.6500	0.4750 ± 0.0435	0.0182 ± 0.0020
8F	35.5134 ± 3.9065	1.3202 ± 0.4316	0.0372 ± 0.0128
9F	32.9775 ± 3.9573	0.1499 ± 0.1500	0.0046 ± 0.0046
10F	18.4570 ± 1.4533	0.3128 ± 0.1317	0.0169 ± 0.0072
12F	235.2992 ± 39.5835	3.8892 ± 1.3723	0.0165 ± 0.0065
13F	338.9691 ± 115.0499	4.7967 ± 3.2430	0.0141 ± 0.0107
14F	154.9910 ± 13.8628	1.3705 ± 0.4319	0.0088 ± 0.0029
15F	95.6495 ± 5.8181	0.9560 ± 0.2240	0.0100 ± 0.0024
16F	144.2807 ± 17.0858	1.7041 ± 0.6008	0.0118 ± 0.0044
17F	352.6793 ± 19.9506	1.3733 ± 0.2961	0.0039 ± 0.0009
18F	59.9592 ± 5.9757	1.2869 ± 0.4011	0.0215 ± 0.0071
20F	13.3891 ± 1.2702	1.1886 ± 0.2911	0.0888 ± 0.0233
21F	92.3758 ± 17.6725	52.2225 ± 10.5225	0.5653 ± 0.1571
22F	23.8637 ± 1.9091	4.4370 ± 0.7608	0.1859 ± 0.0352
23F	32.7050 ± 11.8733	5.2328 ± 3.0593	0.1600 ± 0.1101
25F	130.8372 ± 10.0498	0.8521 ± 0.2907	0.0065 ± 0.0023
26F	288.4497 ± 28.6770	1.5998 ± 0.4700	0.0052 ± 0.0016
27F	302.5500 ± 43.9500	2.5600 ± 0.7400	0.0085 ± 0.0028
28F	129.2453 ± 26.1063	1.5989 ± 0.9895	0.0124 ± 0.0081
29F	1092.7831 ± 73.3061	4.7967 ± 0.7227	0.0044 ± 0.0007
30F	165.7571 ± 19.3304	16.3688 ± 2.5200	0.0988 ± 0.0191
31F	114.6476 ± 26.5428	12.8686 ± 4.7317	0.1122 ± 0.0488
32F	67.7077 ± 5.2446	1.6235 ± 0.3645	0.0240 ± 0.0057
33F	108.8259 ± 20.5620	3.1478 ± 1.3348	0.0289 ± 0.0134
34F	49.1665 ± 11.3935	5.3963 ± 2.1094	0.1098 ± 0.0499
35F	135.1651 ± 26.5213	4.6254 ± 1.7716	0.0342 ± 0.0147
36F	319.2008 ± 69.3482	5.2328 ± 2.1752	0.0164 ± 0.0077
37F	213.5991 ± 24.1660	8.8422 ± 1.5793	0.0414 ± 0.0088
38F	126.0981 ± 11.2078	6.1972 ± 0.9601	0.0491 ± 0.0088
39F	280.2491 ± 63.4131	2.8780 ± 1.5748	0.0103 ± 0.0061
40F	55.6304 ± 6.8586	0.7020 ± 0.3594	0.0126 ± 0.0066
41F	120.4061 ± 9.5569	1.7886 ± 0.4035	0.0148 ± 0.0035
42F	9.8624 ± 0.8654	0.1345 ± 0.0795	0.0136 ± 0.0081
43F	30.4011 ± 2.0842	0.7858 ± 0.2017	0.0258 ± 0.0068
44F	60.8135 ± 11.2299	2.4654 ± 1.1089	0.0405 ± 0.0197
45F	14.0343 ± 1.1980	0.5593 ± 0.1728	0.0398 ± 0.0127
46F	23.6330 ± 2.0330	0.4509 ± 0.1904	0.0191 ± 0.0082

Table 3: Plutonium Analysis (disintegrations/minute per gram) of C#2 Core From Bravo Crater (Bottom Half of Core)

STATION NO.	$Pu^{239-240}$ dpm/gm	Pu^{238} dpm/gm	Ratio $Pu^{238}/Pu^{239-240}$
C#2(105-108)	176.4033 ± 19.7350	11.4921 ± 2.1805	0.0652 ± 0.0144
C#2(108-111)	177.9356 ± 7.3365	10.8475 ± 0.7195	0.0610 ± 0.0048
C#2(111-114)	187.1701 ± 8.7791	16.2931 ± 1.2621	0.0871 ± 0.0079
C#2(114-117)	186.6936 ± 11.8075	12.7248 ± 1.4564	0.0682 ± 0.0089
C#2(117-120)	163.2808 ± 16.0813	15.0911 ± 2.3718	0.0924 ± 0.0171
C#2(120-123)	137.6367 ± 5.1499	6.8930 ± 0.5018	0.0501 ± 0.0041
C#2(123-126)	165.5474 ± 9.3648	7.2869 ± 0.8683	0.0440 ± 0.0058
C#2(126-129)	156.0457 ± 6.9786	2.5396 ± 0.2564	0.0163 ± 0.0018
C#2(129-132)	174.6714 ± 9.5671	9.8406 ± 1.2092	0.0563 ± 0.0076
C#2(132-135)	185.4171 ± 6.4230	7.4954 ± 0.5806	0.0404 ± 0.0034
C#2(135-138)	213.2794 ± 32.5557	10.1908 ± 3.1061	0.0478 ± 0.0163
C#2(138-141)	175.3554 ± 18.8047	9.3845 ± 1.8462	0.0535 ± 0.0120
C#2(141-144)	180.5581 ± 4.7771	9.0868 ± 0.5220	0.0503 ± 0.0032
C#2(144-147)	187.9087 ± 20.7552	8.3012 ± 1.9556	0.0442 ± 0.0115
C#2(147-150)	164.8339 ± 7.1849	9.0864 ± 0.8763	0.0551 ± 0.0058
C#2(150-153)	125.4275 ± 9.7156	5.2238 ± 0.6690	0.0416 ± 0.0196
C#2(153-156)	146.9801 ± 5.2994	7.4567 ± 0.6104	0.0507 ± 0.0045
C#2(156-159)	111.8474 ± 8.3755	5.3437 ± 0.6545	0.0478 ± 0.0069
C#2(159-162)	156.2161 ± 8.6977	8.7459 ± 1.0048	0.0560 ± 0.0072
C#2(162-165)	209.0788 ± 11.0634	11.6651 ± 1.2455	0.0558 ± 0.0066
C#2(165-168)	255.1729 ± 10.8261	9.3758 ± 0.8490	0.0367 ± 0.0037
C#2(168-171)	159.9991 ± 17.0832	6.7653 ± 1.6461	0.0423 ± 0.0112
C#2(171-174)	124.1723 ± 10.9038	8.3601 ± 0.7336	0.0673 ± 0.0141
C#2(174-177)	120.7389 ± 23.3810	8.9136 ± 3.1210	0.0738 ± 0.0295
C#2(177-180)	89.0858 ± 6.2360	3.7744 ± 0.6908	0.0424 ± 0.0083
C#2(180-183)	156.2564 ± 7.3291	6.2443 ± 0.7282	0.0400 ± 0.0050
C#2(183-186)	161.5200 ± 14.8914	5.8381 ± 1.2302	0.0361 ± 0.0083
C#2(186-189)	115.1784 ± 13.3329	4.0515 ± 1.1735	0.0352 ± 0.0110
C#2(189-192)	112.3078 ± 17.5071	4.5377 ± 1.2142	0.0404 ± 0.0125
C#2(192-195)	191.6603 ± 11.4996	5.6229 ± 0.9995	0.0293 ± 0.0055
C#2(195-198)	156.9831 ± 16.0092	6.3388 ± 1.0101	0.0404 ± 0.0076
C#2(198-201)	196.4706 ± 9.4224	9.6331 ± 0.9438	0.0490 ± 0.0053
C#2(201-204)	146.6067 ± 10.7734	6.7854 ± 1.2749	0.0463 ± 0.0093
C#2(204-207)	129.8772 ± 8.0062	2.7156 ± 0.5862	0.0209 ± 0.0047

TABLE 4. GAMMA ANALYSIS

SEDIMENT SAMPLES - COARSE FRACTIONS (G)

ACTIVITY=PICOCURIES/GRAM

STATION NO.	AM241	EU155	SB125	RH102	BI207	CS137	CO 60
STA 1G	4.432+ 0.443	2.552+ 0.374	3.367+ 1.113	************	************	1.107+ 0.160	0.976+ 0.169
STA 2G	6.409+ 0.510	3.820+ 0.394	************	************	1.155+ 0.141	0.158+ 0.149	1.258+ 0.177
STA 3G	16.191+ 0.840	10.774+ 0.541	************	0.158+ 0.109	3.266+ 0.205	0.317+ 0.176	4.196+ 0.279
STA 4G	17.584+ 0.886	7.578+ 0.481	************	************	0.704+ 0.152	0.660+ 0.141	1.471+ 0.187
STA 5G	6.662+ 0.521	3.293+ 0.392	************	************	0.298+ 0.127	0.527+ 0.160	0.988+ 0.151
STA 6G	1.365+ 0.369	1.277+ 0.361	************	************	************	************	0.476+ 0.132
STA 7G	11.310+ 0.696	5.355+ 0.415	************	0.161+ 0.088	1.071+ 0.140	0.401+ 0.150	1.021+ 0.170
STA 8G	19.651+ 0.969	11.685+ 0.565	************	0.178+ 0.119	1.377+ 0.157	0.888+ 0.180	1.787+ 0.193
STA 9G	22.401+ 1.059	16.107+ 0.687	1.401+ 1.159	************	1.335+ 0.159	0.834+ 0.162	1.984+ 0.197
STA10G	3.309+ 0.405	2.553+ 0.369	************	************	0.605+ 0.131	0.165+ 0.180	0.985+ 0.154
STA12G	105.807+ 4.182	105.321+ 3.039	5.901+ 1.345	0.441+ 0.133	************	3.264+ 0.258	5.814+ 0.323
STA13G	79.739+ 3.201	82.058+ 2.417	************	************	1.559+ 0.174	1.096+ 0.193	7.207+ 0.363
STA15G	47.761+ 2.003	46.969+ 1.463	************	0.304+ 0.123	1.171+ 0.172	1.688+ 0.196	3.307+ 0.257
STA16G	48.599+ 2.031	33.180+ 1.101	************	0.109+ 0.136	7.232+ 0.296	0.017+ 0.240	7.130+ 0.372
STA17G	188.932+ 7.318	126.282+ 3.619	************	0.059+ 0.122	1.065+ 0.169	2.203+ 0.224	7.237+ 0.368
STA18G	15.470+ 0.846	9.269+ 0.499	************	0.127+ 0.099	************	0.471+ 0.187	2.360+ 0.224
STA20G	1.510+ 0.376	3.079+ 0.398	************	0.882+ 0.119	0.125+ 0.136	1.430+ 0.199	0.963+ 0.184
STA21G	12.028+ 0.773	37.294+ 1.264	************	22.935+ 1.090	************	7.152+ 0.375	9.925+ 0.450
STA22G	5.569+ 0.515	4.313+ 0.410	************	0.571+ 0.114	************	0.653+ 0.153	1.250+ 0.179
STA23G	7.719+ 0.565	7.015+ 0.474	************	0.500+ 0.108	0.239+ 0.146	0.606+ 0.169	2.112+ 0.217
STA25G	57.235+ 2.379	30.273+ 1.034	************	0.298+ 0.112	9.567+ 0.344	1.386+ 0.230	4.658+ 0.288
STA26G	74.981+ 3.005	50.573+ 1.565	0.983+ 0.839	0.285+ 0.095	3.442+ 0.217	1.347+ 0.212	4.543+ 0.291
STA28G	52.894+ 2.176	53.022+ 1.629	************	0.398+ 0.127	1.642+ 0.169	3.906+ 0.263	4.573+ 0.288
STA29G	84.594+ 3.395	41.726+ 1.324	************	************	1.751+ 0.186	6.374+ 0.333	7.900+ 0.383
STA30G	30.486+ 1.412	22.133+ 0.839	************	0.515+ 0.173	19.936+ 0.549	2.890+ 0.273	5.135+ 0.322
STA31G	61.963+ 2.564	48.682+ 1.524	************	0.663+ 0.188	30.996+ 0.766	4.361+ 0.305	9.018+ 0.413
STA32G	25.995+ 1.189	19.402+ 0.745	************	************	6.176+ 0.270	0.493+ 0.209	3.326+ 0.236
STA33G	28.238+ 1.278	23.231+ 0.847	0.857+ 0.853	0.294+ 0.102	1.604+ 0.168	1.857+ 0.217	4.131+ 0.268
STA34G	48.542+ 2.021	37.266+ 1.208	************	************	2.073+ 0.185	3.501+ 0.257	4.280+ 0.284
STA35G	42.462+ 1.829	30.806+ 1.038	************	0.347+ 0.129	6.812+ 0.284	1.981+ 0.230	4.588+ 0.278
STA36G	168.723+ 6.559	91.981+ 2.695	************	0.994+ 0.202	19.662+ 0.559	24.992+ 0.775	19.542+ 0.695
STA37G	5.403+ 0.548	7.211+ 0.473	************	0.188+ 0.114	3.357+ 0.202	0.519+ 0.185	1.169+ 0.154
STA39G	16.371+ 0.898	16.053+ 0.696	************	0.231+ 0.110	6.256+ 0.272	0.882+ 0.203	5.110+ 0.306
STA40G	6.212+ 0.521	8.186+ 0.498	************	************	3.580+ 0.211	0.465+ 0.214	1.218+ 0.178
STA41G	30.926+ 1.372	21.212+ 0.802	0.126+ 1.211	0.478+ 0.151	8.841+ 0.326	1.870+ 0.244	6.867+ 0.360
STA42G	3.750+ 0.457	0.464+ 0.366	************	0.122+ 0.096	************	2.193+ 0.162	0.626+ 0.160
STA43G	10.654+ 0.674	6.629+ 0.469	************	0.331+ 0.116	0.997+ 0.155	0.093+ 0.200	1.574+ 0.202
STA44G	26.342+ 1.207	16.237+ 0.693	************	0.285+ 0.104	4.068+ 0.216	0.909+ 0.182	3.108+ 0.252
STA45G	5.206+ 0.471	3.121+ 0.404	************	************	0.512+ 0.147	0.433+ 0.135	0.969+ 0.172
STA46G	8.432+ 0.576	4.469+ 0.421	************	************	************	0.373+ 0.164	0.961+ 0.151

TABLE 5. GAMMA ANALYSIS

SEDIMENT SAMPLES - FINE FRACTIONS (F)

ACTIVITY=PICOCURIES/GRAM

STATION NO.	AM241	EU155	SB125	RH102	BI207	CS137	CO 60
STA 1F	4.395+ 0.450	7.186+ 0.397	*************	*************	*************	0.340+ 0.126	0.263+ 0.140
STA 4F	20.200+ 0.976	9.809+ 0.539	0.328+ 0.753	*************	0.340+ 0.171	0.948+ 0.162	1.376+ 0.182
STA 5F	7.623+ 0.549	2.868+ 0.418	*************	0.108+ 0.083	0.322+ 0.139	0.247+ 0.143	0.693+ 0.154
STA 6F	1.592+ 0.408	0.911+ 0.368	1.419+ 0.883	*************	*************	0.372+ 0.140	*************
STA 7F	9.356+ 0.610	4.843+ 0.405	*************	*************	0.558+ 0.155	*************	1.141+ 0.171
STA 8F	19.851+ 1.003	9.654+ 0.532	0.882+ 0.993	0.420+ 0.129	0.458+ 0.145	0.933+ 0.193	1.670+ 0.182
STA 9F	24.997+ 1.164	19.460+ 0.748	0.887+ 0.740	*************	0.734+ 0.141	0.662+ 0.164	2.683+ 0.227
STA12F	343.596+13.153	340.894+ 9.482	*************	0.970+ 0.156	0.166+ 0.134	8.191+ 0.374	5.467+ 0.317
STA13F	298.065+11.440	284.162+ 7.932	*************	*************	1.685+ 0.190	6.555+ 0.331	7.714+ 0.383
STA14F	98.507+ 3.960	143.858+ 4.102	3.434+ 1.486	0.631+ 0.195	0.111+ 0.225	38.934+ 1.078	12.600+ 0.513
STA20F	5.718+ 0.542	5.631+ 0.452	*************	1.183+ 0.147	0.171+ 0.176	2.192+ 0.207	1.336+ 0.191
STA21F	24.082+ 1.233	80.670+ 2.431	*************	53.477+ 2.444	2.559+ 0.421	15.630+ 0.599	14.649+ 0.576
STA22F	9.578+ 0.645	6.360+ 0.466	*************	3.041+ 0.177	1.003+ 0.151	0.538+ 0.186	1.986+ 0.200
STA23F	13.839+ 0.767	11.378+ 0.575	*************	0.585+ 0.127	*************	1.195+ 0.185	1.795+ 0.203
STA27F	261.366+10.053	294.583+ 8.227	4.779+ 1.411	1.197+ 0.235	2.708+ 0.246	40.166+ 1.115	23.068+ 0.779
STA28F	85.194+ 3.418	87.055+ 2.550	*************	0.582+ 0.144	0.736+ 0.174	10.172+ 0.413	5.492+ 0.325
STA29F	829.642+31.537	387.030+10.756	*************	1.331+ 0.254	12.535+ 0.438	47.145+ 1.292	29.886+ 1.005
STA30F	97.946+ 3.915	62.748+ 1.907	0.659+ 1.162	0.806+ 0.182	36.715+ 0.883	9.333+ 0.443	11.330+ 0.488
STA31F	35.364+ 1.571	26.451+ 0.925	*************	0.645+ 0.150	16.689+ 0.480	2.364+ 0.241	3.549+ 0.262
STA33F	70.911+ 2.859	56.229+ 1.729	*************	0.222+ 0.151	3.109+ 0.215	5.633+ 0.316	5.374+ 0.323
STA34F	15.932+ 0.835	14.316+ 0.619	*************	1.781+ 0.157	0.607+ 0.145	1.231+ 0.185	2.294+ 0.211
STA36F	315.437+12.101	171.518+ 4.862	4.323+ 1.455	0.881+ 0.235	18.611+ 0.538	45.210+ 1.231	16.761+ 0.615
STA37F	147.105+ 5.771	118.152+ 3.413	0.867+ 1.129	1.380+ 0.211	25.413+ 0.665	17.395+ 0.606	13.449+ 0.532
STA38F	74.695+ 3.019	64.949+ 1.973	1.824+ 1.142	2.357+ 0.200	9.997+ 0.357	8.125+ 0.394	11.063+ 0.476
STA39F	28.947+ 1.328	28.729+ 0.993	*************	0.669+ 0.126	6.079+ 0.274	2.539+ 0.239	4.556+ 0.283
STA40F	47.099+ 1.989	42.601+ 1.355	*************	1.079+ 0.158	5.901+ 0.269	3.873+ 0.278	6.083+ 0.334
STA41F	78.530+ 3.180	66.483+ 2.004	*************	1.163+ 0.190	13.709+ 0.430	6.768+ 0.358	9.728+ 0.439
STA42F	2.786+ 0.402	1.079+ 0.380	*************	*************	*************	0.296+ 0.147	0.245+ 0.178
STA45F	5.587+ 0.490	4.306+ 0.411	*************	0.260+ 0.109	0.354+ 0.132	0.440+ 0.167	1.307+ 0.170
STA46F	5.143+ 0.509	3.829+ 0.408	*************	*************	0.380+ 0.124	0.338+ 0.182	0.632+ 0.172

TABLE 6. GAMMA ANALYSIS

CORE SAMPLES - C#2 CORE FROM BRAVO CRATER (BOTTOM HALF OF CORE)

ACTIVITY=PICOCURIES/GRAM

C#2 CORE	AM241	EU155	SB125	RH102	BI207	CS137	CO 60
C2 105-108	78.986+ 3.834	91.024+ 2.885	36.135+ 5.650	6.597+ 0.648	483.866+ 9.534	40.872+ 1.401	236.272+ 5.990
C2 108-111	103.240+ 4.619	97.710+ 3.067	36.529+ 5.836	5.571+ 0.651	534.735+10.516	52.648+ 1.649	259.149+ 6.546
C2 111-114	96.533+ 4.444	105.269+ 3.248	48.325+ 7.168	5.963+ 0.640	568.494+11.172	48.787+ 1.584	275.555+ 6.945
C2 114-117	103.523+ 4.646	107.144+ 3.312	39.161+ 6.046	5.288+ 0.627	543.059+10.679	51.652+ 1.634	274.068+ 6.910
C2 117-120	78.059+ 3.782	93.384+ 2.926	35.484+ 5.509	4.492+ 0.558	418.505+ 8.269	45.497+ 1.425	228.736+ 5.808
C2 120-123	66.905+ 3.211	69.437+ 2.258	29.631+ 4.620	4.166+ 0.478	270.076+ 5.403	40.596+ 1.293	171.741+ 4.419
C2 123-126	71.819+ 3.182	63.709+ 2.066	27.755+ 4.231	3.497+ 0.437	174.875+ 3.572	36.966+ 1.199	161.872+ 4.181
C2 126-129	94.140+ 3.977	78.169+ 2.436	27.599+ 4.238	2.788+ 0.412	156.405+ 3.222	40.524+ 1.253	175.212+ 4.506
C2 129-132	84.272+ 3.606	74.480+ 2.342	30.123+ 4.593	4.142+ 0.441	145.960+ 3.020	34.823+ 1.157	160.831+ 4.151
C2 132-135	111.863+ 4.574	73.296+ 2.281	19.236+ 3.249	2.333+ 0.381	113.629+ 2.395	43.184+ 1.288	149.547+ 3.878
C2 135-138	104.498+ 4.272	71.351+ 2.248	27.809+ 4.211	2.778+ 0.393	113.297+ 2.390	39.007+ 1.201	154.791+ 4.010
C2 138-141	99.902+ 4.126	70.033+ 2.219	21.953+ 3.595	2.815+ 0.391	124.803+ 2.611	39.472+ 1.219	153.167+ 3.968
C2 141-144	106.096+ 4.346	60.585+ 1.975	25.541+ 4.021	4.190+ 0.437	138.420+ 2.870	44.987+ 1.338	170.518+ 4.386
C2 144-147	95.025+ 3.984	74.631+ 2.396	26.622+ 4.146	2.220+ 0.436	148.871+ 3.073	43.309+ 1.303	165.951+ 4.275
C2 147-150	83.357+ 3.561	69.392+ 2.194	23.903+ 3.769	3.103+ 0.406	144.838+ 2.991	41.408+ 1.267	156.188+ 4.041
C2 150-153	78.856+ 3.406	65.421+ 2.111	28.379+ 4.283	3.043+ 0.379	133.714+ 2.776	37.296+ 1.168	153.608+ 3.973
C2 153-156	74.317+ 3.275	72.826+ 2.296	29.488+ 4.488	1.996+ 0.461	155.610+ 3.200	42.937+ 1.312	180.433+ 4.627
C2 156-159	76.447+ 3.339	68.422+ 2.170	24.608+ 3.856	3.887+ 0.417	156.717+ 3.222	38.601+ 1.196	163.421+ 4.215
C2 159-162	93.923+ 3.929	72.870+ 2.273	32.691+ 4.895	3.744+ 0.415	145.234+ 3.002	40.743+ 1.268	163.955+ 4.227
C2 162-165	109.590+ 4.465	69.021+ 2.171	16.433+ 2.856	3.460+ 0.385	93.765+ 2.014	39.714+ 1.219	143.400+ 3.727
C2 165-168	113.767+ 4.675	72.668+ 2.266	26.235+ 4.056	2.581+ 0.398	116.156+ 2.447	42.559+ 1.291	152.851+ 3.965
C2 168-171	107.496+ 4.400	70.785+ 2.216	22.075+ 3.494	2.928+ 0.369	104.363+ 2.214	41.772+ 1.255	148.292+ 3.848
C2 171-174	99.125+ 4.074	61.098+ 1.961	25.343+ 3.962	1.939+ 0.369	98.209+ 2.093	43.982+ 1.297	132.868+ 3.474
C2 174-177	81.329+ 3.404	62.101+ 1.995	21.451+ 3.562	2.318+ 0.373	97.896+ 2.087	42.866+ 1.268	132.662+ 3.466
C2 177-180	84.919+ 3.551	58.796+ 1.904	21.198+ 3.371	2.317+ 0.373	95.262+ 2.037	44.380+ 1.291	128.657+ 3.365
C2 180-183	78.167+ 3.284	50.217+ 1.671	20.112+ 3.220	2.683+ 0.348	85.656+ 1.849	39.013+ 1.168	111.013+ 2.942
C2 183-186	67.755+ 2.902	48.086+ 1.620	16.828+ 2.889	2.481+ 0.352	88.931+ 1.911	42.884+ 1.251	108.980+ 2.893
C2 186-189	65.154+ 2.828	45.770+ 1.575	18.347+ 3.072	2.784+ 0.356	85.647+ 1.854	41.209+ 1.217	110.432+ 2.925
C2 189-192	71.399+ 3.038	50.094+ 1.682	17.529+ 3.012	3.022+ 0.371	86.324+ 1.863	42.449+ 1.243	115.278+ 3.047
C2 192-195	76.253+ 3.202	55.475+ 1.813	18.608+ 3.063	2.658+ 0.345	80.594+ 1.755	43.805+ 1.269	110.286+ 2.922
C2 195-198	88.473+ 3.657	55.076+ 1.805	17.041+ 2.906	3.283+ 0.373	80.834+ 1.760	43.027+ 1.268	108.981+ 2.890
C2 198-201	109.486+ 4.421	60.397+ 1.945	17.337+ 2.880	2.962+ 0.366	72.270+ 1.597	45.385+ 1.301	115.401+ 3.049
C2 201-204	108.913+ 4.380	62.905+ 2.023	16.144+ 2.789	3.150+ 0.370	75.475+ 1.661	47.425+ 1.358	122.205+ 3.213
C2 204-207	119.332+ 4.783	74.598+ 2.310	26.005+ 3.981	2.394+ 0.348	74.192+ 1.642	52.221+ 1.476	146.210+ 3.799

TRANSFER AND DISPERSION OF ORGANIC POLLUTANTS FROM AN OIL REFINERY THROUGH COASTAL WATERS

The objective of this study is to determine the organic pollutant load in coastal waters and sediments and its pathways from an oil refinery–petrochemical complex into Guayanilla and Tallaboa Bays.

Research (M. D. Banus and J. A. Castrillón)

The total hydrocarbons in the sediments and water were measured during several sampling periods over a wide grid in Guayanilla and Tallaboa (Sites A through R, Figure 1) by standard analytical methods. Triplicate 2-liter water samples were required for adequate precision. Duplicate analyses on large-surface (1-cm-deep) sediment samples gave excellent precision. The sediment levels indicated accumulated hydrocarbons, and the surface water concentrations showed real-time distributions depending on wind and current action.

The survey data suggested that the two major sources of hydrocarbons were seepage from waste ponds through the mangroves into the adjacent lagoon waters (Sites C and D) and drainage from the discharge canal at Tallaboa (Site I). Next to the main cooling water canal in Tallaboa is a small parallel ditch that appears to be heavily contaminated with hydrocarbons. The mixing zone between this ditch and the bay water was taken as a new sampling site, $I_{(1)}$, and as the base of a sampling grid including Sites B, H, G, Z, and X. A second grid, based on Sites C and D next to the mangroves, was set up by adding Sites T, S, U, and J. Triplicate water samples were taken at the sites of each grid

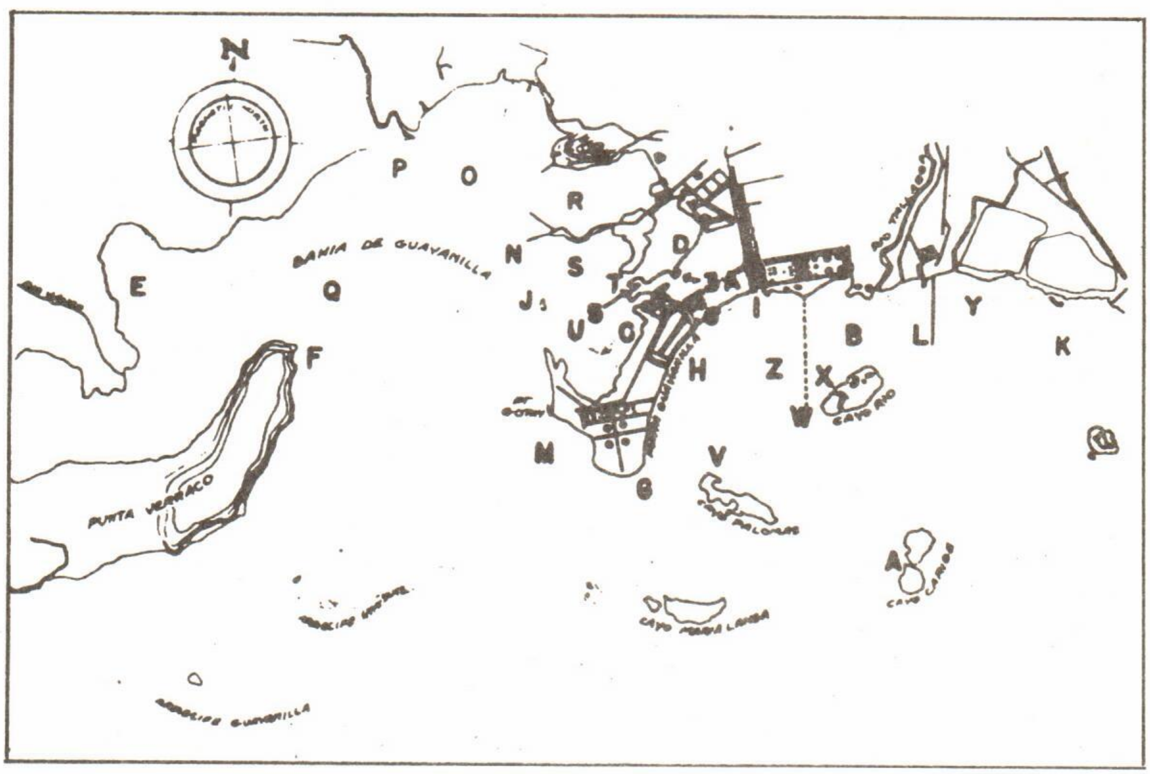


Figure 1: Guayanilla and Tallaboa Bays

within a 2-hr period. Two separate benthic samples were collected for each new site, and duplicate sub-samples were analyzed for total hydrocarbons. Table 1 shows the results.

Table 1: Total Hydrocarbons in Sediment and Water Samples

	Mangrove lagoon grid site						Discharge canal grid site					
	C	D	T	S	J	U	B	$I_{(1)}$	H	G	X	2
Sediment [a] wt % (dry)	0.13	0.44	0.11	0.07	0.18	0.16	0.08		0.33	0.17	0.07	0.20
Water [b] µg/liter	105±[c] 64	[c]	112± 28	163± 25	172± 15	85± 18	77± 26	4780± 4000	42± 8	177± 12	125± 78	52± 18

[a] Mean for two samples at different times, duplicate analyses/sample.

[b] Mean ± S.D. for three replicates collected at the same time, each grid sampled within a 2 hr period.

[c] Previous sampling showed 389±105 for C and 232±39 for D.

In the mangrove lagoon area, Site D is in the seepage area, and globs of oil float to the surface if the sediment is disturbed. The hydrocarbon values in sediment for S, T, and C are significantly lower than for J and U, being the lowest for S. This indicates that hydrocarbons leaving the lagoon or the burner area C accumulate in an area W to WSW of the sources. During the day winds are from the SE so that surface water flow is to the WNW. This is confirmed by the water analyses, which show significantly higher hydrocarbon concentrations in surface water at S and J. However, the daytime winds appear not to be very important to the hydrocarbon movement. Since the water at these sites is only 1 to 2 m deep, except for a deep narrow channel between J and T, it is well mixed between surface and bottom by the winds.

The grid based on the Tallaboa discharge canal shows clearly that the drainage ditch is a substantial source of hydrocarbons, although the ditch itself cannot be tested for hydrocarbon level and flow volume without trespassing on refinery property. Very little of the hydrocarbon has moved east to Site B (near the mouth of a river running through the refinery) or over to the nearest mangrove island (Site X). The wind and wind-driven current move the effluents from the canal and ditch SW along the shore of Punta Guayanilla. During the daytime in the summer, when the wind is E to SE, the current is held close to the shore as shown by the hydrocarbon levels in the water. Site G is ∿100 m from shore and site H, >300 m. Hydrocarbon levels in the sediment show that during the nighttime and in winter, when winds are NE, the effluent plume has deposited substantial amounts of hydrocarbons at H and lower amounts at G.

The shape of the effluent plume has been followed by biweekly temperature measurements as part of another study. The discharge from this canal is 5° to 7°C above ambient. During the day the heated water is closer to shore so that Site H usually has a ΔT of +1°, but Site G almost always has a ΔT of +1.5° to 2°C.

In order to check the efficiency of the sediment extraction process, sediments which had been previously analyzed in duplicate were spiked with 50 mg of Diesel oil and re-analyzed. The results (Table 2) show a mean recovery of 93% of the spike from three sediments with low hydrocarbon levels and three with moderate levels.

Table 2: Recovery of 50 mg Diesel Oil Spike From Sediment Samples

Sample No:	Dry wt. (g)	Mean %hydro from anal.	Wt. hydro (mg)	Total hydro (mg)	Found (mg)	%Recovery of spike
42	22.3	0.061	14	64	58	88
43	22.7	0.056	13	63	66	106
51	44.2	0.045	20	70	74	108
52	29.3	0.217	64	114	96	64
56	36.7	0.182	67	117	115	96
57	34.3	0.220	75	125	122	94

The data so far are for total hydrocarbons only. Identification of specific compounds and determination of relative amounts has not been done because of lack of equipment and personnel, but such information is necessary if the hydrocarbon levels in sediment are to be related directly to a particular source such as petroleum. The problem is complicated by the changes in hydrocarbons due to weathering and bacterial action. The hydrocarbons in surface water are probably of lower molecular weight than those in sediment, and of a different class. Sediment hydrocarbon levels near the loading and unloading docks (Sites N and R) were 0.06 to 0.10% in spite of obvious surface oil spills on several occasions. This oil did not accumulate in sediments down wind: Sites O, P, and Q had levels of 0.05 to 0.07% by wt on samplings a month apart. Therefore, a careful study of the compounds in both water and sediment, along with laboratory experiments on weathering and sediment interactions, will be required for an understanding of sediment burdens in relation to inputs.

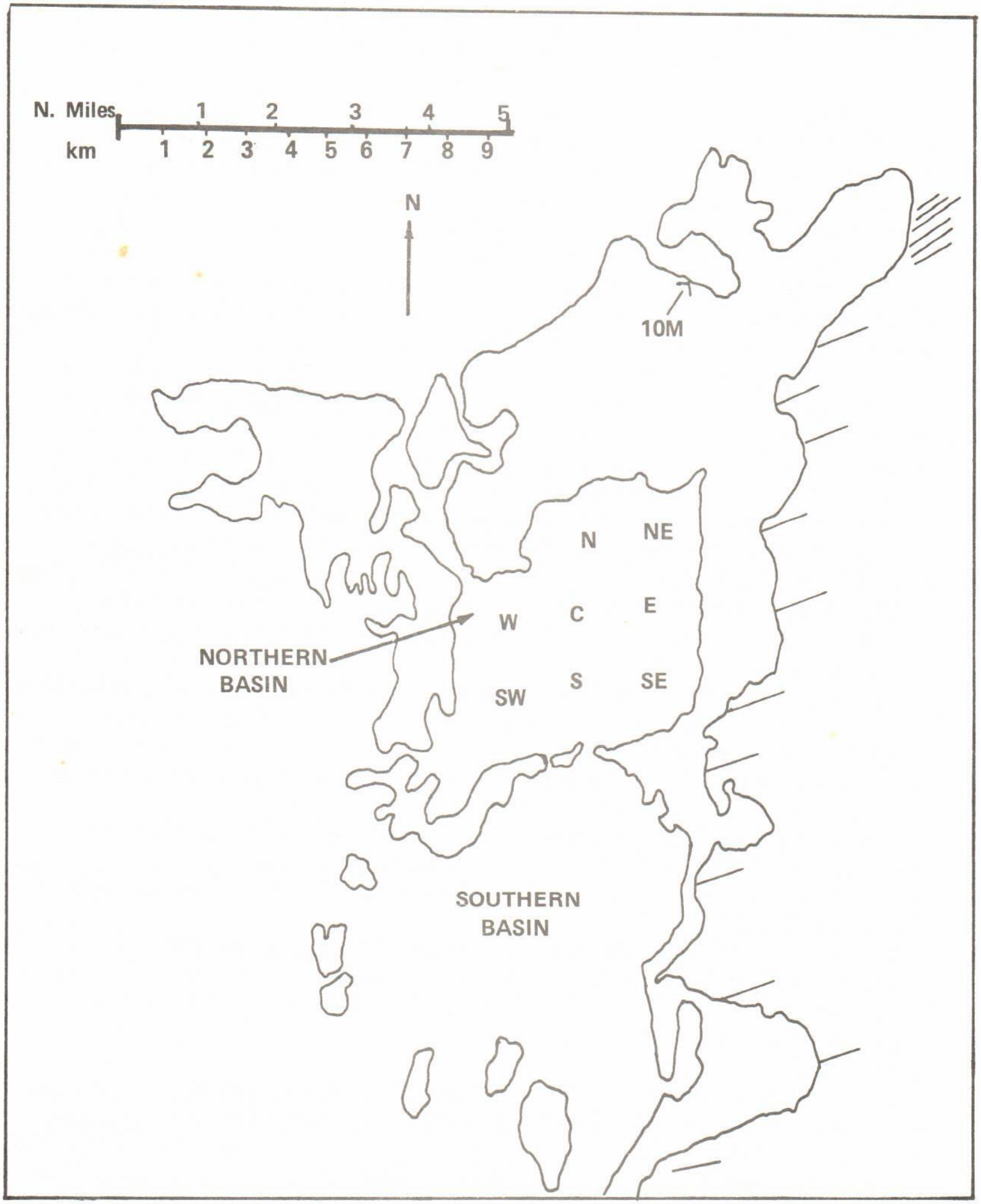


Figure 1: Cabo Rojo Study Area

TRANSFER OF PARTICULATE POLLUTANTS, INCLUDING SEDIMENTS DISPERSED DURING CONSTRUCTION OF OFFSHORE POWER PLANTS

(Gary C. Goldman, Roberto Castro, and Gina Laite Sánchez)

The purpose of this program is to determine the ecological effects that would result from offshore construction of power plants in the Cabo Rojo Platform, an are a few kilometers offshore, west of Mayagüez. The primary effects would be those due to resuspension of the bottom sediments brought up into the water column during the construction phase. The study, begun in January 1976, is expected to last one year. The major aspects are described briefly below.

Depth of Sediment. This must be determined in order to predict how much material would be disturbed by the construction. A literature search will be made; if this does not provide the needed data, sub-bottom profiling will be done if possible.

Physical Properties of Sediment. The size distribution and shape of the particles and, if possible, their origin and mineral content will be determined. To accomplish this, cores will be taken and analyzed as a function of depth into the sediment. Sediment surface samples will also be secured throughout the basin for analysis. Literature will be reviewed.

Benthos. The bottom-living organisms will be sampled throughout the basin for identification and population analysis, and the literature will be searched for information on the effects of resuspending the sediment. The study will be extended to adjacent areas if necessary and if time allows.

Trace Metals. The amounts of potentially toxic trace metals may be increased by resuspension; therefore, their concentrations in the sediment and water at specific locations will be determined.

Water Currents. For adequately prediction of the path of the resuspended load remaining in the water column, the normal current patterns in the basin need to be determined.

Projected Trajectory. The probable path the resuspended sediment will take is projected on the basis of settling rates, current patterns, and bottom topography. This is the most important part of the entire study.

To date, the planning phase has been completed, with the program schedule determined. A significant change in the program duration (reduction to one year) resulted in restriction of the work to the Northern Basin of the Platform (Figure 1). Two cruises have been made into the study area.

The first cruise, 25 March 1976, was made aboard the R/V *Palumbo* (PRNC), with the purpose of obtaining core samples. A piston corer was used to collect three 1.5-m-long cores to be analyzed for particle size and trace metals, as a function of depth. The results will be compared with sub-bottom profiles available from the San Juan office of The U.S. Geological Survey.

The second cruise was made on 20 April 1976 aboard the R/V *Medusa* (UPR), to collect water, sediment, and benthos samples and to make temperature and salinity measurements throughout the Northern Basin at the stations shown in Figure 1. At each station (1) salinity and temperature were measured, (2) three benthos grabs were made, and (3) two bottom sediment samples were taken; water for trace metal analysis was taken at station C only.

The temperature and salinity data (Table 1) were taken one meter below the surface, at mid depth, and one meter off the bottom.

The benthos organisms have been identified (Table 2), but so few were collected by the dredging technique, that diver operations may be needed for further information.

Preliminary work on size analysis of the sediment has shown much of the material to be in the range <64 microns. For this material, the pipette settling technique is applicable. The technique is being tried both with distilled water (for actual grain size analysis) and with seawater (for true settling velocities).

Water current measurements with current drogues are being planned for later this summer.

From the current information and the settling velocities, a particle trajectory will be estimated, as one step toward assessing the impact of the resuspension.

Educational Activities

Mr. Dennis G. Hall, A senior at Northern Arizona University, worked with the project from June to August 1976 as an ORAU Summer Trainee.

Table 1: Temperature and Salinity Data, Northern Basin of Cabo Rojo Platform, April 1976.

Station	Sonic depth (m)	Station depth (m)	Temperature (°C)	Salinity (°/oo)
N	13	1	25.875	36.036
		5	–	.049
		12	25.40	.32
S	17.5	1	26.26	36.092
		7	26.08	.084
		16	26.04	.93
SW	22	1	26.07	36.077
		11	25.92	.081
		21	25.80	.052
W	22.5	1	26.06	36.059
		10	25.87	.041
		20	25.63	.048
C	20	1	26.09	36.073
		10	25.875	.069
		19	–	.067
NE	14.5	1	26.245	.010
		7	25.81	.036
		13	25.48	.035
E	13	1	26.02	36.081
		6	25.96	.076
		12	25.915	.076
SE	12	1	26.19	36.061
		6	26.16	.127
		11	26.125	.076

Table 2: Cabo Rojo Platform Benthos, April 1976

Station		Number	Station		Number
NE-I	*Halophila baillonis*		C-I	fam. *Maldanidae*	1
	Carbula caribaea	1		unident. *sipunculids*	4
	Microcosmus exasperatus	1			
	unident. *Polychaetes*	3	C-II	unident. *sipunculids*	4
				unident. *Polychaete*	1
NE-II	*Halophila baillonis*				
			C-III	*Eulima auricinota*	1
NE-III	*Halophila baillonis*			fam. *Aphroditidae*	1
	Trigoniocardia antillarum	2		fam. *Callianassidae*	1
	Anygdalum dendriticum	1		unident. *sipunculids*	4
	Microcosmus sp.	1		unident. *pelecypod* (broken)	1
	fam. *Orbiniidae (Polych)*	1			
	fam. *Callianassidae*	1	S-I	*Halophila baillonis*	
E-I	*Phacoides muricatus*	1	S-II	*Halophila baillonis*	
E-II	*Chione* sp.	1	S-III	*Molgula occidentalis*	1 small
	unident. *Polychaete piece*			*Nereis* sp.	1
	unident. *sipunculids*	2			
			W-I	*Polycarpa spongiabilis*	1
E-III	unident. *sipunculid*	1		*Chama florida*	1
				Cyamon vickersi	
SE- I	*Halophila baillonis*			fam. *Xanthidae*	1
	Ascidia syndneiensis	1		*Haliclona* sp.	
	Tellina sp.	1			
	fam. *Polyonidae*	1	W-II	*Haliclona* sp.	
				Marphysa sp.	1
SE-II	*Pitar aresta*	1			
	fam. *Didemnidae*		W-III	*Chasmocarcinus cylindricus*	1
				Haliclona sp.	
SE-III	*Halophila baillonis*			*Alpheus* sp.	1
	fam. *Polyonidae*	1		*Cirolana* sp.	1
	fam. *Acoetidae*	1		unident. *Polychaete*	1
N-I	*Eulima auricincta*	1	SW-I	*Tellina* sp.	1
	unident. *Polychaete*	1			
			SW-II	*Halophila baillonis*	
N-II	fam. *Maldanidae*	1		*Chasmocarcinus cylindricus*	1
	fam. *Aphroditidae*	1		fam. *Amphiuridae*	1
	unident. *Polychaete*	1			
			SW-III	unident. *sipunculid*	1
N-III	unident. *Polychaete piece*			unident. *Polychaete*	
				unident. *Natantian*	
				(no key available)	

PILOT STUDY ON RAFT CULTURE OF THE MANGROVE OYSTER

(Kenneth W. Watters)

The project on raft culture of the mangrove oyster (*Crassostrea rhizophorea)* in Puerto Rico was concluded. In previous stages suitability of various organisms for mariculture was tested, and techniques for successful raft culture of the mangrove oyster were developed. The objectives of the final stage were (1) to provide technical support to local fishermen engaged in a pilot raft-culture effort, (2) to obtain data from the pilot studies to enable wider use of oyster rafts, and (3) to prepare a pamphlet in Spanish and English explaining in simple terms the steps necessary to build and successfully operate oyster rafts.

METHODS

Building and Emplacement of Commercial-Scale Rafts

Two fishermen were recruited from the town of Boqueron, to construct and operate two commercial-scale (12 by 16 ft) oyster rafts. The rafts were constructed under the supervision of project personnel from materials obtained from the Puerto Rico Department of Agriculture, and were emplaced in Laguna Rincón, Boquerón, on 26 June 1975. The fishermen were instructed on building, maintaining, and harvesting the rafts. A "demonstration" harvest was made on an experimental raft on 10 July 1975, and the fishermen were allowed to sell the oysters harvested.

During the remainder of the experimental period, project personnel assisted the fishermen (later, only one fisherman) by advising when to clean the cultch plates, when to make repairs, etc. They also inspected cultch plates periodically to determine rates of spatfall and fouling. When the rafts were harvested, in March 1976, they counted the marketable oysters and noted the proceeds of their sale.

Puerto Real Study. The last experimental raft was removed from Boquerón in July 1975, cleaned up, and repaired. It was put into Puerto Real Bay with 20 cultch plates on 5 August 1975 and then periodically monitored for spatfall, the cultch plates being cleaned as necessary.

Preparation of Pamphlet. Material for the pamphlet was gathered throughout the year. Photographs were taken of every phase of each operation, including building the rafts and cultch, plastering the cultch, checking the cultch for cleaning, and harvesting. Procedures that had been worked out on the experimental rafts were modified both at the fishermen's suggestions and by further experience. Data gathered on harvest size and value were included, so that the recommendations in the pamphlet represented as closely as possible the experience of the users of the raft-culture system.

RESULTS

Commercial Raft Experiments

By September of 1975, one of the two fishermen had abandoned his raft, but the other one took it over. Significant spatfall on the rafts did not start until the middle of November 1975. The long delay was probably due to Hurricane Eloise, on 13 September, which dumped enormous amounts of water, making the lagoon virtually a freshwater lake for about a week and keeping salinities lower than normal for more than six weeks. By December, both rafts had considerable numbers of spat, a count on 12 December showing averages of 54 and 48 oysters per plate for the two rafts, all of very small size. After monthly cleaning to remove fouling organisms, the two rafts were harvested in March 1976, yielding 2223 oysters from one raft, and 1512 from the other. The harvest data are summarized below.

	Whole (doz)	Broken (doz)	Total (doz)	Gross income at $0.75/doz.
Raft 1	129	56	185	$94.85
Raft 2	118	8	126	35.40

Both rafts yielded a mean of 46 oysters/frame, and the stated selling price was $0.75 per dozen. The gross income is some low because not all oysters were sold; some of those from the first raft were taken for personal consumption, and ∿70 dozen from the second raft were allowed to spoil.

The initial cost of the materials needed to make one complete raft with cultch was $225.00. Eleven man-hours were needed for construction and another hour for assembly and emplacement. Maintenance is estimated to cost about $35.00 per year for replacement of wire, reinforcing rods, Styrofoam, etc.

Puerto Real Study. From August to December 1975, very little spat settlement occurred on the raft in Puerto Real Bay, the mean count in early December being 2.5 spat per cultch plate. In late December an extremely heavy spatfall occurred, with most of the plates so heavily covered on both sides with oyster spat, in the size range 2 to 6 mm, that counts could only be estimated—the estimate was several hundred spat per side. By late March 1976, it was obvious that growth was very slow, few oysters being >15 mm in size. Since no evidence was seen of a large mortality like that on mangrove roots in Puerto Real due to the oyster drill *(Murex brevifrons)*, it is clear that off-bottom culture denied this predator access to the oysters. In April, half the cultch plates in Puerto Real were cleaned of fouling and moved to Laguna Rincón in an effort to obtain better growth, but by the end of June 1976, this had not materialized. Oysters in both places were about the same size, probably because of crowding, and because the plates were moved when the oysters were more than three months old, well past their growth peak.

Preparation of Pamphlet

By April 1976, all of the data needed were at hand for preparation of a pamphlet in English and Spanish describing in layman's terms how to build and operate an oyster raft, including lists of materials for raft and cultch, and photograph and drawings of the various stages in construction, harvesting, etc. The pamphlet, to be printed in August 1976, will be Volume VIII, No. 1, of the Agricultural and Fisheries Contribution of the Puerto Rico Department of Agriculture, and will be distributed by the PRDA Commercial Fisheries Laboratory.

DISCUSSION

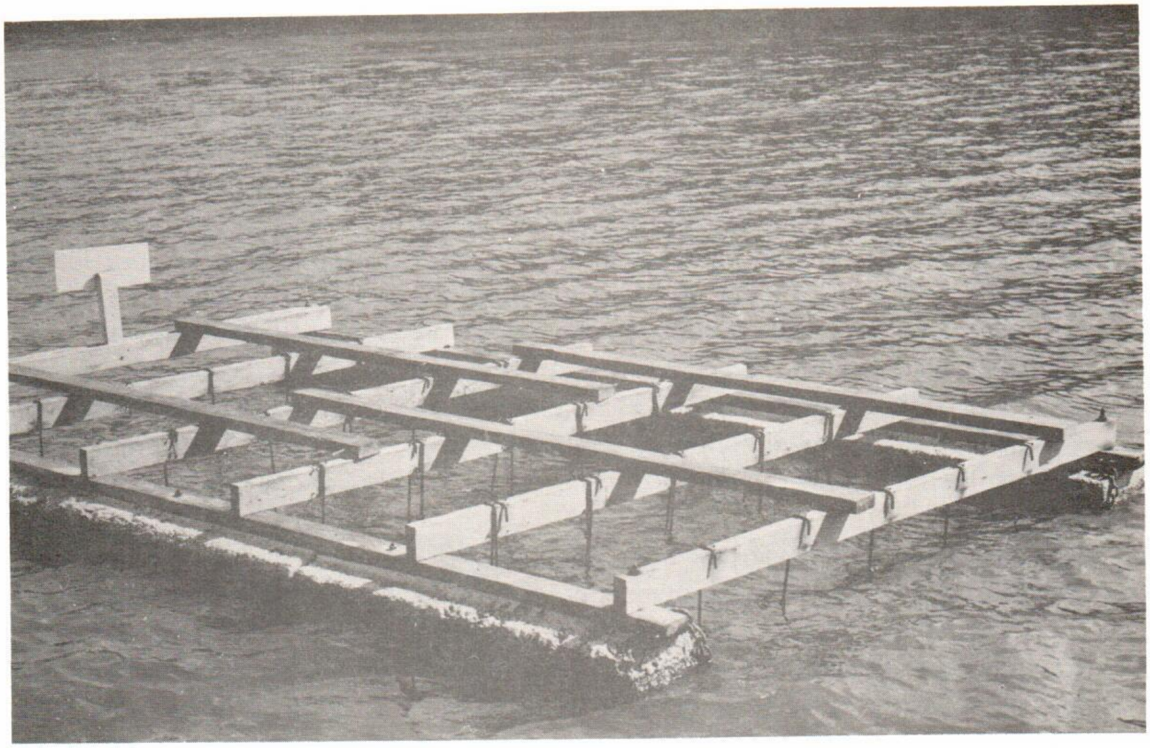
Oyster culture has been brought to a very limited commercial scale in Puerto Rico. A method has been developed, modified, tested, and tried by local fishermen which will produce cultured mangrove oysters at a modest profit. However, the method as it stands is by no means ideal, nor is the environment in which to carry it out. Only one area in Puerto Rico, Laguna Rincón, has been shown capable of producing oysters on a commercial scale. Other areas, such as Puerto Real, show promise for obtaining spat, but spatfall is limited to certain times of the year, and is of unpredictable density. Even in Laguna Rincón, spatfall appears to be the major problem: its prediction is uncertain, and its timing and density even more so. This results in an unpredictable production of marketable oysters, a major problem for the culturist. Although theoretically oysters will grow to market size in three months on raft cultch, it might be six or eight months, as in the case of the pilot project, before sufficient oysters have set and grown to make harvesting worth while.

Also, there is no guaranteee that the existing work force can be induced to become oyster culturists. At present, since there is no way of demonstrating the entire system, the potential culturist has to take a great deal on faith. Economic incentives have lost much of their meaning because of the high level of subsistence support available (primarily food stamps). Such support encourages part-time work, which raft-culture, in contrast to oyster harvesting, is not. The main reason one fisherman dropped out of the pilot project was that he was asked to do some work on a regular basis (clean cultch once a month, etc.), and he stated that this was repugnant to him.

CONCLUSIONS

The oyster culture studies have demonstrated several points: (1) Raft culture of the mangrove oyster is feasible, both technically and economically, in Puerto Rico. (2) Production, however, is very marginal if it must depend on natural recruitment of spat. (3) Although an adequate work force exists to carry on culture of oysters, appropriate incentives and demonstrations must be available for recruitment and training.

Point (2) could be resolved by developing methods of operating a hatchery for the mangrove oyster; this is in the proposal stage. Point (3) could be partly resolved by developing a "model oyster farm." This would have to follow development of the hatchery, and it would demonstrate oyster culture from spawn to market. Finally, a marketing and distribution system would have to be developed to put the enterprise on a sound commercial footing.



Oyster Culture Raft

Oyster harvesting

TERRESTRIAL ECOLOGY

The main effort of the Terrestrial Ecology Division has been redirected to a comprehensive study of the Espiritu Santo Drainage Basin located in northeastern Puerto Rico. The general objective are (1) to provide baseline ecological data for future environmental assessment studies at the local and regional levels, and (2) to provide through an ecosystem approach data for the development of management alternatives for the wise utilization of energy, water, and land resources. The interrelationships among climate, vegetation, soils, and man, and their combined influence upon the hydrologic cycle will be described and evaluated.

Environmental management involves planning and decision making, and both require an adequate data base. At present, little is known about the interworkings of a complete, integrated system such as a drainage basin. A literature survey of the main research areas outlined in PRNC-198 confirmed that, although many individual ecologically oriented studies have been carried out in a tropical environment, few if any provide the data base required for environmental management. In view of rapidly changing socio-economic conditions and natural resource limitations, management urgently requires data from these systems: (1) physical (climatological), (2) biological, and (3) cultural. This integrated drainage basin study has been designed to provide such data.

The scope of this program covers the hydrologic cycle as it is affected by the interactions of the physical, biological, and cultural systems.

RESEARCH ACTIVITIES

The activities this year have been directed toward the initiation of new projects, most of which are of one-year duration and will not be ready for reporting until FY-1977. The projects that have been initiated are discussed briefly below.

Graduate student research has continued; it is reported under Training Activities.

Climatology

The climatology program was made an integral part of the terrestrial ecology program to enhance the interdisciplinary approach to clarifying the ecosystem dynamics in a tropical rain forest. It was thought that, in conjunction with ongoing investigations in plant ecology, animal ecology, soils, and nutrient cycling in the forested area of the Upper Espiritu Santo drainage basin, climatic information consisting of data on temperature, humidity, insolation, precipitation, and precipitation chemistry would be most useful in beginning to understand the ecosystem dynamics of this montane rain forest. To this end, the following studies were initiated during the report period.

Upper Espiritu Santo Precipitation Distribution. (B. Holben, J.A. Colón, M. Canals, F. Santos, and R.G. Clements). A storage rain-gage network was established in the Upper Espiritu Santo watershed to determine annual amounts of precipitation and the effect of topography on its distribution. The network consists of 20 storage rain-gages, each placed equidistantly from adjacent one, forming a symmetric grid over the entire watershed. The precipitation is collected in funnels mounted above the forest canopy, (Figure 1), and conducted by plastic tubing to storage containers on the ground.

Rain gages are monitored biweekly, and this will be continued until February 1977. Preliminary results indicate that the distribution is highly dependent on the direction of storm movement with respect to the orientation of mountain ridges. For example, a strong rain shadow is evident on nearly the highest point in the study area, and a precipitation maximum occurs on the leeward side of a low ridge. Eight months after the start of this study, the amounts of precipitation range from 140 to 230 cm (55 to 90 in.) over the 570-hectare (1400-acre) drainage area.

Element Analysis of Precipitation. (B. Holben, A. Block, R.G. Clements, F. Santos, J.A. Colón, and M. Canals). The purpose of this research is to gather baseline data on element inputs into the ecosystem by precipitation, in order to clarify the spatial distribution of element input and its immediate dependence on precipitaion amounts. Samples are taken biweekly from each of the 20 storage rain gages. They are analyzed by atomic absorbtion for Na^{+}, K^{+}, Ca^{++}, and Mg^{++}. No results will be available until after the storage rain-gage study is finished in February 1977.

Temperature and Humidity Profiles Modeling in a Tabonuco-type Forest. (B. Holben and R.G. Clements). Six hygrothermographs were placed throughout the entire height of a 72-ft tower in the Tabonuco Forest near the El Verde field station in order to determine the principal characteristics of the temperature and humidity profiles and, if possible, to model them statistically for future use in studies of energy balance and bioclimatic relationships.

Preliminary results indicate a daily temperature and humidity lag which increases from the crown towards the ground and a dampening of the diurnal amplitudes of both variables in the same direction. An afternoon temperature maximum appears to occur slightly below the canopy crown. These results and other findins will be substantiated or rejected as the analysis continues.

Insolation Modeling. (B. Holben and R.G. Clements). A computer model to simulate the insolation characteristics of the earth's surface is being used to give a first approximation of the solar energy input in the Upper Espiritu Santo forest ecosystem. Solar energy has long been recognized as a principal component in ecosystem dynamics. Since no data are available for the Upper Espiritu Santo watershed, this model may reveal some interesting relationships with plant distribution, and with precipitation.

The model simulates insolation on square cells of land in a grid totally covering the watershed. Each cell represents a slope and orientation characteristic of a specific area and location of land. The model simulates insolation for land having the given characteristics as a function of time of day, time of year, latitude, clear-sky atmospheric properties, and shading characteristics of adjacent topography.

For this study, insolation will be calculated for 1-hectare cells on a seasonal and annual basis.

The Variability of Surface Characteristics as a Function of Grid Density. (B. Holben) Many meteorological investigations require a knowledge of the topographic characteristics of a portion of the earth's surface. A very rapid and convenient method of approximating these is by programming a computer to manipulate a grid of elevations taken at regular, horizontal intervals from a U.S. Geodetic Survey topographic contour map.

The purpose of this study is to consider how map error and human error will affect computed surface characteristics at horizontal intervals (grid densities) of 100, 200, 400, and 800 meters on a 1:20,000 U.S.G.S. topographic map. Preliminary analysis of the slope characteristic unquestionably shows that variability for any given grid density is independent of changes in slope, but variability of the slope increases rapidly as the grid density increases from 800 m to 100 m.

Limnology

The lack of limnological data for the freshwater streams of Puerto Rico has necessitated the initiation of a basic survey in the Espiritu Santo Drainage basin. The purpose of the survey is to characterize and describe the flora and fauna and to obtain preliminary measurement of selected physical and chemical parameters of the freshwater system. Since the estuary is an integral part of the system, it will be included. This survey will require approximately one year for completion, and the data obtained will be used in planning subsequent linmological research in the basin. The studies now under way, and the preliminary data obtained, are reported below.

Water Quality Parameters of the Rio Espiritu Santo River System. (W. Bhajan, M. Canals, J. Colón, and R. G. Clements.) In November 1975, a survey begun of selected water quality parameters throughout the length of the main river and each of its three tributaries. The data were taken under base flow conditions. Preliminary results are summarized in Table 1, which presents the range of values found. Generally, *p*H and temperature increase from higher to lower elevations, and dissolved oxygen decreases.

Table 1:

STREAM	No. Sampling stations	Altitude range, m	*p*H range	Temperature range, °C	Dissolved O_2 range, mg/liter
Quebrada Jimenez	34	20–800	6.5–7.1	17.5–23	7.0–9.0
Quebrada Grande	13	26–850	6.7–7.35	17.5–23	7.9–9.0
Quebrada Sonadora	13	185–945	6.6–7.1	17.1–20	7.9–9.0
Upper Rio Espiritu Santo	29	5–750	6.8–7.5	17.0–23.2	7.9–9.0
Estuarine Rio Espiritu Santo	13	0–5	–	23.5–26.8	3.9–7.2

In the estuary the lowest observed values for dissolved oxygen were found at the confluence of the Quebrada Juan Gonzalez, which drains a mangrove area containing an egret rookery and the mixing zone of the outfall from the Rio Grande sewage treatment plant. The O_2 values were 3.90 and 4.60 mg/liter, respectively.

The data on plantonic invertebrate larvae are presented in Table 2, along with preliminary results for decapod crustaceans, molluscs, and fish. The crustaceans *Atya lanipes*, *Xiphocaris elongata*, and *Machrobrachium carcinus* were observed both fresh and estuarine waters. The upper altitudinal limit for the first two species was 780m, but *M. carcinus* was not found above 523m. All other decapod crustaceans except *M. ancanthurus* were observed only in fresh water.

Table 2: The Altitudinal Distribution (in meters) of Planktonic Invertebrate Larvae, Decapod Crustaceans, Molluscs, and Fishes in the Rio Espiritu Santo System (Dash indicates species not observed.)

	Quebrada Jimenez	Quebrada Grande	Quebrada Sonarodra	Upper Rio Espiritu Santo	Estuary
Plantonic invertebrate larvae					
Amphipoda	–	–	–		upper reaches to mouth
Coleoptera	–	–	–	18	upper reaches
Decapoda	–	–	–	15–18	upper reaches to mouth
Diptera 1	20–800	26–700	185–945	18–730	upper reaches
Diptera 2	554	–	185–945	18–720	upper to middle reaches
Diptera 3	215–461	350–500	462–945	15–520	upper to lower reaches
Diptera 4	20–388	26–250	185–945	15–400	upper reaches to mouth
Diptera 5	150–462	–	380–523	27–40	–
Ephemeroptera	388–431	–	185–295	5–550	–
Hemiptera	–	–	–	–	middle reaches
Hidracarina 1	20–800	350–500	185–945	5–720	upper to middle reaches
Hidracarina 2	–	–	–	–	upper reaches
Odonata	320–800	26–700	380–780	–	upper reaches
Pleocoptera	295	–	794	12–80	–
Trichoptera	20–554	44–850	185–945	5–720	–
Decapod crustaceans					
Atya innocuous	–	–	295-440	–	–
A. lanipes	36–461	26–700	185–750	5–750	upper reaches
*A. scabra**	–	–	–	–	–
Machrobrachium acantharus	–	–	–	–	upper reaches
M. carcinus	20–523	39–150	185–462	5–520	upper reaches
M. faustinum	150–388	39–150	185–440	15–80	–
M. heterochirus	–	–	185–380	150–550	–
Micratya poeyi	–	–	380	–	–
Xiphocaris elongata	20–554	39–700	185–780	5–750	upper reaches
Epilobocera sinuatrifons	82–388	39–150	185–668	18–750	–
Molluscs					
Marisa cornuaretis	70	–	–	–	–
Neritin reclivata	20–76	26–85	–	5–70	middle reaches
Tarebia granifera	20–70	34–44	–	6–15	–
Fishes					
Agonostomus monticola	20–90	39–350	185–603	5–60	upper reaches
Anguilla rostrata	70–200	–	–	5–15	upper to middle reaches
Belome sp.	–	–	–	–	upper to middle reaches
Centropomus parallelus	–	–	–	–	upper to lower reaches
Gobiomorus dormitor	–	–	–	–	middle to lower reaches
Mugil curema	–	–	–	–	upper to middle reach
Sicydium plumieri	20–523	39–550	185–440	5–600	upper to middle reach

* Previously collected in a small brook near the El Verde field station by Gifford and Cole.

Bioassay of Some Decapod Crustaceans for Salinity Tolerances. (W. Bhajan, M. Canals, J. Colón, and R. G. Clements). Very little is known about the ecology of the ten species of decapod crustaceans found in the Espíritu Santo River System. Chase and Hobbs, Bull. 292, 258 pp., Smithsonian Institute Press, (1969) suggested that a marine phase is necessary for the family Atydae, but Gifford and Cole, A.S.B. Bull. **19**(2):29 (1971) raised serious questions about this requirement.

Preliminary studies on the salinity tolerance of larvae, juveniles, and adults are being conducted in preparation for life-cycle studies. Results to date suggest that *A. lanipes* do not have an extended tolerance when salinity reaches 60% that of seawater, but the of this species exhibited low tolerances, in the range of freshwater to salinity values 15% that of seawater. Juveniles of *Xiphocaris elongata* did not survive longer than 24 hr in seawater, but when salinity was reduced to 80% that of seawater, survival was 100%.

Plant Succession Study (R. G. Clements and E. Cuevas). The radiation study on a tropical rain forest by H. T. Odum at the El Verde site has presented a unique opportunity to study and evaluate plant succession in a forest of this type. Following the experiment in early 1965, a yearly census of the 672 one-square-meter plots was made in 1966, 1967, 1968, and 1969. Beginning in 1971, the census was taken biannually. After the 1975 census, a start was made on tabulating and analyzing the succession that has taken place. The transfer of data to IBM cards for analysis has been difficult because the early data were not collected in a consistent format. However, the transfer is now nearly complete, and data reduction, analyses, and reporting are expected to be completed in late FY-1977.

TRAINING ACTIVITIES

During this reporting period, four advanced degrees were completed and successfully defended; two doctoral and two for a Master of Science. Research investigation has been completed for another doctorate. Five additional students have initiated thesis research investigations for Master of Science degrees.

Name	Title of Thesis	Major Professor
D. Padgett	The Contribution of Aquatic Hyphomycetes in the Decomposition of Submerged Leaf Litter. Ph.D. dissertation completed. Collaborative effort between PRNC and Ohio State University.	R. Seymour R. Clements
D. Conant	Ecogeographic and Systematic Studies in American Cyatheaceae Ph.D. Dissertation completed. Harvard University	R. Tryon R. Clements
Maria L. Lebrón	An Autecological Study of *Palicourea riparia* Bentham (Rubiaceace) Ph. D. Dissertation completed University of North Carolina	J. F. McCormick R. Clements
E. Cuevas	Changes in Water Quality as Influenced by Land Use Patterns M.S. Degre. completed U.P.R. Biology	R. Clements
F. Villamil	Some Aspects of the Ecology of the Freshwater Shrimps in the Upper Espiritu Santo River at El Verde, P.R. M.S. Degree. Completed U.P.R. Biology	R. Clements

Name	Title of Thesis	Major Professor
R. Mosquera	Relationship Among Selected Macro-nutrients, Salinity and Structural Characteristics of Riverine Mangroves. For M.S. U.P.R.	R. Clement
L. Negrón	Leaf Litter Production as an Index of Primary Productivity in Riverine Mangroves For M.S. U.P.R.	R. Clements
I. Corujo	Identification, Distribution, and Description of the Fishes of the Espiritu Santo Estuary. For M.S. U.P.R.	R. Clements
A. Garcia	The Relative Abundance of *Anglis* Lizards as a Function Available Food Resources. For M.S. U.P.R.	R. Thomas
P. Cebollero	Limiting Factors Affecting the Distribution of *Caracolus caracolla* in Puerto Rico For M.S. U.P.R.	R. Clements

Thesis Abstracts

The Contribution of Aquatic Hyphomycetes in the Decomposition of Submerged Leaf Litter (D. Padgett) abstract not available.

Ecogeographic and Systematic Studies in American Cyatheaceae (D. Conant). This thesis deals with the biology of tree ferns. I have approached the study of this unusual group of plants by embracing aspects of their population biology, ecology, and their systematics and evolution. The first chapter of the thesis deals with spore dispersal, an important parameter to consider in relation to the breeding dynamics of tree fern populations. The second chapter is a study of the autecology of two tree ferns. Here aspects of the autecology of two quite different species are compared to develop an understanding of the growth and adaptive strategies in these plants. The third chapter is a systematic revision of the American species of the genus *Alsophila.* Specification in the Cyatheaceae is seen as an ecogeographic process, and the taxonomic revision applies the conclusions from the previous chapters to the problems of classification of species. An unforseen aspect of the systematic studies has been evidence that interruption of ecological barriers between species has resulted in extensive hybridization which demonstrates that sterility barriers have not evolved between species.

An Autecological Study of Palicoure riparia Benthan (Rubiaceae) (Mariá Luz Lebrón). Present accelerated rates of destruction of tropical rain forests have resulted in renewed attention on the process of secondary succession in these areas. Although a number of studies of this topic have been conducted, there is only slight knowledge of the behavior of the ecologically important species participating in this process.

The present study focuses on *Palicourea riparia*, an ecologically important species in disturbed areas of the tropical rain forest of Puerto Rico.

Demographic studies show that *P. riparia* is important in disturbed areas in terms of density and that it is also present under mature forest conditions at reduced levels. Studies on seedling seasonality indicate that there are no significant variations in periodicity in the forest in terms of frequency or density. Germination studies indicate that, regardless of season, seed germination is always higher in open than in closed canopy areas. Reciprocal transplant studies reveal that there is no ecotypic differentiation in this species. Field photosynthesis values are low but compare favorably with previous reports in the literature for lowland tropical rain forest species. Under controlled conditions, it was demonstrated that this species can carry out photosynthesis at light levels as low as 20 $\mu e\ m^{-2} s^{-1}$, and that increases in light intensity consistently enhance photosynthetic rates.

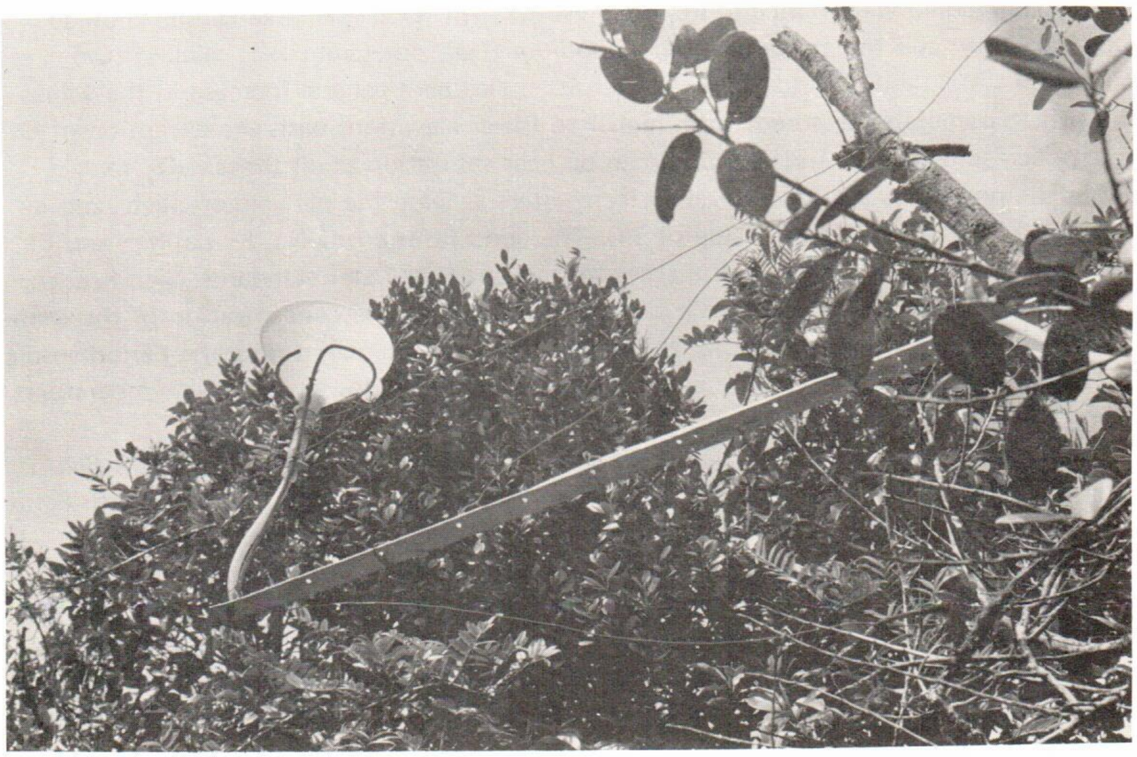
The present study provides an important contribution towards the understanding of ecologically important species in lowland tropical rain forest areas.

On the basis of these studies, it is proposed that *P. riparia* be considered a 'gap opportunist' — a species that can maintain itself under undisturbed forest conditions but which will benefit greatly from forest disturbances (Baur, 1964).

Changes in Water Quality as Influenced by Land Use Patterns (Elvira Cuevas). Bi-weekly measurements and samples were taken on the surface waters of the Espiritu Santo river and its tributaries Quebrada Grande, Quebrada Jiménez, and Quebrada Sonadora. The parameters studied were temperature, dissolved oxygen (DO), pH, free carbon dioxide (CO_2), salinity, and the concentrations of sodium (Na), potassium (K), calcium (Ca), magnesium (Mg), and chloride (Cl). The results indicated a general increase in the values of all the parameters measured, from higher to lower elevations with the exception of DO which decreased slightly and was found to be near saturation at all times. CO_2 ranged within the normal values for natural surface waters as were the pH values which ranged from 6.5 to 8.2 with a modal value of 7.0. The concentration of Na, K, Ca, Mg, and Cl were found to be below or near the accepted for drinking water standards. Significant differences were found between each river or tributary for the concentration of the elements mentioned above. No marked seasonal variabilities were observed during the period studied except for the temperature of the water which reflected the lowering of air temperatures during the winter months.

Some Aspects of the Ecology of the Freshwater Shrimps in the Upper Espiritu Santo River at El Verde, P.R. (F. Villamil). A survey was performed in the upper Espiritu Santo River to collect, identify and trace the distribution of the shrimp fauna. The species encountered were *Atya lanipes, Xiphocaris elongata, Macrobrachium heterochirus* and *Atya innocous.* Selected physical and chemical characteristics of the stream were measured to describe the habitat of each species and their effect on the distribution. The physical parameters which affected the habitat selection and the distribution were, waterflow, substrate type and elevation. No apparent relationship was found between the chemical characteristics and the distribution.

The ecology of the species encountered was described. Intraspecific differences in habitat selection was observed in *Atya lanipes.* Preference for sunlit areas in low-flow conditions and gravel substrate were observed for *Xiphocaris elongata. Macrobrachium heterochirus* was observed in shaded areas, residence under rocks and low-flow conditions. Selected anatomical characteristics were measured for *Atya lanipes* and *Xiphocaris elongata.* Size differences were found between sexes in *Atya lanipes* and *Xiphocaris elongata.* The division of the genus *Xiphocaris* into three species using a criterion of length of rostrum was found to be related to development.



Raingage installation used to measure rainfall
in the upper Espiritu Santo Basin.

MATERIALS SCIENCE

The Materials Science Division is engaged in research on physical properties of materials and the effects of radiation upon them. This involves solid state materials undergoing phase transitions, energy storing materials, and biomaterials. The Division also offers research facilities for M.S. and Ph.D. thesis work in the fields of physics, chemistry, materials, and radiation sciences in cooperation with the various colleges and departments of the UPR Mayagüez Campus. It is anticipated that it will serve as a catalyst in starting energy-related research programs in cooperation with UPR faculty, especially programs involving solar energy. To encourage and promote cooperative efforts, contact is maintained with former graduate students and with visiting scientists from Latin American research institutions.

RESEARCH ACTIVITIES

Energy Conversion Making Use of Thermal Differential in Triglycine Sulfate (J. A. Gonzalo and R. Purcell).

Introduction. Recent work at PRNC and UPR (Gonzalo, *Ferroelectrics*, in press, 1976; Purcell, PRNC Internal Report, 1975) on ferroelectric materials as energy converters, using a general thermodynamic approach, has yielded a general expression for the available work per cycle (between temperatures $T_1 = T_c - \Delta T_0$ and $T_2 = T_c$). From this, the ideal efficiency can be obtained as

$$\eta = \frac{1}{2}\left(\frac{\beta M}{\rho \overline{C}'}\right)\left(\frac{\Delta T_0}{T_c}\right) \simeq \left(\frac{\overline{\Delta C'_F}}{\overline{C}'}\right)\left(\frac{\Delta T_0}{T_c}\right)$$

where β is the mean field coefficient, M is the temperature derivative of the squared spontaneous polarization, ρ is the density, and $\overline{\Delta C'_F}$ and $\overline{C}'$ are the ferroelectric and total (ferroelectric plus "background") average specific heats respectively. $\Delta T_0/T_c$ is the Carnot factor, which puts an upper thermodynamic limit to the ideal efficiency. Thus the factor determining conversion performance is $(\beta M/\rho \overline{C}')$.

The operation of a single-stage ferroelectric converter (spontaneous process) was also examined. The differential equations governing thermal flow and charge flow involve respectively a thermal relaxation time τ_T and an electric relaxation time τ_e. Optimum power output is obtained when the load resistance is equal to the internal resistance of the ferroelectric material, and the ratio of the thermal to the initial electric relaxation times $m = \tau_T/\tau_{e0}$ is unity. The optimum thickness of the ferroelectric plate is given by

$$d = (k\tau/\rho C')^{1/2} \simeq \text{const.} \times (T_c/\Delta T_0)^{1/2}$$

where k is the thermal conductivity of the ferroelectric plate and $\tau = \tau_T = \tau_{e0}$, in other words, it is determined by the maximum range ΔT_0 over which the performance factor remains close to its maximum value. From here it is easy to determine the specific power output (per unit mass), which can be expressed as

$$\frac{\overline{P}_{out}}{\rho \overline{V}} = \frac{1}{2} \left(\frac{\beta^2 M T_c}{\rho \rho_e}\right) \left(\frac{\Delta T_0}{T_c}\right)^3 .$$

If multistage converters are used between the maxim available T_c ($\sim$1500° K) and room temperature, taking $(\beta M/\overline{C}')$ as 0.25, which is a not unreasonably high value in light of the available experimental evidence (Gonzalo, *op. cit.)* for ferroelectrics with transitions above room temperature, one comes up with ideal efficiencies in the 10% range. Specific power output estimates for those few ferroelectrics for which transport parameters (k and ρ_e) are known appear to be competitive with those typically obtained with other conversion methods such as photovoltaic cells. Also, ferroelectric converters do not require single-crystal plates, working equally well with polycrystalline material having preferred orientation along the ferroelectric axis, which can probably be produced more economically. To obtain electric power by thermocycling one must keep the single-domain state of the crystal or at least keep a larger fraction of the dipoles fixed in one of the two possible directions, which can be done in several ways. A unipolar configuration can be maintained by using ionizing radiation, or, in some materials, by applying a permanent shear stress to the crystal along the proper direction.

Reported here are preliminary measurements of efficiency and specific power output in single crystals of triglycine sulfate (TGS), with a radiation-induced preferred direction for the spontaneous polarization (Okada, Gonzalo, and Rivera, *J. Phys. Chem. Solids*, **28**, 689, 1967). TGS crystals were chosen to test the theory, not because they were the best possible candidates for ferroelectric energy conversion, but because of their easily accesible Curie temperature and the availability of γ-irradiated samples with net nonzero polarization fixed along one preferred direction.

Experimental. The samples were old γ-irradiated TGS single-crystal plates with areas between 0.25 and 1 cm^2 and thicknesses between 0.5 and 2.5 mm, cut normal to the ferroelectric axis and provided with gold-leaf electrodes on the main surfaces.

On the screen of an oscilloscope using a Sawyer-Tower circuit, the 10-year-old γ-irradiated (with $\sim$2.5 Mrad) TGS samples, which originally had presented a single biased hysteresis loop, showed a double asymmetrical loop (the change presumably being due to spontaneous aging, through migration of charged free radicals under the spontaneous field. The two partial loops, biased in opposite directions, had different heights, which meant that at zero external field a net fraction of the spontaneous polarization was always pointing in one direction. With P_1 and P_2 being the heights of the larger and smaller loop respectively the effective fraction of the spontaneous polarization was

$$a = (P_1 - P_2) / (P_1 + P_2) = 0.34.$$

Note that, at a given temperature $P_1 + P_2 \simeq P_s$ gives the total spontaneous polarization. The value obtained for the resistivity (R) is 1.07 × 10^{11} Ω-m.

The thermal relaxation time of the sample holder with the crystal was about 30 sec, a value larger than that estimated for a thin plate, $\tau_T \simeq (\rho C'/k)d^2$, which, for $d \sim 1$ mm, gives $\tau \sim 2$ sec; this indicates that the thermal resistance of the air between the cylindrical container and the sample, rather than that of the sample itself, was the limiting heat transfer factor.

Figure 1:

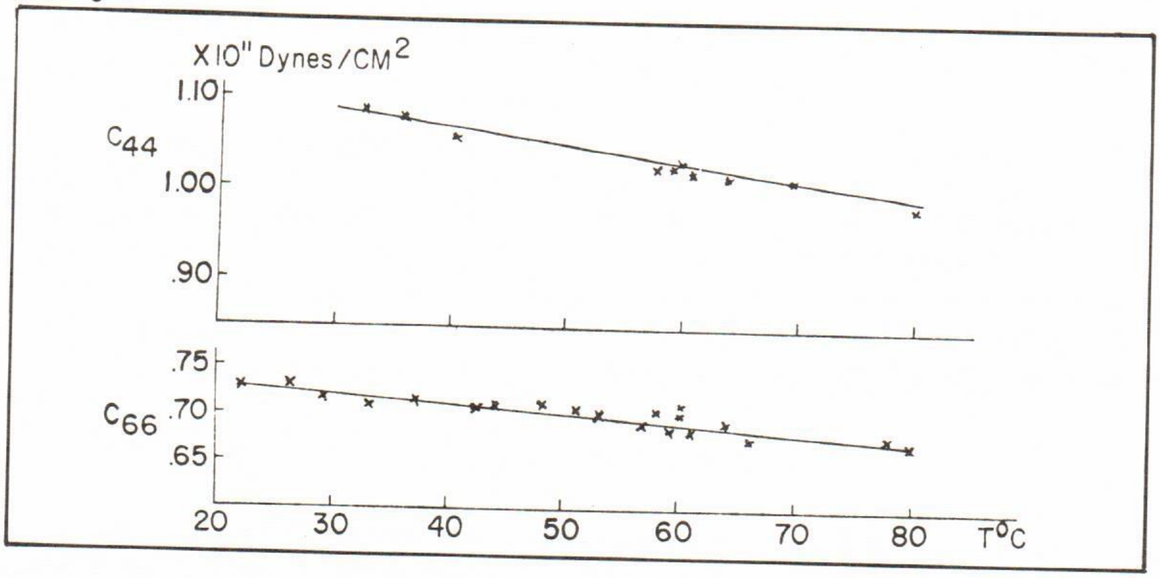
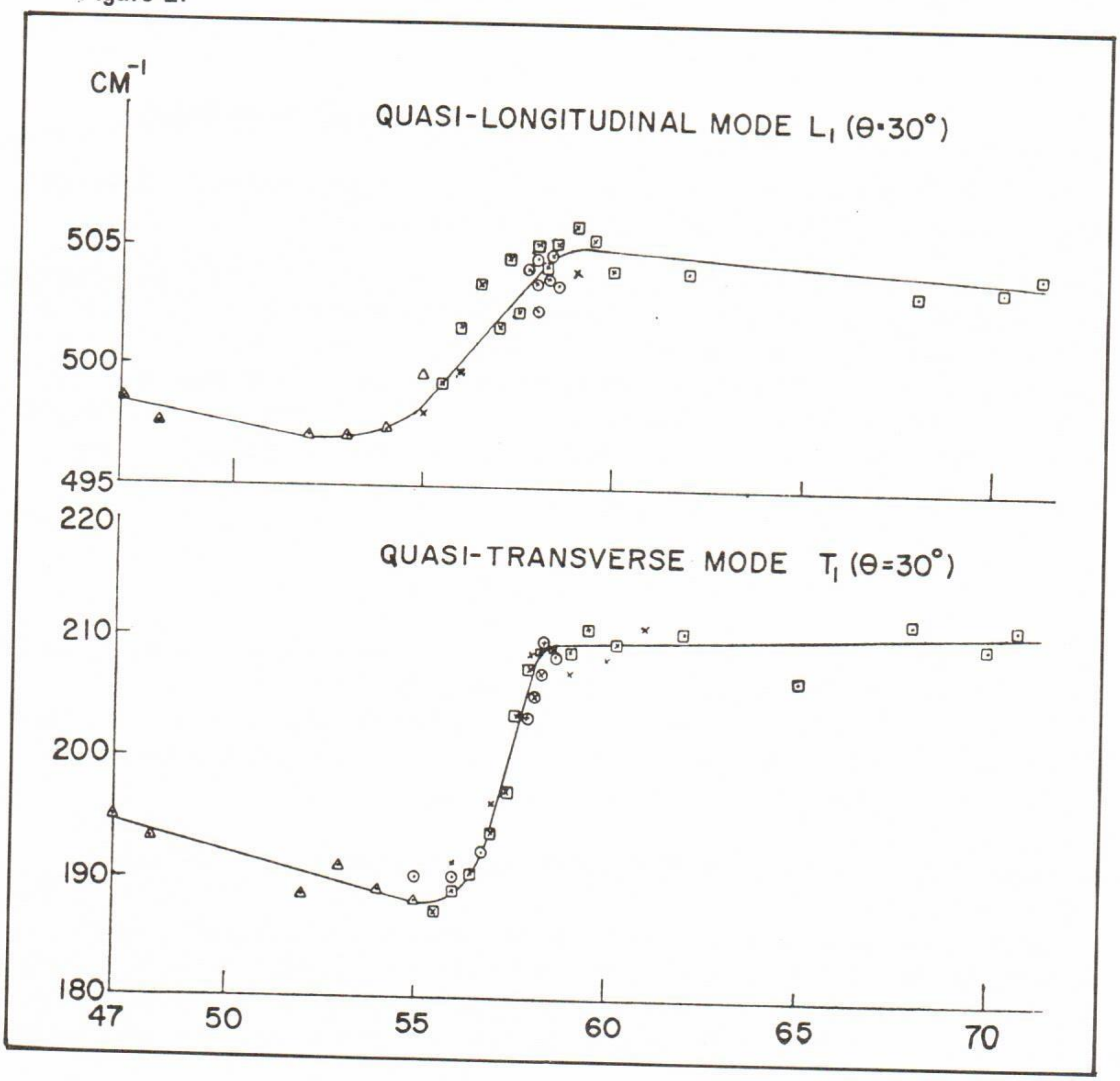


Figure 2:



Results and Discussion. Comparison of measured and experimental values of efficiency gives

$$(\eta_{exp}) / (\eta_{calc}) \simeq 0.92 ,$$

which indicates reasonably good agreement between calculation and experiment.

For the specific power output, the comparison is not so straightforward, because the calculation (Gonzalo, *op. cit.*) has been carried out completely only for the case when $\tau = \tau_T = \tau_{eo}$, which requires, for a given ΔT_0, a specific sample thickness determined by the electrical resistivity value. However, if τ_T and τ_{eo} are unequal but of the same order of magnitude, the specific power output calculated by Gonzalo (*op. cit.*) could serve as a useful estimate. The ratio of experimental to calculated power output was

$$(P_{out} / \rho V)_{exp} / (P_{out} / \rho V)_{calc} \simeq 0.75 .$$

In summary, rough experimental observations of the behavior of TGS as an energy converter indicate that theoretical estimates of the potential of ferroelectric converters are realistic. The experimental observations reported here were preliminary, and further systematic work is planned.

Brillouin Scattering of DTGS at Room Temperature and Through the Transition. (F. Vázquez and J. A. Gonzalo).

By use of the Brillouin scattering technique, 10 of 13 elastic constants of deuterated tryglycine sulfate (DTGS) have been obtained. They are (in 10^{11} dynes/cm^2): $C_{11} = 5.06$, $C_{12} = 2.04$, $C_{13} = 2.05$, $C_{22} = 3.51$, $C_{23} = 2.40$, $C_{44} = 1.10$, $C_{55} = 1.21$, $C_{66} = 0.73$, and $C_{46} = 0.03$. The temperature dependence (30° to 80°C) of some of the elastic constants has been studied, with emphasis on the transition temperature region. Raising the temperature through T_c caused a sharp increase of the Brillouin shift (See Figures 1 and 2) for the quasi-transverse and quasi-longitudinal modes, but no pronounced change for the pure transverse mode. Fitting of the results with a velocity dispersion relation of the type of Landau and Khalatnikov,

$$V^2 = v_\infty^2 - \frac{V^2 - v_0^2}{1 + (\omega\tau)^2} , \qquad (1)$$

with τ^{-1} proportional to $\Delta T = T_c - T$, gave a value $\tau^{-1} = (4.4 \pm 0.4) \times 10^{10} (T_c - T)$, for TGS. Nevertheless the results could not be fitted with Eq. (1) for T close to T_c. Careful measurements with $T_c - T < 0.1$°C showed that the transition starts rather abruptly. This indicates that the simple relaxation formula, Eq. (1), does not completely explain the behavior of DTGS.

Elastic vs. Polarization Energy in TGS Near the Phase Transition. (J. A. Gonzalo and F. Vázquez).

The elastic energy of ferroelectrics has been examined. If only a harmonic contribution is considered, the spontaneous strain along the ferroelectric axis turns out to be proportional to the spontaneous polarization. This leads to an expression for the corresponding elastic constant in terms of the basic ferroelectric parameters. From it anomalies in several physical properties, such as the ferroelectric axis linear expansion coefficient, can be estimated. If an anharmonic contribution is also considered, an expression giving correct temperature dependence for the spontaneous polarization far from T_c is obtained. The transition's temperature and pressure dependence can also be obtained. Study of the elastic behavior of TGS (Second-order transition) along these lines gives estimates of various anomalies in physical properties in reasonable agreement with observations. The elastic energy appears to be of the same order of magnitude as the purely electrostatic polarization energy.

Phonon Raman Spectra of Crystals Under High Pressure. (R. S. Singh).

A high pressure pump to generate hydrostatic pressure (10kbar) has been procured. The pressure cell is currently being built. The systems will be tested soon. A few selected crystals will be studied under hydrostatic pressure.

Phonon Raman Spectra of TGS and DTGS in Ferro- and Paraelectric Phases. (R. S. Singh and O. Matos).

Both TGS and DTGS are ferroelectric at room temperature and belong to the $C_2^2-P_{2_1}$ space group with two formula units per cell. On the basis of group theory, the 45 zone-center optical phonons are distributed as 11A(T) + 12A(R) + 10B(T) + 12B(R), which are al IR as well as Raman active. In the paraelectric phase, both belong to the $C_{2h}^2-P_{2_{1/m}}$ space group with two formula units per cell, and the zone-center optical phonons are distributed as 6Ag(T), 6Ag(R) + 6Bg(T) + 6Bg(R) + $5A_{2u}$(T) + $6A_{2u}$(R) + $4B_u$(T) + $6B_u$(R). Only g-types are active in Raman and u-types in IR. Polarized phonon Raman sepectra of single-crystal TGS and DTGS have been measured in the ferroelectric phase, and nearly all the zone-center optical phonons have been identified. Measurements in the paraelectric phase are in progress. The temperature dependence of the observable modes in ferro- and paraelectric phases, and the nature of the interatomic forces, the mechanism of phase transition, and the thermodynamic properties are being studied. Work will be extended to test the mechanism postulated from the diffraction data.

Uniaxial Pressure Dependence of the Elastic Constants Around the Transition Temperature. (F. Vázquez).

Uniaxial pressure in the direction of the ferroelectric axis will be applied in order to observe the dependence and coupling of the acoustic modes. Uniaxial pressure may give important results because it breaks some of the symmetry selected properties of the crystal.

Phonon Raman Spectra of Hydrogen-Bonded Ferroelectrics in the Para- and Ferroelectric Phases. (R. S. Singh).

Phonon Raman spectra of TGSe, DTGSe, and TGFB are being studied in both the para- and ferroelectric phases. These crystals are isomorphic in structure with TGS, which has been studied recently. Further study of these may help in assigning their lattice modes unambiguously and may shed further light on the mechanism of phase transition.

Brillouin Scattering of DTGS Around the Transition Temperature. (F. Vázquez).

The elastic constants are known for TGS and are being obtained for DTGS. This will allow comparison of the effects of hydrogen bonds on the elastic properties. Studying the scattering through the transition temperature will provide insight into the dynamics of the second-order phase transition and relate it with the results obtained with TGS. Data have been taken for the elastic constants and they are being computed.

EDUCATIONAL ACTIVITIES

Thesis Research

M.S. theses being done under Materials Science Division auspices are listed below. Students are from Puerto Rico unless otherwise noted.

Radiolysis of Aqueous Solution of Sulfur-Containing Amino Acids.
Luz del Mar García (under Dr. R. A. Lee; completed 11/75).

Raman Scattering of Hydrogen-Bonded Ferroelectric Crystals.
Osvaldo Matos (under Dr. R. S. Singh, Physics; completed 12/76).

Phonon Raman Spectra of TGSe, DTGSe, and TGFBe.
Fernando Noriega, Guatemala (under Dr. R. S. Singh).

Study of Phase Transition in Crystals by Light-Scattering Techniques.
Luis Mera Romero, Dominican Republic (under Dr. R. S. Singh).

Dielectric Constants in TGS and DTGS With Uniaxial Pressure.
Jorge Ortiz (under Dr. F. Vázquez, Physics).

Infrared Studies of the Bromine-Benzene Complex.
Roberto Torres (under Dr. T. C. Jao, Chemistry).

Raman Scattering of Ribosomal RNA, Ribosome, and Some Antibiotics.
René S. Vieta (under Dr. Jao).

Raman Scattering of Some Polyamino Acids, Peptides, and Proteins.
Gloria O. Márquez (under Dr. Jao).

Phase Diagram and Shift in Curie Point for Doped $NaNO_2$.
Mario Rojas, Colombia (under Drs. Jao, Vázquez, and M. I. Kay, Neutron Diffraction).

Special Training

Mrs. Claribel Vélez has an ORAU undergraduate fellowship, and is working on the project, Radiation Chemistry and Radioprotection of Biologically Important Compounds (Purines), under Prof. G. Infante of Catholic University, who holds an *ad honorem* appointment at CEER.

STAFF ACTIVITIES

International Conference

The International Conference on Low-Lying Lattice Vibrational Modes and Their Relationship to Ferroelectrics and Superconductors, held in December 1975, was organized by Drs. M. Gómez, J. A. Gonzalo, and M. I. Kay. They handled both the scientific program and the local organization, and are now editing the proceedings. Sponsorship was provided by UPR, ERDA (via PRNC), the International Union of Pure and Applied Physics, and the American Physical Society. Funding was by the National Science Foundation and the

Office of Naval Research. The 150 physicists attending came from the U.S., U.S.S.R., Japan, Europe, and Latin America.

Visitors

Dr. J. B. Cohen, Head of the Materials Science Department and Frank C. Engelhart Professor at Northwestern University, visited PRNC for two weeks, March 21 to April 4, 1976, to start an experiment on diffuse scattering from TGS, now under way at PRNC, to study the details of correlation through the phase transition.

Dr. Michael Butler of Sandia Corporation visited the Division on June 11, 1976, and gave a seminar.

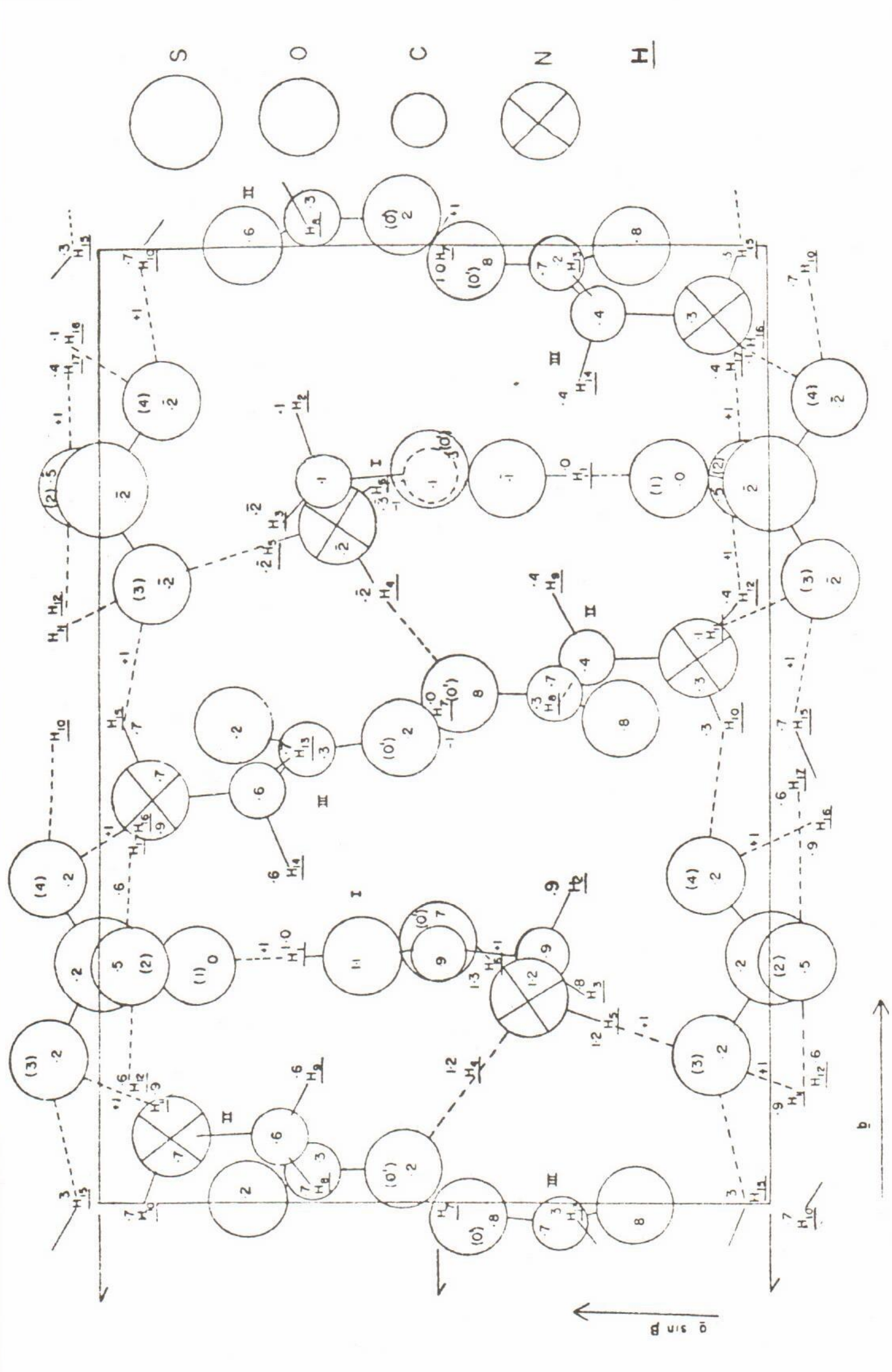


Figure 1: View of TGS looking down the short coaxis. Dashed lines indicate hydrogen bonds.

Neutron Diffraction

The Neutron Diffraction Program is funded by the National Science Foundation (Grant DMR-71-01785-A02) and is concerned with investigation of the structural changes in materials undergoing ferroelectric and antiferroelectric transitions. The microscopic molecular structure of crystals defines their lattice vibrational and molecular spectra, which determine their response to impressed fields. Thus, the crystal structure and its changes through phase transitions provide the basic information needed for predicting and interpreting transition mechanisms via their dynamics.

Ferroelectric, antiferroelectric, or more generally ferroic materials have been used as optical gates, infrared detectors, transducers, and optical memory devices. The application of these materials, via the pyroelectric effect, as possible (solar) energy converters is dealt with earlier in this report. It should be noted that the study of most materials and their interactions with various force fields leads, in one form or another, to "energy conversion." Certain solids have wear-term possibilities for use as superconductors, superionic conductors, and perhaps ferroelectrics, but almost all materials will react and respond to electromagnetic and mechanical inputs. As data are accumulated on these properties and interactions, it is hoped that theories will be put to use in producing devices and "effects" for conversion, storage, and transmission of energy in its desired form.

RESEARCH COMPLETED

Deuterium Atom Positions in the Paraelectric Phase of DTGS — M. I. Kay, A Neutron diffraction study of deuterated triglycine sulfate (DTGS) has been carried out to determine the changes in position of the hydrogen atoms above the ferroelectric phase transition temperature of 60°C. Since the hydrogen bonding scheme plays a critical role in stabilizing TGS, and in the transition, it was decided to attempt to determine the DTGS structure above the transition. Since deuterium is a heavier scatter than hydrogen and has a lower incoherent cross section, a crystal whose exchangeable hydrogen atoms were deuterated (DTGS) was sued in place of TGS to increase the reliability of the determination even at the expense of an isotope effect which could distort a comparison with the ferroelectric phase.

The final value of $R = \Sigma| F_0^2 - F_c^2| / \Sigma F_0^2$ from least-squares refinements was 0.062. The least-squares results were checked by three-dimensional Fourier and difference maps. A diagram of the numbering scheme in the ferroelectric phase is given in Figure 1. To obtain the paraelectric phase it is necessary to imagine a mirror plane passed through the planes of the sulfur atoms.

Comparison of the hydrogen bonds in TGS at room temperature and DTGS in the paraelectric phase (Table 1) shows that the donor to deuterium distance for the $O\text{-}D_1$ bond remains about 1.00 A and for the $D\text{-}O_1$ increases from 1.52 to 1.58 A above transition.

Table 1: Hydrogen Bonds (Ferroelectric Phase in Parentheses)
(r_1 = donor to hydrogen distance; r_2 = acceptor to hydrogen distance)

From Glycine I	r_1	r_2	Angle
$O - D_1 - O_1$	1.01 (1.00)	1.58 (1.52)	179 (179)
$N - D_4 - O'II$	0.94 (0.97)	1.99 (1.84)	167 (169)
$N - D_5 - O_3$	1.02 (1.06)	1.73 (1.73)	176 (177)
$N - D_6 - O'I$	1.05 (1.00)	2.02 (1.96)	136 (139)
From Glycine II			
$O' - D - - O'$*	1.245 (1.10)	1.245 (1.41)	180 (176)
$N - D_{10} - O_3$**	1.00 (.99)	2.07 (2.04)	143 (146)
$N - D_{11} - O_3$	1.01 (1.06)	2.08 (2.00)	156 (161)
$N - D_{11} - O_1$		2.19 (2.23)	129 (126)
$N - D_{12} - O_2$	1.02 (0.97)	1.99 (1.95)	152 (154)
From Glycine III			
(Ferroelectric phase only. II and III are equivalent in the paraelectric phase).			
$N - H_{15} - O_3$	(1.06)	(2.01)	(141)
$N - H_{16} - O_4$	(0.95)	(2.09)	(158)
$N - H_{16} - O_1$		(2.06)	(115)
$H - H_{17} - O_2$	(1.05)	(1.80)	(153

* Dissordered in paraelectric phase.
** O_3' is equivalent to O_4 in ferroelectric phase.

The average H-H distance in the ammonium group is 1.01 A below the transition and 1.00 A above it. The H or D to 0 bonds are 1.86 A below the transition and 1.91 above it. For Glycine II, the N-H distances average 1.01 as do the N-D distances. The D-0 distances (excluding the bifurcated bond, which has a low 0-D-0 angle of 126° and a long distance of 2.23 A and is probably almost completely electrostatic) increase from 2.00 to 2.05 A. The N-H bonds for Glycine III from an average of 1.02 to 1.01 (the same). The three higher-angle bonds average 1.97 below the transition and 2.05 above. Here the 4th bond increases in length from 2.06 to 2.19 A. Although one may doubt the precision of the structure, every bond does increase in length. The average magnitude of the increase is 0.06 A, which is larger than would be expected from an isotope effect in long hydrogen bonds. It is concluded that the hydrogen bonding weakens noticeably in the high temperature phase.

Figure 1 also shows that the breaking of the $N-D_4-O'II$ bond with polarization reversal is probably correlated with the OII'H- - O'III reversal. This effect should be visible to Raman spectroscopy and will be examined by R. S. Singh of this laboratory.

Table 2: **Comparison of X-Ray and Neutron Bond Distances (angstroms), Angles and Principal rms Amplitudes (U_i), With Standard Deviations in Parentheses**

	Neutron			X-ray		
A_sO_4						
A_s-O			1.684 (2)			1.682 (1)
$O-A_s-O$			111.2 (2)			111.08 (7)
$O-A_s-O$			108.6 (1)			108.67 (6)
Arsenic						
$U_{\parallel c}$			0.166 (7)			0.164 (1)
$U_{\perp c}$			0.119 (7)			0.131 (1)
Oxygen						
U_1			0.127 (6)			0.135 (2)
U_2			0.139 (7)			0.143 (2)
U_3			0.233 (4)			0.235 (2)
	Angle from					
	a	b	c	a	b	c
U_1	105(23)	28(5)	67(11)	106(7)	29(2)	67(3)
U_2	156(15)	95(21)	113(10)	155(5)	97(7)	114(3)
U_3	109(2)	117(2)	34(2)	108(1)	108(1)	34(1)
NH_4						
N–H			0.997 (5)			1.05 (8)
H–N–H			112.3 (8)			
H–N–H			108.1 (4)			
H – O			157.2 (6)			
H–H			1.614 (8)			
H–H			1.656 (15)			
Nitrogen						
$U_{\perp c}$			0.181 (4)			0.183 (2)
$U_{\parallel c}$			0.166 (6)			0.164 (3)

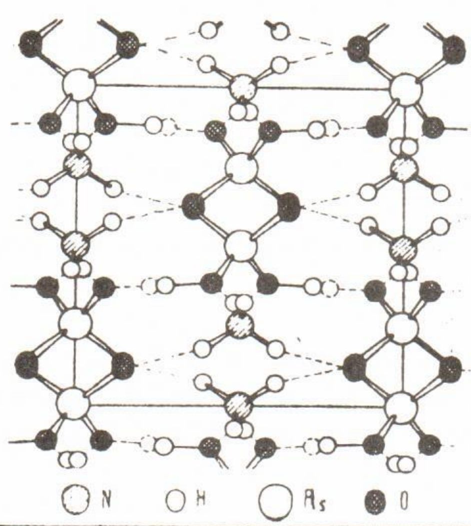


Figure 2: $(NH_4)H_2AsO_4$ projected down the *b* axis

Table 3: Short Hydrogen Bond Geometry

All parameters

$$R(F^2) = 0.037$$
$$Rw(F^2) = 0.044$$

O —1.19— H —1.31— O′ (∠ 177°)

U_1 = 0.08
U_2 = 0.25
U_3 = 0.29 ∿11 to O - O bond

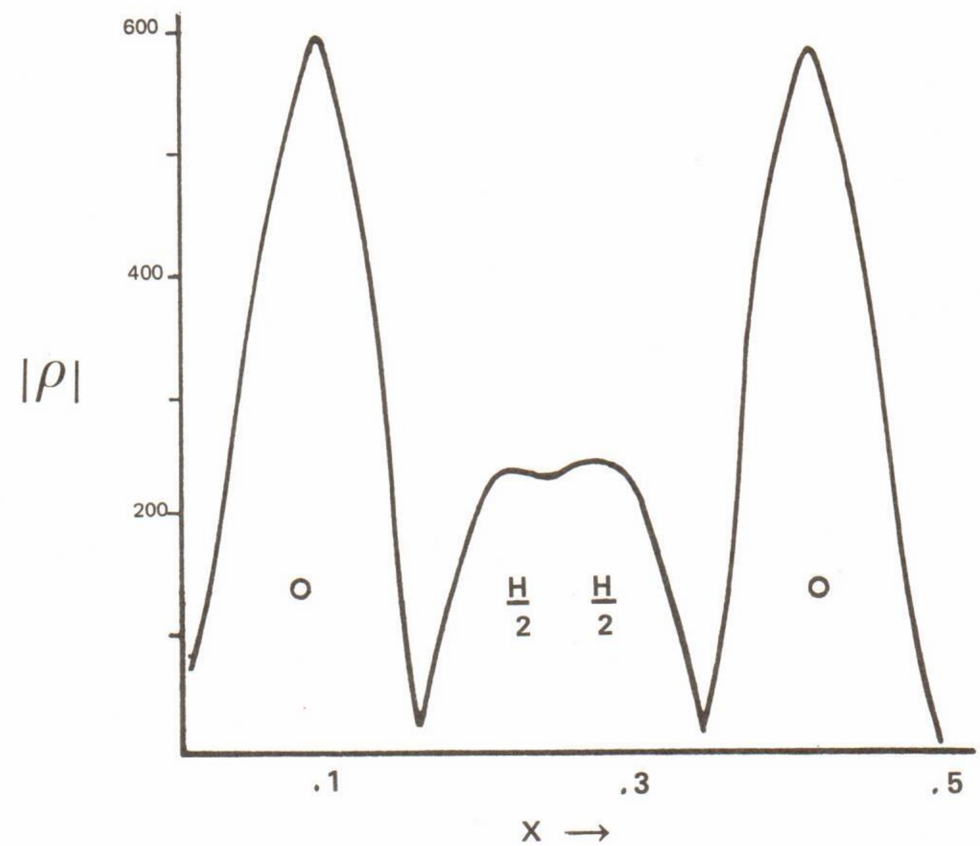


Figure 3: Fourier line through y = 0.16, z = 0.12, showing the short hydrogen bond, consisting of two oxygen atoms and the disordered half hydrogen atoms.

The Hydrogen Positions in Paraelectric Ammonium Dihydrogen Arsenate — M. I. Kay.

Ammonium dihydrogen Arsenate (ADA) is isomorphous with the phosphate. The material is antiferroelectric below its transition temperature of -57°C. It goes from $I\bar{4}2d$ to $P2_1 2_1 2_1$. The tetragonal lattice parameters are a = 7.69 and c = 7.72 as given by Kahn and Baur (*Acta Cryst.* **B29**, 2721, 1973). A projection of the structure is given in Figure 2. It is interesting to compare the neutron and x-ray results given in Table 2. The agreement is startling for As, N, and O. Table 3 presents the O-H--- O bond geometry. Although there is a great deal of uncertainty due to disorder, the hypothesis of a linear of centered bond can be rejected at the 0.05% probability level. Figure 3 shows a trace at y = 0.16, z = 0.12, the small double hump indicating two disordered hydrogen atoms. It is somewhat unusual for an O-H-O bond of 2.5 A to be nonlinear. The effect seen is due to the receptor oxygen in the disordered system being displaced inward from the average position toward the As. Thus the H position should be shifted, as indeed it is. A detailed analysis of the transition mechanism will have to await an structure of the antiferroelectric phase. To this end crystals of deuterated ADA have been taken through its transition under uniaxial stress in an attempt to obtain a single domain crystal.

WORK IN PROGRESS

Diffuse scattering data are being collected in the region of the forbidden 0*k*0 reflections in DTGS to examine correlated motions through the transition.

Mr. Mario Rojas is carrying out exploratory work on the KNO_2–$NaNO_2$ work and because of possible uses of $NaNO_2$ in energy conversion.

Table 1: Experimental and Predicted Argon-41 Concentration

	Location		Meteorology			Stack Conditions			Ground Conditions		Results	
Run No.	Distance from source X(m)	Height of source h(m)	Wind frequency f(%)	Wind speed μ(m/sec)	Temp. gradient	Emission rate (μCi/sec)	Concentration at stack (μCi/cc)	Activity at stack (counts/ 4Ksec-tank)	Activity at ground (counts/ 4Ksec-tank)	Pressure in tank (atm.)	Predicted concentration (μCi/cc)	Experimental concentration (μCi/cc)
1	117	10	Low	1.5 ±0.5		0	0	0	0	139	0	0
2	117	10	Low	1.9 ±0.5	[illegible]	7.3 ±0.2	$(10.3 \pm 0.26)10^{-5}$	$(364.5 \pm 0.6)10^{3}$	41 ±6 4	140	-	$(8.3 \pm 1.3)10^{-11}$
3	117	10	100	3.5 ±0.5	[illegible]	7.3 ±0.2	$(10.3 \pm 0.26)10^{-5}$	↓	900 ± 30	148	$(1.7 \pm 0.3)10^{-9}$	$(1.7 \pm 0.07)10^{-9}$
4	117	10	100	2.2 ±0.5	[illegible]	7.3 ±0.2	$(10.3 \pm 0.26)10^{-5}$	↓	1048 ±32	149	$(2.6 \pm 0.5)10^{-9}$	$(2.0 \pm 0.08)10^{-9}$
5	117	10	98	4.9 ±0.5	[illegible]	7.3 ±0.2	$(10.3 \pm 0.26)10^{-5}$	↓	382 ±20	146	$(1.2 \pm 0.2)10^{-9}$	$(0.74 \pm 0.04)10^{-9}$
6	90	10	100	3.4 ±0.5	[illegible]	7.4 ±0.2	$(11.0 \pm 0.29)10^{-5}$	$(579.2 \pm 0.76)10^{3}$	2173 ±47	140	$(1.8 \pm 0.35)10^{-9}$	$(3.2 \pm 0.1)10^{-9}$

NUCLEAR ENGINEERING

The Nuclear Engineering Division is engaged in both teaching and research. Staff members teach both graduate and undergraduate courses at the UPR Mayagüez Campus and direct the thesis work of nuclear engineering students. They do research on their own projects and assist the staff of other PRNC divisions as the need arises. The scientists on the Division's staff all hold joint appointments at PRNC and UPR, and they make up the faculty of the UPR Nuclear Engineering Department, the Head of the PRNC Division being also the Chairman of the UPR Department. The Division provides the classrooms, offices, laboratories and equipment, and most of the administrative personnel required for the education and training of the graduate students at the UPR Nuclear Engineering Department.

RESEARCH ACTIVITIES

Method for Monitoring Environmental Argon-41 (D. S. Sasscer and C. Andreu)

The *Draft Standard for Restrictions on Radioactive Effluents From Research Reactors* of June 1974 recommends that the allowable concentration of ^{41}Ar in unrestricted areas be reduced by a factor of 50, to 8×10^{-12} μCi/cc. The objective of this work was to develop a simple and accurate procedure for ^{41}Ar measurements in unrestricted areas when its concentration is significantly below the new recommended allowable concentration. The purpose of such measurements is to provide verification of the results obtained from prediction models for the spatial variation of the concentration of gases released from a source. The ability to measure ^{41}Ar at a concentration $<2\%$ of the previously allowable value required a high-sensitivity radiation detection system. A system was developed (Figure 1) in which a 4X4- in. and a 3X3- in. sodium iodide detector are connected in parallel, concentrated samples of air are measured in a scuba tank filled to 2200 psi by a high pressure pump, and the radioactive background is kept low by 6- in.-thick lead walls.

The argon concentrations measured at ground level and converted to atmospheric pressure are compared with the predicted ground level concentrations in Table 1. Run 1 was a background measurement taken before reactor startup, and the ^{41}Ar concentration in the off-gas system was zero. In Run 2 concentration could be measured but not predicted since the model does not apply when the sector wind frequency is low. The average difference between the experimental and predicted concentrations for the last four runds was 25%. The concentration in the off-gas system was $\sim 10.3 \times 10^{-5}$ μCi/cc at the 1000-kw power level. The radiation detection system determined a ground level concentration of 5.0×10^{-11} μ Ci/cc, which is $<10\%$ of the new recommended allowable concentration and indicates an attenuation factor of $\sim 2 \times 10^6$.

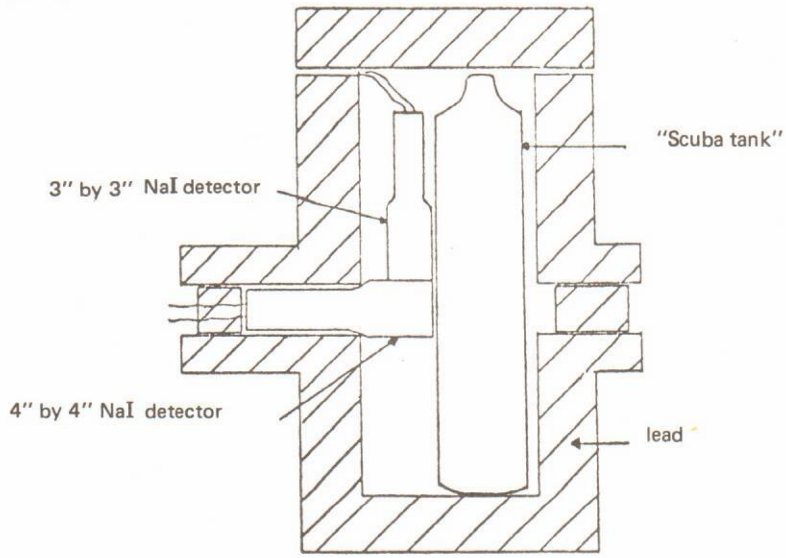


Figure 1: Schematic Diagram of the High-Sensitivity Counting System

Methane Gas Production From Activated Sludge (K. P. Pedersen and A. L. Rivera)

During the 1950's several systems were described in which raw waste was mixed with a large anaerobic biological mass maintained in the digester for more efficient and rapid treatment. This was called an anaerobic contact process. A newer process for soluble wastes is termed the anaerobic filter process because it involves a system similar to a trickling filter. The stabilization of the organic contents may be considered to be a function of the density of the microbial mass, which tends to form and grow in the spaces around and between the filter medium.

The objective of this work was to evaluate the feasibility (under local conditions) of producing methane gas as an energy resource from city sewage by the anaerobic filter process. A bench-scale unit capable of treating several gallons of sludge per day was installed in a local sewage treatment plant, and its ability to produce gas continuously was evaluated by gas and liquid analysis. The hydraulic retention time was varied, bia the liquid flow rate, to study its effect on the system's operational state. The temperature inside the filter was recorded by three probes at the bottom, middle, and top. The collected gas was tested for volume percent of methane gas chromatography and for gross heating value by burning a known volume and recording the temperature rise of the heated water.

After the anaerobic filter started producing gas, the feed to the system was initially anaerobic digester feed for about half a month and was then changed to the returned activated sludge normally fed to the aerobic digestor. The bench-scale unit had the disadvantages that the mixer had to be filled at time intervals depending on the operations liquid flow rate and racked a control on the COD load fed to the anaerobic filter. The activated sludge used as raw material had to be filtered before being fed to remove the garbage that can clog the bellows-type metering pump. Because of these limitations, only two liquid flow rates were used.

With a liquid flow rate of 94.5 ml/min, used for 12 days, the average equilibrium gas production was ∿5053 ml/day at STP (this represents an average at a timewhen gas production does not change greatly from one day to another). With the liquid flow rate increased to 157.5 ml/min, the average was ∿18,539 ml/day.

Land Sited Integrated OTEC– Nuclear Facilities (D. S. Sasscer and F. Ferrer). A major attraction of ocean thermal energy conversion (OTEC) systems is that they use the ocean for energy storage and therefore can produce power at a constant rate. An OTEC plant operates the temperature difference between the surface water and the deep water, which even under ideal conditions seldom exceeds 40° F, and therefore, has a low thermal efficiency which increases rapidly with increasing temperature difference.

The location of OTEC facilities floating near the shore along warm ocean currents involves technical difficulties and high costs associated with construction, maintenance, anchoring, and power transmission that raise doubts as to their engineering and economic feasibility and justify the investigation of alternatives. One proposal is to locate OTEC facilities on land in shoreline areas near deep ocean water. This not only would be more feasible but also would allow judicious integration with a conventional plant, which might be cost effective because the waste heat from the latter could be used to increase the efficiency of the OTEC plant. The primary objective of this work is to determine the feasibility of land sited OTEC electrical power facilities integrated with conventional ones.

The tropical waters around Puerto Rico have a year-round surface temperature of 75° to 85° F, and, within 1.5 to 5 miles from shore, 40° to 45° F water is found at a depth of 3000 ft. A secondary objective, therefore, is to determine the feasibility of using a site in Puerto Rico for field testing OTEC components (possibly as part of a Solar Energy Research Institute field station) or for setting up a demonstration OTEC facility (with or without a conventional plant). The first site selected for study, Punta Higuero, is on the west coast of Puerto Rico, near Rincón; the second, Punta Tuna, in the southeast, near Yabucoa, and the third Barrio Islote, on the north coast, near Arecibo. The distance from shore to a source of 40° F water at a depth of ∿3000 ft is 5 to 7 miles for Punta Higuero, 1.7 for Punta Tuna, and 10 for Barrio Islote. The 28 mills/kW-hr quoted by CMU for its floating OTEC model (a 100-MW independent module) was assumed to remain constant regardless of site and power production level. At the Punta Higuero and Punta Tuna sites, the production cost of electricity for the land based systems would be less than for the floating CMU OTEC. At Barrio Islote, the land based systems would cost less except for the OTEC alone, which would cost more up to a power ratio of 1.16. Punta Tuna, the site nearest deep water, is the most advantageous for a land based system and Barrio Islote, the least.

THESIS RESEARCH

Seven students have completed all the requirements and been awarded the M.S. degree in Nuclear Engineering. Their thesis are summarized below.

Population Exposure to Natural Radiation in Puerto Rico. Antonio J. Gonzalez– Rodriguez (under Dr. A. E. Gileadi). The average whole-body dose equivalent (DE) from natural radiation sources to an individual in Puerto Rico was measured by thermoluminescent dosimetry in 35 municipalities (covering 61% of the Island population) and found to be

53±8 mrem/yr per person, ranging from 108±16 in Ciales to 34±5 in Carolina and Ponce. To check the results, personal dosimeters were worn by four volunteers; these gave an average value of 54±8. Within the municipalities surveyed, the cosmic component of the DE has been found to vary by only 3±3 mrem/yr per person; therefore, the DE variation was assumed to arise from the terrestrial component. The natural background activity level in Puerto Rico is one of the lowest known being 20% lower than in "normal" areas and 59% lower than the best mean of all countries reported by UNSCEAR in 1962.

A Cost-Benefit Analysis of Condenser-Cooling Systems for Nuclear Power Plants in Puerto Rico. Juan M. Cajigas (under Dr. K. B. Pedersen). A cost-benefit analysis was done on systems including once-through cooling, cooling pond, wet cooling towers, and dry cooling towers. Computer programs were used to design the different alternatives, optimized to minimum cost. General environment impact was also studied. The results indicate that the once-through system is the heat rejection method best suited to the cooling needs of Puerto Rico's future nuclear power plants. Its design total system cost was calculated to be 0.076 mill/kW-hr less than that of the closes competitors, mechanical draft wet cooling towers, and its environmental effects are within tolerable limits.

Determination of Argon-41 Dose at the PRNC Site Boundary. Carlos Andreu Villegas (under Dr. D. S. Sasscer). The objective of this work was to determine the yearly average maximum concentration, needed for verifying the model used for calculating the attenuation factor between the off-gas stack outlet and ground level. The model uses the diffusion equation for average long-period concentration from a continuous point source. The Kane chamber, which is the constant air monitor of the reactor off-gas system, had to be calibrated to allow accurate and easy determination of future concentration at any power level, and this was satisfactorily done, with a probable error of $\sim$5%. The system used allowed measurement of a ground level concentration lower by a factor of 6.75×10^5 than the concentration in the off-gas stack, or to $\sim 1.6 \times 10^{-10}$ μCi/cc. The average ratio of estimated to measured concentration is 1.1. This excellent agreement gives a high degree of confidence in utilizing the model to calculate the yearly average maximum concentration, the largest value of which occurred during one-shift operation, dry season, at 125 m from the stack in the ENE sectors and was 2.69×10^{-10} $\mu Ci/m^3$, which is 33.6% of the allowable concentration.

Economic and Engineering Feasibility of Integrated Ocean Thermal Gradient and Nuclear Plants for the Production of Electric Power at Several Sites in Puerto Rico. Frank Ferrer Almodóvar (under Dr. D. S. Sasscer). The performance of three different land based integrated systems and a land based OTEC for the production of electric power was analyzed to determine the optimum integrated system and its economical and engineering feasibility at several sites in Puerto Rico. Geometric programming was used as the optimization technique. The optimum integrated system was one in which the heated water from the nuclear plant is used to raise the temperature of the surface ocean water. The trade-off between plant components showed that the piping is responsible for the major part of the cost,followed by the pumping and then the heat exchangers. The best location for a land based system, integrated or not, was found to be Punta Tuna.

Methane Gas Production From Returned Activated Sludge Using the Anaerobic Filter. Angel Luis Rivera (under Dr. K. B. Pedersen). The objective of this research project was to evaluate the feasibility, for Puerto Rico, of producing methane gas as an energy resource from city sewage by the anaerobic filter process. The raw material was returned activated sludge, and, once the system started, it produced gas continuously. Increasing the liquid flow rate from 94.5 to 157.5 ml/min resulted in fairly good gas production, $\sim$1.58 ft^3 (at STP) per pound of total suspended solids removed on the average. This does not necessarily represent a maximum and/or optimum production, and further research is needed. At this flow rate the gas had an average methane content of 80% and a gross heating value of 601 Btu/ft^3.

Population Dose Due to Transportation of Irradiated Fuel From a Nuclear Power Plant in Puerto Rico. Luis Reyes Medina (under Dr. H. Plaza). Calculations were made of the exposure dose from irradiated nuclear fuel to persons along the shipping route under normal conditions, and of the probabilities for the occurrence of various types of accidents during shipment. The dose to a person 20 ft from the centerline of the shipping route was conservatively calculated to be 7×10^{-3} mrem.

Atmospheric Transport of Gaseous and Volatile Radioactive Effluents from the PRNC TRIGA Reactor. Rolando Pérez Ortiz (under Dr. A. E. Gileadi). A computer code was developed for evaluating certain radiological hazards associated with the discharge of gaseous and volatile radioactive effluents from the PRNC TRIGA-FLIP research reactor, with use of actual operating parameters and local meteoroligcal data. The code is written in FORTRAN IV and executed on the PDP-10 computer of the UPR Mayagüez Campus. On the basis of the mathematical model of the generalized Gaussian plume, the code calculates the concentration of any isotope of interest at any given position with respect to the source, using such input parameters as position coordinates, source intensity, and climatologic data, with allowance made for effective stack height, reflection at the ground surface, and depletion by ground deposition and radioactive decay. The model is tested for accuracy by comparing estimated concentrations with available diffusion data.

EDUCATIONAL ACTIVITIES

Master of Science Degree Program. UPR, in close cooperation with the PRNC Nuclear Engineering Division, offers a Master of Science degree in Nuclear Engineering, in which 12 graduate students were enrolled during 1975. The seven theses completed are summarized above. One student,Dick Carrero, is no primarily engaged in thesis research, and four in academic course work: Edmundo Martínez, César Pérez Arenas, Manuel López, and Milton Soto.

Special Courses. Short courses (one week to three months) on a variety of topics related to nuclear engineering are offered approximately once a year for scientis, engineers, and other interested persons. In June a one-week Summer Workshop on Energy and the Environment was offered for high school science teachers, sponsored jointly by ERDA, PRNC, the UPR Mayagüez Campus, and the Puerto Rico Water Resources Authority, to provide these teachers with sufficient background to enable them to guide their students and communities towards a more factual and less emotional consideration of the trade-off between energy and the environment in Puerto Rico. The 39 participants came from cities and towns throughout Puerto Rico.

The staff of the Division taught ten semester-length graduate courses and one undergraduate course in the UPR Nuclear Engineering Department and eight undergraduate sections in the Mechanical Engineering and Electrical Engineering Departments. (See Table 2).

Table 2: Courses Taught by Nuclear Engineering Faculty

Course	No. of Students	Professor
	First Semester	
Math 675 - Math of Modern Sc. 1	11	A. E. Gileadi
NuEg 605 - Elem of Nuc. Eng.	3	K. B. Pedersen
NuEg 621 - Reactor Theory	3	H. Plaza
NuEg 603 - Nuc. React. Meas. & Instr.	3	D. S. Sasscer
NuEg 699 - Research	3	Pedersen, Ortiz, Sasscer
ME 340 - Thermodynamics	62	Pedersen
EE 311 - Elect. Eng.	59	Plaza
	Second Semester	
NuEg 622 - Adv. React. Theory	3	H. Plaza
NuEg 625 - Nuc. Reactor	3	K. Pedersen
NuEg 626 - Reactor Laboratory	3	D. S. Sasscer
NuEg 616 - Seminar	3	Staff
NuEg 699 - Research	7	Staff
NuEg 551 - Intro. to Nuc. Eng.	7	D. S. Sasscer
ME 341 -- Thermodynamics	56	Pedersen, Sasscer
EE 311 - Electrical Eng.	61	H. Plaza
	Summer	
Summer Workshop	39	All Staff

TROPICAL AGRO–SCIENCES

The Tropical Agro–Sciences Division has two functions: conduct research on the impact of air pollution on tropical agricultural and to provide training to UPR graduate students and visiting scientists. Since the reorientation of the Center's interests under ERDA, the Division has directed its research activities, with particular emphasis on the effects of atmospheric pollution on tropical agriculture in the Guayanilla-Peñuelas region, which has a fossil-fuel power plant, petroleum refineries, and associated industries. This new area of research is important to ERDA because the knowledge gained regarding the effects of air pollution related to energy technology on the agricultural environment and productivity will be useful in planning future energy developments. Information about the potential harm of air pollutants to man through the food chain and about ways of alleviating their impact on agriculture are of practical importance. Studies of the mechanisms involved in pollution injury, protection, and tolerance are of basic significance.

RESEARCH ACTIVITIES

Installation of a Field Station for Pollution and Climatological Monitoring. (F. K. S. Koo and J. Cuevas-Ruĭz). At the beginning of this fiscal year, trips were made to Guayanilla–Peñuelas area to survey the general air pollution status, cropping system, vegetation, soils, and climatic conditions and to find localities suitable for field stations. Two locations were chosen for preliminary monitoring, and one of these was made into a field station. Financial limitation precluded establishment of five stations on a pollution concentration gradient as aoriginally planned. The preliminary monitoring indicates an irregular daily SO_2 distribution pattern differing at the two locations. In general, a heavy SO_2 influx lasting 1 to 6 hr occurred one to three times a day, with concentrations ranging from trace to 0.5 ppm or more but usually about 0.2 ppm; it was thought to depend on wind direction. Additional monitoring will be done with all the instruments installed, including SO_2 analyzer/recorder, total sulfation collector, high-volume air sampler, dustfall collector, wind speed and direction instrument, rainwater collector, hygrothermograph, etc. Planting of test material at the field station will begin in July 1976.

SO_2 Effect on Leaf Fresh Weight and Net Photosynthesis in <u>Phaseolus vulgaris</u> seedlings (F. K. S. Koo, J. Cuevas-Ruĭz, and J. Garcĭa-Villalobos). In experiments on the effect of SO_2 on 10-day-old bean seedlings (*Phaseolus vulgairs* L.), seedlings in a sealed 12.5×9.5×12-in. glass chamber were exposed for 1 hr to concentrations of SO_2, generated by heating 10 ml each of 2 *M* HCl and 1 *M* $K_2S_2O_5$ in a small polyethylene bottle and injected into the chamber. The symptoms of injury and the protective effect of ascorbic acid have been reported earlier. The results of the present study suggest that the leaf fresh-weight loss, presumably due to leaf tissue injury, ensuing water loss, and lowered photosynthetic activity, can be used as a criterion for measuring the extent of leaf injury caused by acute SO_2 exposure. The weight loss 3 days after exposure at 5.6 ppm was not appreciable, but at 14 ppm it was about 6% (compared with the control) and at 28 ppm it increased to 29%. Net photosynthesis, measured immediately after exposure and 24 and 48 hr later, showed a marked decrease as the SO_2 concentration increased. Immediately after exposure at 5.6 ppm, the decrease was about 18% (compared with the control); at 14 ppm it was 37%; and at 28 ppm it reached >80%. Various degrees of recovery in photosynthetic activity were seen 24 and 48 hr after all treatments.

Trace Amounts of Heavy Metals in Higher Plants (J. A. Ferrer-Monge). The heavy metals Cd, Co, Ni, Cu, and Pb have been determined by atomic absorption spectrophotometry in the leaves of mango (*Mangifera indica*) and bird's nest (*Tillandsia* sp), and the latter was consistently found to contain much higher concentrations of all of them. The results are given below as μg/g sample (dry weight).

	Tillandsia	Mango
Cd	0.41	0.18
Co	2.31	1.80
Ni	7.35	2.83
Cu	23.70	12.26
Pb	85.12	12.18

Additional materials in both polluted and nonpolluted areas are being samples for further analysis.

Availability of Methionine for Synthesis of Different Protein Fractions in Soybean Seeds During Development (B. F. de Riesco and F. K. S. Koo). The quantitive changes in nitrogen, free amino acid pool, total protein, three protein fractions (globulin I, globulin II, and free methionine, and methionine in proteins were studied in soybean seeds, *Glycine max* (L.) Merrill, at various stages of development. Total nitrogen remained relatively constant on a per unit dry weight of meal basis, but increased steadily on a per seed basis as a result of protein accumulation as the seeds developed. The level of free amino acids (FAA) was high in very young seeds and then decreased with a concomitant increase in protein synthesis and accumulation. Protein synthesis had two peaks, in 30– and 70-day-old seeds. The type of protein synthesized and accumulated varied during development. Albumins were relatively abundant in the young seeds, then their synthesis slowed down until near maturity, when a slight increase in albumins per unit weight was observed. Globulin I was a very small fraction in the young seeds, but as development proceeded it was synthesized and accumulated very rapidly to form the bulk of the proteins in the mature seeds. The globulin II fraction was relatively high in immature seeds and decreased slowly until maturity. Methionine in the FAA pool per unit dry weight of meal was high in the immature seed and decreased as the pool decreased. Methionine in terms of percent of total FAA was highest at 30 days and also slightly elevated at 70 days, times of increased synthesis of methionine-rich proteins. Methionine in the proteins was higher at the early stages and decreased during development.

TRAINING ACTIVITIES

The Division continues to provide instruction and training to students and to researchers at the graduate and postgraduate levels in the fields of agriculture and biology, frequently related to the Division's basic research activities.

During FY 1976, Division staff members holding joint or adhonorem appointments in the various science departments of the University of P.R. taught the courses listed in Table 1.

Table 1: Courses Taught at UPR, 1975–1976

		Course	No. of students	Professor
		FIRST SEMESTER		
Biol	614	Nuclear Techniques in Biological Research	2	J. Cuevas-Ruíz and J. A. Ferrer-Monge
Biol	618	Cytogenetics	3	J. A. Ferrer-Monge
Biol	699	Research	1	F. K. S. Koo
Biol	699	Research	1	A. Cedeño-Maldonado
Biol	699	Research	1	J. A. Ferrer-Monge
CiFi	648	Photophysiology and Crop Productivity	6	A. Cedeño-Maldonado
Hort	402	Plant Breeding	1	F. K. S. Koo
Hort	605	Nuclear Techniques in Agricultural Research	3	J. Cuevas-Ruiz
		SECOND SEMESTER		
Agro	415	Special Problems in Agronomy	1	F. K. S. Koo
Hort	668	Growth Regulators in Agriculture	3	A. Cedeño-Maldonado
Biol	699	Research	1	F. K. S. Koo
Biol	699	Research	1	A. Cedeño-Maldonado
Biol	699	Research	1	J. A. Ferrer-Monge
Hort	402	Plant Breeding	1	F. K. S. Koo

Thesis Research

During FY 1976, three undergraduate students were doing thesis research in the Division.

Cytogenetic Effect of Insulin on Human Chromosomes. (Alice Ortíz, Puerto Rico (for M.S. in Biology under Dr. J. A. Ferrer-Monge).

Effects of Cadmium on Some Photosynthetic Reactions of Isolated Chloroplasts. (Carmen Asencio, Puerto Rico (for M.S. in Biology under Dr. A. Cedeño-Maldonado).

Availability of Methionine for Protein Synthesis in Soybean Seeds During Development. (Blanca Riesco, U.S. (for M.S. in Biology under Dr. F. K. S. Koo).

Special Training

The Division has been active in technical and scientific training programs. During FY 1976 five trainess (Table 2) under the sponsorship of (OAS) and of the Gran Mariscal de Ayacucho (GMA) Fellowship of Venezuela have received special training in the fields of plant physiology and application of nuclear techniques in agriculture.

Table 2: Trainees, 1975–1976

Name	Country	Sponsor	Date
Jesús García Villalobos	Venezuela	GMA	JUL 75
Lilia Delgado Martes	Venezuela	GMA	JUL 75
Héctor Flores Merino	Peru	OAS	JUL–SEP 75
Julia Radosevich Yrigoyen	Peru	OAS	JUL–SEP 75
Rúter Hiroce	Brazil	OAS	AUG 75–JAN 76

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