PUERTO RICO NUCLEAR CENTER ANNUAL REPORT
July 1, 1975 - September 30, 1976
CENTER FOR ENERGY AND ENVIRONMENT RESEARCH

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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 for 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:

1. 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.
2. To serve as a 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.

In subtropical zones, particularly the Caribbean and Latin America, the aim is to aid Puerto Rico in developing its manpower needs in energy and energy-related areas. The aim is also 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 research and training programs, attract and develop University System talent in energy and environmental research, promote academic excellence in the development of energy curricula, and 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 intention is to add a strong energy program to these, emphasizing conservation and solar sciences and engineering, including ocean thermal energy conversion and materials research and development. The Center 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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Puerto Rico's energy requirements:

A. Current Needs

At present, Puerto Rico's economy 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, the Island's petroleum refineries and petrochemical plants produced practically all the fuel oil, gasoline, and other products used locally. They also exported substantial quantities, mainly to the United States. According to OPFA, local consumption of petroleum in 1975 amounted to 69.9 million barrels. The Puerto Rico Water Resources Authority (PRWRA), a government corporation which is the sole vendor of electric power on 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, consumed 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 85 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.

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% per year during the next four or five years, assuming a very low rate of population growth (Table 1). On the basis of historical trends and the Planning Board's projections, OPFA estimates that with a 3.74% per year GP growth, petroleum consumption would increase by close to 10% per year, assuming no special effort to reduce energy consumption through continuing or new conservation programs or use of alternative energy sources.

Energy sources or technologies are vital in this context. Therefore, petroleum consumption could reach 98 million barrels in 1980 and is expected to continue rising through 1985 if the Gross Product (GP) continues to increase. The Puerto Rico Water Resources Authority (PRWRA) forecasts indicate that the demand for electric power consumption will increase at an average rate of about 6% per year in the near-term. Consequently, PRWRA's petroleum consumption would steadily increase until at least 1984. Nuclear power could begin to contribute to the electric energy supply in 1985 if the Puerto Rican Government decides within the next few months to proceed with the construction of a previously planned, then postponed, 600-MW plant.

For electric power alone, PRWRA estimates the petroleum requirement in the fiscal year 1986 to be 26.9 million barrels, costing $31 a barrel or $833 million. Assuming the first nuclear plant goes into operation, the uranium need would be about 450,000 pounds, costing $45 to $50 a pound or roughly $23 million. If a 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 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% per year, the impact of petroleum costs will increasingly be 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 1978. Calculations based on Office of Petroleum and Fossil Fuel Analysis (OPFA) estimates, PRWRA forecasts, and currently known Organization of the Petroleum Exporting Countries (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.

Mid and Long-Term Needs (1985-2000): The best projections currently available are those of the PRWRA, which cover only electric power and are based on a steady 6% per year consumption increase into the 1990s. Assuming that one nuclear plant can go into operation in 1985, PRWRA considers it feasible that three others, each of 800-MW, could follow.

The capacity of nuclear plants could potentially 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 would generate 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. By FY 1991, 15.3 million barrels of oil costing $50 a barrel, or a total of $753 million would be needed, plus 1,750,000 pounds of nuclear fuel at $60, amounting to a total of $106 million. If not, the petroleum need would be 44.7 million barrels costing more than $2.2 billion.

If the petroleum needed for electricity continued to make up one-third of total usage, the total oil bill in 1991 would reach $6.6 billion. Assuming that the Gross Product (GP) could grow 6 to 7% per year up to 1991, it would reach around $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. However, counting 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 develop energy alternatives that will reduce its dependence on imported petroleum will be beneficial. This is important while striving to achieve a good rate of economic growth and assuring protection of the environment. This 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 that of Puerto Rico. They also lack significant fossil-fuel or uranium resources and 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 a recent report. Another report analyzes a scenario in which the energy growth rate is kept at slightly less than 2% up to the year 2000. Both reports show how substantial energy savings can be achieved with no appreciable change in lifestyle. 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 taking other steps. The new administration is examining numerous energy-saving options. Recovery of municipal and industrial wastes for the 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 pyrolytic recovery plant serving the San Juan metropolitan area could generate electricity from waste equal to that from more than 800,000 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. However, at the petroleum prices forecast for 1980, it could pay for itself and begin to yield a net profit during the 1980s.

B. Alternative Energy Sources

Puerto Rico has long

The Puerto Rico Water Resources Authority (PRWRA) had considered nuclear power as one of its best options. They had plans for a 600-MW nuclear plant, had already purchased the components for it, and were planning to begin construction on a coastal site near the northern city of Arecibo. However, a 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. As a result, they shelved the construction plans and put the components up for sale, although they are still proceeding with the site licensing.

Ironically, seismic studies conducted during the site selection process raised the possibility of petroleum reserves off the north coast. However, confirmation of economically significant reserves would require time, highly expensive, and sophisticated drilling technology. It remains a question whether such reserves would belong to Puerto Rico or the Federal government.

Given Puerto Rico's climate and geography, solar energy presents a potentially attractive alternative, even in the near-term, and substantial for the mid-term. The island has high insolation, averaging over 2500 hours per year for San Juan and up to 2800 for other areas, particularly the dry southern and southwestern coasts, and 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 businesses are located, require air conditioning for 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 viable solutions.

Manufactured and adequately distributed, solar heat collectors and innovative marketing concepts require general acceptance by both builders and owners. The world’s fossil fuel reserves are the result of the natural conversion of solar energy into plant materials through photosynthesis and the 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. These could be used either for direct combustion or for conversion into enriched fuel. Other organic materials that could be used this way include large amounts of wastes - agricultural, animal, industrial, and urban - that are currently serious environmental and political problems but are potential sources of energy.

Oceans, which cover 71% of the Earth's 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 level, where there are cold currents emanating from the polar regions, is approximately 25°F. Theoretically, this nearly 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 8%.

The Gulf Stream between Florida and Puerto Rico carries 1000 to 1500 million cubic feet per second of near-tropical seawater. Within an 8500-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 approximately 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 into this heat source could produce an annual energy supply of 0.7 x 10^8 Btu. Since both the heat reservoir and the heat sink are replenished by solar energy, this, in effect, represents an unlimited renewable resource. Considering...

In 1974-75, Puerto Rico imported petroleum equivalent to 0.6 X 10^6 Btu. If it could realize 5 X 10^10% of the available ocean thermal energy, it would gain a substantial contribution to its energy balance. Due to 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. This presents 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, which has only 3400 square miles of land for nearly a 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 is a significant issue. The Puerto Rico Water Resources Authority (PRWRA), for instance, has estimated that if all of its 227,000 electric hot water heaters were supplemented with solar collectors, total electricity demand would drop by approximately 6%, equivalent to 1.2 million barrels of oil. Additional savings could be achieved by using solar air conditioners, and even more by substituting flat plate and concentrator collectors for process heat in manufacturing. Such savings, potentially totaling 20 to 25% of electric power demand, would undoubtedly be beneficial. However, a substantial capital cost would need to be considered.

The potential utilization of all options, including all solar options, necessitates further study and analysis. This highlights the need for the development of a regional energy model, like the one proposed by the Office of Policy and Financial Analysis (OPFA). This would help illustrate, for example, the degree to which Puerto Rico might rely on energy derived from U.S. coal rather than imported petroleum, which poses both a balance of payments issue for the United States and an economic problem for Puerto Rico.

The energy equation is also subject to great variation due to population growth. Planning Board estimates of a very low rate of growth must be considered alongside those that project Puerto Rico's population in the year 2000 at 6,000,000 or more. One must conclude that Puerto Rico's timeline for energy conservation and the development of alternative energy sources is, if anything, more critical than that of the United States. The challenge for the Center for Energy and Environmental Research (CER), the University (as the largest single pool of scientific and technical skills), the Government, and society at large is significant and urgent.

The University of Puerto Rico, a member of the national system of state and grand colleges, is an island-wide university with approximately 1000 students. It has three large campuses, two four-year university colleges, and five community colleges. Additionally, it has an agricultural research network and a... [Text cut off].

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 Rio Piedras campus, the 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, and Planning.

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, there are well-equipped medically-oriented facilities located adjacent to the UPR Medical School. These facilities include a biomedical building, animal quarters, and a maintenance shop.

Mayagüez Site: The principal nuclear facilities of the Center are located on 20 acres of property adjacent to the UPR campus in the city of Mayagüez. These facilities include laboratories and several.

Adjacent structures house offices, nuclear engineering facilities, maintenance shops, and a greenhouse. Near Mayaguez are 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 (Grebe)

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The text is unclear and appears to be a mix of various phrases and information. Here is an attempt to fix it, but please note that without a clear context, accurate corrections are challenging:

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4. Butler, J. M., Ferguson, F.F., Palmer, J. R., and Jobin, W. R. (1975). Displacement of Colony of Biomphalaria glabrata by an Invading Population of Tarebia granifera in a Small Stream in Puerto Rico. Presented by W.R. Jobin at American Society of Tropical Medicine and Hygiene 28th Annual Meeting, New Orleans.

5. Carrasco-Canales, J. A. and Colén, J. (1976). Study on the Adaptation of Nucleic Acid Hybridization Techniques to the Classification of Fungi Using the Microsporum ypseum Complex. Presented by J.A. Carrasco-Canales at the Annual Meeting, Association of Clinical and Laboratory Science, UPR School of Medicine, San Juan.

6. Castillon, J. P. (1976). Thiaxanthen-Sone Carboxylic Acids and Their Corresponding Sulfoxides and Sulfones. Presented at IV Xavier-MBS Biomedical Symposium, New Orleans.

7. Chellapan, S., Pedersen, K. B., and Plaza, H. (1975). Mercury and Cadmium Concentrations in Milk in Puerto Rico. Presented by S. Chellapan at the International Nuclear and Atomic Activation Analysis Conference, Gatlinburg, Tennessee.

8. Colén, J. I., Rios Olivares, E., Rodriguez, M., and Carrasco-Canale, J. A. (1976). Evidence of the Genetic Control of the Synthesis of Interferon in Chick Fibroblast Monolayers. Presented by J.I. Colén at Annual Meeting, American Association of Clinical Laboratory Science, San Juan.

9. Gilead, A. E., Lebron, D., and Gonzalez, A. (1975). Natural Radiation Background in Puerto Rico. Presented by A.E. Gilead at 20th Anniversary Meeting, Health Physics Society, Buffalo.

10. Gileadi, A. E. and Pérez, R. (1976). Atmospheric Transportation of...

"Volatile and Gaseous Radioactive Effluents from the PRNC-TRIGA Reactor" read by Sasscer, D.S. at the Health Phys. Soc. Midyear Topical Symposium, Denver. Gonzalo, J.A., and Purcell, R., 1975. "Energy Conversion Making Use of Thermal Differentials by Means of Ferroelectric Materials" was presented by J.A.G. at the International Conference on Low Lying Vibrational Modes and Their Relationship to Superconductivity and Ferroelectricity, San Juan. Gonzalo, J.A. and Vazquez, F. (UPR), 1975. "Elastic vs Polarization Energy in TGS: Near the Phase Transition" was presented by J.A.G. at the International Conference on Low Lying Vibrational Modes and Their Relationship to Superconductivity and Ferroelectricity, San Juan. Jobin, W.R., 1975. "The Use of Mathematical Models and Systems Analysis As Guides for Schistosomiasis Control Measures" was presented at the International Conference on Schistosomiasis, Cairo. Kay, M.I., 1975. "A Refinement of the Para-electric Phase of Copper Formate Tetrahydrate From Neutron Diffraction Data" was presented at the International Union of Crystallography, Amsterdam. Kay, M.I., 1975. "Neutron Diffraction Study of the Para-electric Phase of Deuterated Triglycine Sulfate" was presented at the International Conference on Low Lying Lattice Vibrational Modes and Their Relationship to Superconductivity and Ferroelectricity, San Juan. Lanaro, A.E., 1975. "Cardiovascular Studies With Lung Scans and Radio-angiocardiology: Qualification of Nuclear Medicine Specialists" was presented at the 2nd Latin American Regional Meeting on Nuclear Biology and Medicine, Caxias do Sul, Brazil. Lanaro, A.E., 1975. "Teaching of Nuclear Medicine" was presented at the Regional Workshop for the Northern Zone of the Latin American Association of Societies of Biology and Nuclear Medicine, Mexico. Marcial, V.A., 1976. "Carcinoma of the Esophagus; Management of Tumors of the Female Pelvis; Radiation Hepatitis" was presented at the Midwinter Radiology Conference, Los Angeles. 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 Annual Meeting of Argentine College of Radiotherapists, Buenos Aires, Marcial, V.A., 1975. Current Policies on Cancer Education of the National Cancer Institute. Presented at Meeting of Society of Chairmen of Academic Radiation Oncology Programs, San Francisco. Marcial, V. A., 1975. Irradiation Treatment of Cancer of the Tongue; Treatment of Ganglionic Metastases in Head and Neck Cancer (in Spanish). Presented at Annual Meeting of Argentine Society of Pathology of Head

and Neck, Buenos Aires. Marcial, V. A., 1976. Management of Invasive Carcinoma of the Cervix. Presented at American Cancer Society, National Conference on Radiation Oncology, San Francisco. Montgomery, I. R., 1975. Leaching of Heavy Metals From Secondary Treated Sewage Sludge by Sea Water and Possible Pathways in a Tropical Marine Ecosystem. Presented at International Conference on Heavy Metals in the Environment, Toronto. Rios Olivares, E. and Colon, J. I., 1975. The Effect of Gamma Radiation and Actinomycin D on the Multiplication of Sindbis virus. Presented by (E.R.O.) at Annual Meeting of Tissue Culture Association, Montreal.

25. Sasscer, O. S. and Andrew, C., 1976. Environmental Monitoring of Argon-41. Presented by (D.S.S.) at 5th Midyear Topical Symposium on Operational Health Physics, Denver. 26. Singh, R. S., 1976. Study of Structural Phase Transition in Crystals Using Light Scattering Techniques. Presented at American Association of Physics Professors Meeting, Ponce, P.R. 27. Vazquez, F. and Gonzalo, J. A., 1975. Brillouin Scattering of OTGS at Room and Through the Transition Temperature. Presented by (F.V.) at International Conference on Low Lying Lattice Vibrational Modes and Their Relationship to Superconductivity and Ferroelectricity, San Juan, P.R. 28. Waters, K. W., 1976. Commercialization of Raft Oyster Culture in Puerto Rico. Presented at 1st National 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: "7% Te 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 Pabén: "Xerography" (October 28, 1975). Dr. Raymond Seeger, Director, Sigma Xi Bicentennial Lectures: "The Scientist’s Responsibility to Society" (November 7, 1975). Dr. Gratton D. Chase: "Theoretical Versus Empirical Approaches to RIA Data Reduction" (November 24, 1978). Ms. Cecilia Ramivea: (November 4, 1975). Mr. Michael A. Gribble: "Somatic Effects of Whole-Body" (November 11, 1978). Mr. Karl L. Prado: "A Revision of Dosimetric Properties of LiF and CaF, 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 Bitharzia" (May 27, 1976). 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. 4.8. Cohen, Northwestern University: "Diffuse Scattering" (March 1976). Dr. Michael Butler, Sandia Corporation: "H2 Production by Photoelectrolysis of H2O" (June 11, 1976).

Table 1: Enrollment in PRNC Training and Education Program from July 1, 1975 to June 30, 1976. "Tene Rene, Ph.D., Ecology. "Thovt Rem, MS Degree, Sandy Thesis Research MS, Oncology, Forest. 'Soc Training. Ave Eee 'hein Research.

P.O. Daye, say "These Reach MS. Ong, B00 pact Trang. There Can 'These Reach, P.O. Dept. site! 200108) 'Tacs Reach PD. en, Meracion 'Theo Reach MS. Oegee abi 'ee Reach Ms. Bopee Bosra 'ress Reseweh MS. Cee, Atom Seca! Trig tamer Eetoy 'hess Remweh MD, Beton Tras uch, MS. Door, Aono Spa! Tansg PantPysciony Crane Cour, Tropico Sen, 'Then Reson eS De, vse, 'Thos Rewer, Omrsry 'Tha ae, MS ge, Ec. Engg Spec! Tang Mawr Soanat Creo Cove Mane Scores rade Cours, MS Doge, We Ergerng 'Sorc Trang, utr Enprng Baie Rul Mcne Sea! Tang Nace ene 'acme Corn Re Maine Feworan 308 Program Raton They Rey Sproat Tronng. Hanon They Spell Tring Wen Pen 'Simmer Tag AL. Ong, Palos! ah 'on 2 ear yo.

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 the 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 fa 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-1988 through FY-1976 listed by country of origin is presented in Table 4.

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 $9,560 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. (The subsequent text appears to be names and titles that are partly illegible and would require more context or source material to correct.)

(The subsequent text appears to be names and titles that are partly illegible and would require more context or source material to correct.)

"Getting Saved (One at a Time) - A Lot of People Are Going Straight to the City of Rest Now. It Seems Reconciliation is Fast Coming. Self-Autonomy is Our Present. Bear in mind to Be Calm. 2 + 0. Senior Deferral Range 0% - 20%.

Table 3: Geographical Distribution of PRNC Students, FY 1970 through FY 1976. Geographical era 1970s, there are North American Zones 7B, 2, 8, 8. Content (084) is 5.

Table 4: PRNC Students by Country — FY 1958-FY 1976. When now 20, 2, 2, 7, 6, 4, 7, 5, 5, 2, 4, 28, 6, 3, 3, 1, 2, 1, 1, 23, 2, 2, 1, 8, 8, 2, 2, 2, 4, 8.

Cases A. Sousa Argentina. Act Two, Nine Nine August, 1978 — November 30, 1978. Actor Fowler re MS. Oe, Apiculture. August 1975 — November 30. Ang Lancnote Pte Rin Sas Capes Sat Ferraro Norge Guat MS Ong, Pr, Tse Rech Anges Sucre Sale —— Rasoorope Techie, UC end Intricacy and 2.

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 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 Land."

The Training Program Workshop was 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 main objectives of the Radiation Oncology Division have been to operate an academic training program and conduct research on radiation therapy for cancer. Since fiscal year 1975, in response to a directive from ERDA, there has been an increased focus on research. The research activities have been complemented by the training program, aimed at producing radiation oncologists, offering 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 current radiation therapy modalities for cancer.

As in previous years, the division has operated as the Radiation Oncology Program of the Department of Radiological Sciences at the University of Puerto Rico School of Medicine. It has provided radiation oncology support to patients at the University Hospital and to academic programs at the University of Puerto Rico Medical Sciences Campus. The patients have, in turn, provided the clinical basis for the educational and research projects of the division. Funding has been primarily sourced from PRNC (approximately 40%) and from National Cancer Institute grants channeled through the School of Medicine (approximately 60%).

Special inter-institutional relationships with the San Juan Veterans Administration Hospital and the Metropolitan Hospital in San Juan have allowed for the 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 shift in the center's mission from multidisciplinary to energy-oriented, coupled with a gradual budget reduction, has been accentuated by... [text cut off]

Inflation, along with the scheduled elimination of National Cancer Institute training grants on June 30, 1976, have handicapped the programs, introducing considerable uncertainty and instability. This has resulted in a reduction of personnel, affecting both the training and 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, enrolling 32 patients. These patients were analyzed based on sex, age, survival after treatment, and symptomatic and radiological appraisal of tumor progression with and without carbogen (5% CO, + 95% oxygen) breathing. The results will be published.

B. Staff — Intramural Projects

1. Floor of the mouth project: This ongoing project is gradually incorporating follow-up information on approximately 200 patients who have been treated by the staff of the Radiation Oncology Division. The material is pending analysis of factors that affect the survival of these patients.

2. Effect of therapeutic radiation of the lung studied by pulmonary function tests and lung scan techniques: This project is continuing at a slower pace due to lack of funding. Additional follow-up information on previously registered patients is gradually being incorporated.

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

4. Radiation-induced tumor regression in a mouse chondrosarcoma: This project is being conducted 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 the resumption of work is anticipated as soon as the Comprehensive Cancer Center of the P.R. School of Medicine recruits the services of a radiobiologist.

One project focuses on radiation-induced liver damage. Conducted in collaboration with the Surgical Research Laboratory of the School of Medicine, the Nuclear Medicine Division of the CConter, and a private veterinarian (Dr. Carlos Gémez), the aim is to determine the factors involved in radiation damage to the liver. Dogs are subjected to varying levels of liver irradiation, ranging from 3000 rads in 3 weeks to 4000 rads in 4 weeks. Prior to irradiation, liver biopsies, liver scans, and chemical blood studies are performed. These tests are repeated after irradiation to assess the extent of liver damage. The information gathered should aid in preventing radiation hepatitis in humans. A paper on this topic was presented at an IAEA meeting and is set to be published in the proceedings.

Extramural Projects include the Carbogen Study. As of June 1976, a total of 320 cases were registered, mostly from this Division, and the accession of new cases was halted. The preliminary impression suggests that breathing carbogen (5% CO_2 + 95% oxygen) during radiotherapy does not enhance the survival of patients with cancer of the head, neck, and esophagus. Analysis of the results is expected to be completed during the fiscal year 1976-77.

The project on Treatment of Brain Metastases aims to determine optimal methods of treating brain metastases with radiation. Patient accession was interrupted as of June 1976, and the results are currently being analyzed.

The project on Treatment of Brain Gliomas seeks to determine the best methods of treating brain gliomas. Various radiation dose levels are being tested, along with a combination of chemotherapy (BCNU). In June 1976, over 100 cases had been registered.

The objective of the Medulloblastoma project is to compare survival rates of medulloblastoma

patients treated by craniospinal 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 the fiscal year 1975-76.

B. Medical Students' Projects

Bone scan in sarcoma of the prostate — Néstor C. Tirade

Lymph node metastases in carcinoma of the breast — Maria C. Cardona.

Carcinoma of the endometrium, stage II — Noel Tott.

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 Activities of the Radiation Oncology Division, July 1975 to June 1976.

Name Dates Present Position

A. Radiation Oncology Resident

Dr. Jorge A. Moscol, 1975-1976, 2nd year resident

B. Training Course for Medical Students

Lis A. Almodévar, June-July 1975, Internship

Marta M. Cardona

Antonio G. Sotomayor

Néstor C. Tirado

Noel Tott

Francisco J. Vizearrondo

Carmen D. Zorila, 4th-year medical student

Maria E. Vélez, Internship

Nayda Figueroa

C. Short-Term Radiotherapy Course

Dr. Guillermo Guerrea, Oct 1975 - Mar 1976, Returned to Colombia

Dr. Arturo Yadrach, Feb 1976 - Apr 1976, Comprehensive Cancer Center

MEDICAL SERVICES

In the fiscal year 1975-76, service was

The text has been revised as follows:

Radiation therapy continued at the University Hospital for patients who required it. This was necessary to provide a foundation for teaching 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 1.5 hours twice a week, to decide on 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 attended the Annual Meeting of the Puerto Rico Medical Association in Nov. 1975, San Juan, and the 3rd Annual Cancer Course for Physicians, P.R Division of American Cancer Society, in Jan. 1976, San Juan.

Dr. Jeanne Ubifis attended the Annual Meeting of the Puerto Rico Medical Association in Nov. 1975, San Juan, and the 3rd Annual Cancer Course for Physicians, P.R Division of American Cancer Society, in Jan. 1976, San Juan.

Dr. Juan Reusche attended the Semi-Annual Meeting of the Radiation Therapy Oncology Group in San Diego, CA, in Jan. 1976, and the 3rd Annual Cancer Course for Physicians, P.R Division of American Cancer Society, in Jan. 1976, San Juan.

Dr. Victor A. Marcial attended several meetings and conferences, including the Cancer Education Committee Meeting at the National Cancer Institute in Jan. and June 1976, Bethesda, MD, Midwinter Radiological Conference in Jan. 1976, Los Angeles, and the 2nd Plenary Meeting of the

Scientific Program Committee 12th International Cancer Congress in May 1976, Toronto, among others.

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, 1976, to June 30, 1976.

Site of Cases:
Buccal Cavity and Pharynx,
Bone,
Connective and Soft Tissue,
Skin.

Number of Cases:
Base of tongue - 6,
Bone - 2,
Anterior two-thirds of tongue - 1,
Parotid gland - 2,
Salivary gland - 1.

Dermatofibrosarcoma 1. Submaxillary gland 1. Skin Py Lower grade 2. Breast: Floor of mouth 9. Rectal cancer 3. Palate 2. Retromolar 4. Uvula 1.5. Oropharynx 3.2. Tonsil 1. Tonsilar fossa 9. Faucial arch 6. Kidney 1. Neuroblastoma: Wilms tumor 1. Hypopharynx 6. Other and Unspecified Sites: Pyrite sinus 4. Pharyngeal wall 1. Brain 6. Neuroblastoma 3. Digestive Organs and Peritoneum: Esophagus 2. Meningioma 1. Stomach 2. Malignant paraganglioma 1. Rectum. Thyroid 2. Pancreas 4. Pituitary gland. Primary unknown 3. Lymphatic and Hematopoietic System 7.5. Reticulum cell sarcoma 3. Larynx 1. Lymphosarcoma 1. Vocal cords 8. Hodgkin's disease 2. Lungs 2. Eosinophil granuloma 1. Malignant lymphoma 8. Multiple myeloma 4. Leukemia 8. Total New Cases 956. Radiotherapy Applications (Co), Mev. XI Superficial 17045. Follow-up 11964. Curitherapy Applications 26.

Table 1: Nuclear Medicine Division Training Activities, July 1975 to June 1976. Institutions given in parentheses are sponsors. From June 30, 1975, to February 3, 1976, various training activities were conducted at different institutions.

BASIC NUCLEAR MEDICINE COURSE: October 31, 1975 to December 30, 1976. Instructors from Argentina (RNC), Colombia (FNC), and Puerto Rico (PRN) were present.

HUMAN BIOLOGY: Focused on Endocrinology.

NUCLEAR MEDICINE: The Nuclear Medicine Division conducts clinical research in nuclear medicine and offers training in the medical applications of radioisotopes for physicians and medical professionals.

Technicians principally from Puerto Rico (USA) and Latin America provide diagnostic and therapeutic services for patients from the University Hospital. This is done to ensure an adequate patient load for research and training.

Research activities include:

A. Completed Work:

1. Vitamin Absorption in Pregnancy Followed Via Whole-Body Counter by A. E. Lanaro and J. J. Corcino. The data has been analyzed and a paper is in preparation. (See PRNC-198, p.50)

2. Use of Te-DMSA for the Diagnosis of Myocardial Infarction by A. H. Sarmiento, A.E. Lanaro, and A. Suarez. The results have been written up and submitted for publication. (See PRNC-198, p.50)

3. Evaluation of Liver Detoxification with C Phenobarbital by A. Rodriguez Olleros, R. Dietrich, E. Taveras, and A. E. Lanaro. The data has been analyzed and a paper has been submitted for publication. (See PRNC-198, p.50)

B. Work in Progress:

1. Use and Usefulness of Ga in Tumor Localization by E. Vélez Garcia and A. E. Lanaro. Data were collected on approximately 160 patients with different malignant and inflammatory diseases. Evaluation of the data is now in progress. (See PRNG-198, p.50)

2. Effects of External Irradiation on the Normal Thyroid and Pituitary Gland by A. E. Lanero. 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 restrictions, and no conclusions have been reached. (See PRNC-198, p51)

3. Effects of External Irradiation on the Normal Lung by A. E. Lanaro. This study is an extension of work begun with special funds from the AEC program RX O103. Follow-up with perfusion scans is being done on patients seen during 1973-74 in order to determine late effects on lung tissue.

4. Follow-up on Hyperthyroid Patients Treated With Iodine-131 by A. E. Lanaro. Hyperthyroid patients treated at PRNC were again asked to come in for an annual check-up. Of the 104 patients given

Clinical examinations and thyroid uptake tests revealed 61 individuals were euthyroid, 34 were hypothyroid, and 9 were hyperthyroid. Refer to PRNC-198, p. 51 33.

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

Radiation Injury to the Liver by E. Santiago Delpin, V. Marcial, and A. E. Lanaro. A group of dogs

was tested with sulfocolloid "Te and Rose Bengal "I liver scans, "Te kidney scans, and Rose Bengal "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. Refer to PRNC-198, p.50.

Biological and Effective Half-Life of Radionuclides in Children by A. E. Lanaro and A. Sifontes. A protocol was prepared and presented to the National Institutes of Health. The study includes the determination of biological and effective half-lives of different radionuclides in children undergoing routine nuclear medicine tests in the Division to establish any relationship 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 by 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 time.

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 Te sulfocolloid scans in the Anger camera. Digoxin Levels in Patients Submitted to Closed Cardiovascular Surgery by A. Martinez Picd, J. Sinchez, A. E. Lanaro, and J. M. Caamafo. 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 after surgery. The effects of such surgery on digoxin levels and 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, 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 from July 1975 to June 1976 include Thyroid studies, Absorption studies, Hematology studies, Circulation studies, Total body water, Liver studies, Organ and tumor localization, and Camera studies. Staff Activities. A. Attendance at Scientific Meetings. Dr. A. E. Lanaro attended the First Regional Workshop of the North Area of the Latin American Association of Societies of Biology and Nuclear Medicine in August 1975, in Mexico.

"Second Latin American Regional Meeting of Nuclear Biology and Medicine, Caxias do Sul, Brazil, September 1975; Seminar on Endocrinology, Children’s Hospital, Buenos Aires, October 1975; Lectures on Nuclear Medicine at VA Hospital and at P.R. Society of Nuclear Medicine, December 1975; Lectures on Ultrasound at VA Hospital, February 1976; Symposium on the Thyroid (Bayamon Committee of Continuing Medical Education and Hospital Meléndez Inc.), San Juan, February 1976; Lectures on Immunobiology at Medical Sciences Campus and at P.R. Medical

Association, February 1976; P.R. Society of Nuclear Medicine Annual Convention, San Juan, May 1976; Planning Committee of Second Congress of World Federation of Biology and Nuclear Medicine (attended as representative of Latin American Association of Societies of Biology and Nuclear Medicine), Dallas, June 1976; 23rd Annual Meeting of Society of Nuclear Medicine, Dallas, June 1976. A.H. Sarmiento — Lectures on Ultrasound at VA Hospital, February 1976.

8. Changes in Staff Appointment: Mr. Vietor Serrano, Nuclear Medicine Technician, February 5, 1976. Resignations: Mrs. Aida Avila de Medina, Nuclear Medicine Technician, January 16, 1976; Dr. Aristides H. Sarmiento, Senior Scientist 1, 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 mainly concerned with solving physical problems and developing 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: 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. Gomez 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 B-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. 1976.

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 Garzén-Quiréz, 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. The 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 of experience, from the Poole General Hospital in England, joined the staff of the Medical Physics Section in August 1975. Mr. Gribble has a 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 provides 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, the Division focuses on international education and training in the Caribbean and research activities.

One such research activity is the Hydroelectric Reservoir Project, led by M. Bhajan, A. 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 those impacts. The ecology of existing hydroelectric reservoirs in Puerto Rico is being studied to determine the factors that cause or prevent health problems related to them. The major health problem being investigated is schistosomiasis. Methods are being developed to predict the extent of disease transmission from new reservoirs that are being designed but not yet constructed. Alternative designs and other preventive or control measures are being studied.

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

Lake Carite was found to have very low algal productivity (0.7 mg/liter per day). Despite its turbidity, the lake 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. Biomphalara 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 significant 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 Water General Non Name Bet Me Te Pa Ph Ly Te Hyacinth Vegetation

1 Adjuntas = x - Sparse

2 Caonilies = : Sparse

3 Carite x x : Sparse

4 Carraizo x x x Abundant

5 : 6 = x x

7 x

8 a on ox x

9 Comerio #2 = XX x

10 Dos Bocas XXX x

11 Moca XXX x

12 Guajateca = XX

13 Guayabal = XOX

14 Cuyo =X

15 Guinmo = > Xx x x

16 Jordan > x

17 Plata > x x x Moderate

18 las Curias = Xx . Sparse

19 Yeco > x x

20 Lucchetti = xx x

21 Matrullas = x - Sparse

22 Patillas = x x 2 Sparse

23 Pellejas =

24 Prieto =x : Sparse

25 Rio Blanco =

26 Toa Vaca x x Sparse

27 Toro

28 Tortuguero XOX x

29 Vivi - x

30 Yahuecas >

Bet = Biomphalaria glabrata

Me= Marisa cornuartetis

Te= Tarebia granifera

Pa= Pomacea australis

Ph= Physa sp.

Ly= Lymnaea sp.

Te= 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, 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 supports reports suggesting that the water hyacinth is very efficient in removing nutrients from the water. Cidra Lake has more chlorides than most other lakes, suggesting that chlorides may serve as an indicator of contamination. Iron samples taken from lakes early in the year were very low, but in samples taken from other lakes during the winter, they were much higher; this may reflect the overturn of previous methods.

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 vacuum be used for the filtration. 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 rather consistent at 25%.

The results of using sentinel snails for detecting schistosome miracidia were compared with the results of coliform bacteria sampling in the Carraizo Reservoir and its tributaries on two occasions, and in Carite and Cidra Lakes. Twelve stations on Carraizo Lake were found to have high coliform levels (10^6 to 10^8 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 a 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 Reservoir

Whenever feasible, biological control methods are highly desirable because they are generally inexpensive and environmentally safe. This is especially true for schistosomiasis control in Puerto Rico’s hydroelectric reservoirs, as many of them are also used 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

(No. of Historical samples: 383)

HE samples: 10.142.0 0.0940.08 0.0440.01 0.0440.03, 99 a 1841.0 10:6 6.14.7 7

From 25 samples,

Lajas Valley irrigation and hydroelectric power system. 43

The 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, thus decreasing the probability of successful snail infections. Four snail species, Maria, 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. Negrén and C. M. Nai)

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 Puerto Rico is in the tropics, a subject of special concern is the relationship of tropical diseases to hydroelectric impoundments, which are common in Latin America."

Africa has 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. These also merit attention. The purpose of this project is to develop epidemiological models that can be used to predict 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 Três 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 with 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. 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 more than 18,000 children using the same procedure used in the surveys of 1963 and 1969.

The provided reference data indicates that in the eastern region of Puerto Rico where bilharzia is endemic, a serious increase was found.

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

Original Control Programs 1954-1976:
- Aibonito: 40 / 443 / 90
- Arroyo: 27 / 236 / n/a
- Guayama: 31 / n/a / 141
- Naguabo: 63 / 281 / 262
- Patillas: n/a / 444 / 95
- Vieques: 30 / 156 / 193

Total: 293 / 2168 / 135

New Control Programs 1969-1976:
- Gurabo: 33 / 327 / 10.1
- Humacao: 228 / 730 / 32
- Juncos: 120 / 464 / 259
- Las Piedras: 125 / 390 / 324
- Maunabo: 35 / 258 / 97
- Salinas: 3 / 426 / 10.1
- Yabucoa: 214 / 708 / 302
Total: 798 / 3303 / 242

Areas Not Controlled (Samples):
- Aguas: n/a
- Canóvanas: 124 / 453 / 477 / 187 / 50.1
- Rio Grande: Total 372
- San Lorenzo: 68
- Trujillo Alto: 253
Weighted mean: 28.1

In municipalities directly downstream and east of Lake Carraizo (Canóvanas, Carolina, Rio Grande, and Luquillo), 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).

The Schistosomiasis Control Project, led by W. Jobin, F. Liard, and M. Bhajan, and 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). The project was completed in 12 months. The conclusions reached after review and analysis of 41 projects on schistosomiasis are as follows...

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. Annual costs per 100 cubic meters of treated habitat are approximately $20 in natural drainage systems and around $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

approximately $10 per capita per year.

5. Of six major control projects, only one encountered a problem in meeting its 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 a prevalence of less than 1% in any nation, would cost about $3 billion. The major costs being $1 billion each for Brazil and Egypt, and would take approximately 20 years. (See Table 5.)

8. Because of international market considerations, it is doubtful that cheaper drugs or 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.

Human contact with infected water can lead to disease. The methods to prevent this involve costs that are generally outside the international market structure. These methods depend primarily on local materials and unskilled labor. The areas where control operations are most cost-effective 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.

Air Pollution Project (J. M. Chiriboga and V. A. Lopez): This project is concerned with the effect of pollution due to the 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 Espiritu 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.

The text was 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 (refer to Table 7). 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," by José Luis Tortes (for M.S. in Anatomy under Dr. J. Chiriboga), studies the alteration of normal Fasciola hepatica metacercariae as a function of storage time at 4°C, showing a significant decrease only after 100 days. The in vitro viability of normal metacercariae compared with 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 15th day by doses of 3.5 and 6.0 kR.

Rats were used to study the 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, a phenomenon tentatively associated with the developing worms' inability to find the liver ducts. Metacercariae irradiated with 2.5 and 5.0 kR only produced a slight elevation of SGPT. There was a good correlation between SGPT level and macroscopic and microscopic liver lesions in rats infected with unirradiated and irradiated worms.

Adult F. hepatica incubated in Hedenhain's solution for 6 hours release many types of proteins, some of which are neoformed judging by the incorporation of Se-methionine. These proteins were purified by Sephadex G-100 and gel electrophoresis. The Sephadex elution curve had two peaks, A and B.

Precipitates specifically with Fasciola 51.

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

Asthma	98%
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	Percentage of Micronuclei
Control	0.2%
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 18Jun75 - 20Apr75
Schistosomiasis, 15 Inspectors, Health Dept. 1Sep75 - 5Sep75
Michael G. Ubrin (PA) 10Jul75 - 30Aug75
Angel Laracuente 1Jul75 - 30Jun76
Hydroelectric Reservoirs Martha Caballero (Peru) 1Jul75 - 31Dec75
4 Students, UPR-Cayey 1Jul75 - 31Jan76
Ada L. Irizarry 1Jun76 - 30Apr76
Luz E. Torres 1Jun76 - 30Apr76
Amarilis Silva 1Jun76 - 30Apr76
Parasitology Vin Cartion 1Jul75 - 30Jun76
Fossil Fuel Ana L. Rodriguez 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 less than 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-kFitradiated 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 parasites increases with 1.5 and 2.5 KR irradiation, but slightly decreases with 5.0 KR irradiation.

Flukes are not significantly affected by radiation doses as high as 6.0 KR. Genetic Analysis of Microsporum Gypseum Complex at the Molecular Level by José A. Carrasco (for Ph.D. in Microbiology, under Dr. J. Colén). A new procedure for the isolation and purification of fungal DNA yields a highly purified and polymerized product. During the development of the procedure, 2 protamine-like proteins of nonhistone chromosomal protein were 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 dls/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 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 by Nitza Magali Divila (for M.S. in Microbiology, under Dr. J. Colén). 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 was managed by changing the medium every two to three days. Chronically infected L-cell monolayers were treated by adding 220 units of interferon per ml to the system. 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 PR8. 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 similarly to previously uninfected cells. A review of the literature on interferons and their importance in persistent infections is included.

Interferon Production in Viral Mutated L-cells by Mercedes Rodriguez (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 protein substance 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 by Eddy O. Rios-Ortivares (for Ph.D. in Microbiology).

The research under Dr. J. Colén focused on the effects of gamma radiation and actinomycin D on Sindbis virus reproduction in chick embryo fibroblast monolayers. Radiation doses of 1,000 rads or more than 25,000 rads, administered 1 hour before infection, significantly inhibited viral reproduction. In contrast, a dose of 10,000 rads significantly stimulated it. The post-radiation increase was more pronounced when a complex medium was used instead of one deficient in amino acids. The number of cells forming the monolayer and the multiplicity of infection had no impact on the enhancement of virus growth.

Treatment of monolayers with 2 ug/ml actinomycin D, 2 hours before virus infection, also stimulated viral production during the early stages of the growth cycle. Normal cells treated with actinomycin D

showed a 98% reduction in uridine incorporation, while radiation (10,000 rads) slightly inhibited it. During the first 6 hours of infection, cells treated with 10,000 rads showed an increase in uridine and those treated with actinomycin D showed a significant decrease.

Although not at the same rate, both 10,000 rads and actinomycin D decreased normal cellular DNA synthesis and consequently protein synthesis. These results suggest that both agents may act by inhibiting a cellular constituent, possibly a protein similar to interferon, which regulates viral synthesis. The results indicate that changes in the capacity of chick embryo monolayers to support Sindbis virus growth after exposure 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 likely 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 mechanism.

Protein creates the antiviral refractory state in the cell. The production of this protein is terminated when sufficient protein has been transcribed. This process is stopped by a blocking protein coded by the 18th gene, which could act as a super repressor or interferon gene repressor or at the level of the translation of the interferon gene mRNA.

Proteolytic Enzymes in F. hepatica is a study by Genaro Ortiz, who is pursuing a Ph.D. in Biochemistry under Dr. Chiriboga. Another study titled Biological Methods for Testing Environmental Hazards is being conducted by Lette Ramos, who is pursuing an M.S. in Biochemistry under Dr. J. Chirbowsky.

A Jon-boat is being loaded for photosynthesis studies in hydroelectric reservoirs at Lake Dos Bocas in the Arecibo River below Utuado.

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

Marine Pollution Studies is a research project in the field of Marine Ecology. The purpose of this study 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.

The energy complex, which includes an oil refinery, two fossil-fuel power plants, 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, carrying pollutants.

Through Tallaboa Bay into Guayanilla Bay and then out to sea, the flow of water occurs. 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; however, 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 due to 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 temperature 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 from both the canal and the 1100-MW fossil-fuel plant. Additional measurements were made during fish and benthic sampling.

The text appears to be a scientific report with several errors in punctuation, capitalization, and formatting. Here's the corrected version:

Periods. Because the power plant discharge was 7.

Table 2: Percentage Breakdown of Monthly Zooplankton Counts at Guayanilla Power Station. SSR, ees, me, Tos in TC, TG, TS, Octet, B 2, OS, & © & MN, OR, TE, SG, Crome, Ome, 8, OW, Svapenion, Copa, Sti, Leeton, PPC, Ceca, ECM, ESE, Stroanton, TNE, Ana, Ripe, Sep, ARNT, ER, Ened, EPS, THE, Terreno, VEE, Buchen, NPG, OD, IY.

Table 3: Total Standing Crop Values of Thala Testudinum, 1976. Station Date Crop: Guayanilia ? an zis 1 an aso Tome ane aat09 Jobos x wm 6183 a a8 rso:61.

It was 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 the shutdown of one 440-MW unit from June 13 until about July 6, 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 delta T of -2°C with a delta R 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 Tallabos Bays, and that delta T 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 1) flowing southwest along Pta. Gua and having a delta T that varies from 1.4° to 7.2°C with most values at 6°C. At night and in...

During winter, weak winds from North to Northeast allow the warm effluent to spread into the zone between points H and Z. However, in the daytime, strong winds from East to Southeast compress it, causing it to remain within approximately 100 m of the shoreline. At point H, in the daytime, the temperature (AT) is approximately 1°C. Closer to the shore, at point G, the temperature (A7) is higher, ranging from 1.5° to 2.0°C. A transect from point H to the shore shows an increase from 29.3°C (with a standard deviation of 1°C) to 32.5°C within about 25 m from the beach. Simultaneously, the temperature at point G is 30.5°C. This warm water circulates around Pia Guayanilla, with Site M being 0.5° to 1.0°C above the ambient temperature in Tallaboa Bay. It transports hydrocarbons from the canal and possibly heavy metals and other pollutants.

The Plankton Project in Guayanilla Bay was conducted from 1975 to 1976 by Mary Nutt, Hilda Rojas, and J. Suarez Caabro. This research continued the work on thermal tolerance of plankton started by Youngbluth (PRNC-179, 'bs125). The species Acartia sp. was chosen for the study as 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. It is still unclear whether the Acartia sp. population in the cove is tolerant to thermal stress or a separate population of Acartia sp. is adapting to the thermal conditions in the cove. The population of Acartia sp. collected in the winter (30° to 34°C) could not survive in vitro at 37°C and above, while the summer population (exposed to at least 37°C in the cove) could survive in vitro at 38°C for 2 hours and at 41°C for 10 minutes.

Monthly sampling of the plankton population in Guayanilla Bay, initiated by Youngbluth (PRNC—1796), was continued. Table 2 presents the results for the thermal cove and intake. Monthly sampling was also conducted 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, particularly 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 Guayanila(B) stations.

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

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*), 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.

The levels of 'Thalassia' in Guayarilla Bay have shown various effects. The two beds exposed to thermal effluents do not form sexual reproductive bodies, and the two at ambient temperature are practically inhibited from the formation of buds, flowers, or seeds. This is probably due to some type of pollution other than thermal.

In contrast, 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 also prolific (refer to Table 4).

Both the leaves and the rhizomes of 'Thalassia' exposed to effluents are thinner than those of undisturbed 'Thalassia' (refer to 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 exposed).

Reductions have also been seen 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 formerly forming part of a 'Thalassia' faunal composition have been killed, only recent fossils remaining.

Temperature, visibility, 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 Check No. %

Laguite ME coast 5/22/76 “0 10

P. Las Marine N coast 8/22/76 50 °

P. Arenas West coast 5/27/76 “6 15

Las Croabas (migéle) E Coast 5/23/78 50 2 . 2

Jobos Bay

The growth of mangrove seedlings has been studied and reported (PRNC-198, p.92). Current research shows a survival rate from seedling to small tree of 54% after two years for 100 seedlings put in a 4x4-ft net cage with a 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±6.9 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 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 1D 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)

The text has been fixed as follows:

At sites D and 3A, seedlings placed in mud substrate on September 12 showed little further growth, although many formed roots. By December at Site D and by February at Site 3A, all the seedlings were dead except 16 of the control seedlings at Site 3A, which grew rapidly and well starting in December. The results show that temperatures greater than 37°C, even for part of the day, are eventually lethal for seedlings. Temperatures 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, with 25 having 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 June 1, 1976 (Table 12).

Table 10: Water Temperature and Seedling Growth, June 12 to September 12, 1976 (Small roots; At Site)

The survival at Site D was higher than the previous year, perhaps because of lower temperatures.

Features in mid-June. During the period from 1 June to 20 July, most of the trees planted in December at Site D continued to grow established small trees if they were gradually acclimated. The loss of five trees at Site 3A was due to planting in water that covered them during part of every tide. The 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 many elements necessary for the growth of the trees. These metals can be toxic if present at high concentrations (e.g., 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 concentration in the sediments and on the presence of compounds such as sulfides or chelators in the pore water.

The absorption of trace metals from sewage sludge by mangrove 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 C4, 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 60 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 Guaynilla-Tallaboa area and from trees in...

"Trace metals such as Fe, Mn, Cu, Zn, Cd, Pb, and Ni have been analyzed in Baqueron Bay and Pra. Ostiones (Table 13). All sites have been sampled twice, however, the analyses are not yet complete. One unusual observation is the extremely high Mn values in the Guayanilla leaves, particularly in the leaves from apparently unstressed trees. The high Fe and Cu values in the heated Guayanilla leaves could be due to stress or a higher metals content in the sediment.

The 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) show a manganese concentration 3 to 4 times higher in the top as compared to the bottom, possibly due to photosynthetic processes in the growing shoot. Moreover, Mn content is significantly higher in seedlings from the three Guayanila sites than in those from other sites.

Iron content does not significantly differ in tops and bottoms and is lower in the seedlings from Pta. Ostiones and Tallabos, likely due to these locations having the lowest agricultural and/or industrial inputs. Copper content is similar in tops and bottoms, and is significantly higher in the seedlings from Guayanilla mangal, both inside and outside the thermal lagoon.

Zinc content is higher in tops than in bottoms of seedlings, except those from Tallaboa. It is lower in those from Tallaboa and Pta. Ostiones than in those from Boqueron and Guayanila.

Table 13: Trace Metals in Mangrove (ppm dry wt.), Mean + 8.0. of 10 Replicates (6 tops and 5 bottoms for seedlings)

Figure 4: Italic numbers represent foraminifers per sample; underlined numbers represent 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 that are 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 Ca (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.

Foraminifers of Guayanilla and Tallaboa Bays (George A. Seige) 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, an area 10 cm2 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 Mayaguez Bays. The length/width ratio of Fursenhoinea 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 cm2 and 1 or 2 cm deep, which were preserved in 30% ethyl alcohol and stained in the laboratory with Rose Bengal for about 8 hours and then washed in an 0.0625-mm-mesh sieve. The various species of living and dead foraminifera were 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 are released into the shallow waters (up to ~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. The water quality here 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.

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 (x F. pontoni), with living specimens occurring in silty clays containing visible amounts of oil; he found no specimen of Buliminelis 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, with a total of 59 species identified (see Table 14). The individuals in the samples were counted according to the major taxonomic units that occur in Tallaboa Bay: Foraminiferida, Gasteropods.

Table 14: Living Foraminifers in Tallaboa Bay

Amsobaculites cf, directus ae saisus
Ammonia catesbyana
Angulogerina angulosa
Astrononion sp.
Elphidium advenum

Fursenkoina complanata
Fursenkoina punctata
Globorotalia menardii
Globorotalia truncatulinoides
Quinqueloculina seminulum
Rotalina floridana
Seminulina subrotunda
Tritaxia tricarinata
Valvulineria complanata

"Sagrina cubana, Siihalenctte Signo, Topsis arenata, Spriitna densepunctata, Spirolocutina communis, Ianina advens, Ti quadri tops.

Figure 5: Specific diversity of fauna amber of PCI Sa TAL? {8 Number of eon St 00-8 Boece ovary nin TAL? 1 species ses MS Go-8.

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 6). 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 Mayaguer, 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 (Segle, Aguirre Power Project Environmental Studies 1971 Annual Report, pp. 54-7; Carib, J. Sch 14, No. 1-2, 168, 1974).

(3) The total number per sample is larger for foraminifera than for nematodes at four stations in a line N-S of the confluence, 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 Carioca (Seigle and Bermidez, Unio. Oriente Bol. Oceanogr. 2, No. 1, 1-88, 1961), all of which have upwelling waters and abundant."

Nutrients are found in large numbers in the lagoons of the Gulf Coast and in the Mississippi Delta (W. R. Walton, in Approaches to Paleoecology, pp. 161-237, Imbrie and Newell, ed., Wiley, 1964),

where nutrients are abundant. Since González found no B. elegantissima in Tallaboa Bay in 1968, its presence - and the large foraminiferal populations - are probably due to the increased nutrients from the CORCO outfall.

Fish Studies in Guayanilla Bay by Joseph J. Kimmel have been conducted over the past year 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 the condition of fishes in thermally stressed and unstressed zones.

3. Determine the spawning time of fishes in thermally stressed and unstressed areas.

4. Examine the food habits of fishes in and near thermally stressed areas.

5. Compare species diversity with that found in other studies.

6. Record the incidence of fish parasitism in fishing areas.

7. Determine thermal tolerances, including critical thermal maxima and preferred temperatures, of several species of fish.

8. Analyze fish muscle and viscera for heavy metal and possibly for hydrocarbon content.

9. Investigate the life history and ecology of Lupinoblennius dispar Herre, a fish collected from Guayanila that was not previously reported from Puerto Rico.

Fishing in Guayanilla Bay was initiated, with gillnet samples taken monthly in and near the thermal cove in the eastern sector of Guayanilla Bay (Figure 6). At each of the five stations, a bottom-rigged monofilament gill net, 40 X 2.5m with # 5-cm stretched mesh, was set for an average period of 2.2 hours. 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 16: Most Abundant Fishes in Gill Net Samples From Guayanilla Bay. (Upper number shows number; lower number shows weight in grams)

Family AUG SEP DEC

JAN, FEB, MAR, MAY, JUN, JUL, AUG, SEP, OCT, NOV, DEC - Page Break - 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 Avicenna 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 blue-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 mud 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°C to 30.4°C with a yearly mean of 36.3°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 Bay. They represent 21 families and 43 species. The most abundant are listed in Table 15. Five species of mojarras (Fam. Gerreidae) occur.

The Gerridae family and four species of jacks (Family: Carangidae) numerically represent 26.4% and 26.5% of the catch respectively. Among mojara, 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, Archotargus rhomboidalis), Elopidae (ladyfishes and tarpon), and Mugilidae (mullets) numerically represent 11.8%, 9.0%, 7.7%, and 6.5% of the total catch respectively. If the fishes are ranked by biomass, the order is Carangidae (26.7%), Geridae (21.3%), Elopidae (17.0%), Mugilidae (9.3%), Sciaenidae (7.1%), and Sparidae (5.2%). Although the gillnet 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 rhonchus from September to February, with much overlap in occurrence. Archosargus rhomboidalis, Family: 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) is calculated for each sampling trip at each station due to uncontrollable variables such as inclement weather, sickness, equipment failure, etc., which may cause the field sampling efforts in studies like these to vary from sample period to sample period.

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

The C/E values discussed below are in units of number of fish/hr. "E" is calculated as the Number or Weight of fishes sampled divided by the Number of gillnet sets times Average sampling time.

Exceptions to C/E values as biomass, 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 due to 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 the 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 the 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, the 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. SSE 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 area in large numbers but hesitate to venture into such areas for any 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 of 38°C exclude all fish.

"Diurnal-Nocturnal Differences: The C/E values at all five stations show diurnal-nocturnal differences (Table 16), with a greater abundance of fishes being captured at night than 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. These 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/he) for Each Station, From July 1975 to July 1976

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, two large office laboratories, and a sample preparation and study area. A dual pumping system supplies seawater to a 10,000-gallon tank from which the dual supply lines feed the various experimental areas. A system with titanium heat exchangers and control valves circulates 60°C seawater through the experimental area to various microcosms, 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 are planned."

On optimum growth temperatures, studies on the effects of temperature on reproductive cycles and on the survival of juveniles will be possible. Moreover, 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 CER. 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 on the Osmotic Behavior of Acanthophora spicifera by Hilda M. Rojas de Morales (for M.S, UPR Mayaguez, under Drs. T. R. Tosteson and L. R. Almodévar) — Acanthophore spicifera (Rhodophyceae) is a red alga associated with the roots of mangroves in shallow water along the southwest coast of Puerto Rico. 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 H20 for periods of 18 min to 18 hrs at a constant temperature (28°C) in the light and in the dark. The isotonic water content of A. spicifera was 10.886±0.3, 9 H20/g dry wt, which remained constant over 18 hrs of incubation and was independent of the light regime. During osmotic equilibration for up to 18 hrs, in both the light and dark, in tonicities of 700 to 1300 mOsmol/kg H20, the mean fraction of the total water that was osmotically responsive (43.11%) remained constant. The Cl- content of the alga remained constant through all periods of incubation in the light, and the estimated Cl- concentration (6756.8 µmole/g H20) in the algal water remained constant through 18 hrs of incubation in isotonic media in the light, as did the Na content and estimated concentration (20426.1 µmole/g H20). The K+ content of the alga increased with incubation time in the light and the estimated average K+

The concentration of algae in the water after 4 hours was 2721.9 micromole/g H20. This algae was found to have a higher Cl- and K+ and lower Nitrate concentration than seawater, with the Cl- and K+ contents of incubated algae being dependent on light but not the Nitrate content. On the basis of the Nitrate, Cl, and K+ contents, A. micifera appeared to be in a state of incipient plasmolysis. The data were consistent with the idea that this algae equilibrates automatically by gaining or losing water. The experimental conditions did not affect the algae’s subsequent viability.

Effect of Thermal Stress on Nitrogen Fixation in Guayanila Bay. Marilyn C. Kimball (for MS, 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 10 to 20 ng N/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 chthonoplastes, a non-heterocystous blue-green alga.

Rates of fixation were correlated with the development of the mat along a depth gradient. Mean monthly maximum rates ranged from 1893 microg N/m3/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.

The mean was 230 in July. The data collected up to August did not indicate a direct relationship between temperature and nitrogen fixation. Nitrogen-fixing microbial populations appeared to be selectively stimulated due to thermal tolerance and/or the elimination of less tolerant competitors. Synergistic effects with seasonal changes in light were also observed.

Oak Ridge Associated Universities conducted a study on 'The Effect of Thermal Stress on the Photosynthetic Potential of Mangrove Leaves.' The research was carried out by Luise Ferrara from the College of Mt. St. Vincent, New York for a summer project under M. D. Banus.

Another study on the 'Comparative Ecology of Seagrass Bed Communities' was conducted by William Allan Flynn from St. John’s University, Minnesota for a summer project under V. P. Vicente.

KINI ATOLL PROJECT (Ross J. Santiago, Fausto Mufioz-Ribadencira, M. Pérez-Padré, 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 Pu, Pu, and 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.

During this reporting period, the 44 sediment samples (coarse and fine fractions) collected during the October-November 1974 resurvey of Bikini Atoll and the C42 core from Bravo Crater were analyzed for plutonium content. Determination of Am, Eu, Sp, 19h, 7Cs, Bi, and Co in the sediment and core samples was carried out by gamma counting. A computer program for this was developed.

The calculation of gamma analysis results was developed. The ten water samples collected in the 1974 resurvey were analyzed for Pu and Am. The taxonomic classification of the 47 plankton samples collected at 38 different stations in the Bikini Lagoon was completed.

Research was completed on Plutonium Analysis of 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 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 and HCl; the residue was dissolved in 1 M HNO 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. The results are given in Tables 1 and 2.

Core Samples were analyzed as well. The bottom half of the core (C82) 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 was used to determine the contents of Am, Eu, Sb, Rh, Cs, Bi, and Co in the sediment and core samples. Homogenized and ground samples were placed in 125-ml, 2-inch-diameter 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 less than 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 in 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 provide reasonable statistics were chosen. The designated channels from the spectrum of each standard were processed by the CAUWA 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-absorption and geometry characteristics of the samples, the curves are in good agreement at energies, and provide some idea of the reproducibility of the system. Two points on the curve do not fit exactly: the Sb peak at 463.5 keV and the 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 Rh was not available, the counting efficiency was read from the graph 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 Rh) were supplied to the CAUWA program along with appropriate portions of the spectrum of each experimental sample. The program 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 were also conducted. The 10 water samples collected were also analyzed.

During the October-November 1974 resurvey of Bikini Atoll, analyses were conducted for Pu and Am content. About 20 liters of filtered water were collected at different stations (see Figure 1) and brought to PRNC. At PRNC, each sample was acidified and spiked with Pu and Am-3 to check the chemical yield. The transuranium elements were then 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 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 includes the analysis of fish samples for Pu, Pu**, and Am**. This is to obtain additional information needed for defining the mechanisms causing the difference between the uptake of Pu** and 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 in 1) Bikini Lagoon at present, 2) the plankton samples collected in 1972, 3) the 1974 water samples, and 4) the bottom sediments.

Analysis of the remaining sediment core samples from the Bravo, Tews, and Zuni Craters for radionuclides will continue.

Figure 1 shows a chart of Bikini Atoll, indicating the stations where samples were collected during October and November 1974. The top represents sediment, and the bottom represents seawater.

The subsequent pages contain various tables and figures, and end with the discussion on the transfer and dispersion of organic pollutants from an oil refinery through coastal waters. This forms the objective of the next segment of the research.

The purpose of this study is to determine the organic pollutant load in coastal waters and sediments, and to trace its pathways from an oil refinery-petrochemical complex into Guayarilla and Tallaboa Bays. Research by M. D. Banus and J. A. Castrillén examined the total hydrocarbon levels in the sediments and water over several sampling periods. This covered a wide grid in Guayarilla and Tallaboa (Sites A to R, Figure 1) using standard analytical methods.

For adequate precision, triplicate 2-liter water samples were required. Excellent precision was achieved with duplicate analyses on large surface (1-cm-deep) sediment samples. The sediment levels indicated accumulated hydrocarbons, while surface water concentrations showed real-time distributions influenced by wind and current action.

The survey data suggested two major sources of hydrocarbons: seepage from waste ponds through the mangroves into adjacent lagoon waters (Sites C and D), and drainage from the discharge canal at Tallaboa (Site 1). Next to the main cooling water canal in Tallaboa, a small parallel ditch appears heavily contaminated with hydrocarbons. The mixing zone between this ditch and the bay water was established as a new sampling site. This forms the basis 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 within a 2-hour period. Two separate benthic samples were collected for each new site, and duplicate sub-samples were analyzed for total hydrocarbons. The results are shown in Table 1.

Table 1: Total Hydrocarbons in Sediment and Water Samples

[Table content]

In the mangrove lagoon area, Site [needs specification] is in the seepage area.

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, with the lowest being 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 do not appear to be very important to the hydrocarbon movement. The water at these sites is only 1 to 2m deep, except for a deep narrow channel between J. It is well mixed between surface and bottom by the winds.

The grid based on the Tallaboa discharge canal clearly shows that the drainage ditch is a substantial source of hydrocarbons. However, 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 about 100 m from shore and site H is more than 300 m. Hydrocarbon levels in the sediment show that during the night 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 tracked 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 temperature increase of +1°, but Site G almost always has a temperature increase of +1.5° to 2°C.

In order to check the

The efficiency of the sediment extraction process was evaluated using sediments that had been previously analyzed in duplicate, which were then spiked with 60 mg of diesel oil and re-analyzed. The results, as shown in Table 2, indicate a mean recovery of 93% of the spike from three sediments with low hydrocarbon levels and three with moderate levels.

So far, the data collected is only for total hydrocarbons. Identification of specific compounds and determination of relative amounts has not been done due to a lack of equipment and personnel.

However, such information is necessary to directly relate the hydrocarbon levels in sediment to a specific source, such as petroleum. The issue is complicated by changes in hydrocarbons due to weathering and bacterial action. Hydrocarbons found in surface water are likely to be of lower molecular weight than those in sediment and belong to a different class.

Despite obvious surface oil spills on several occasions, sediment hydrocarbon levels near the loading and unloading docks (Sites N and R) were between 0.06 to 0.10%. Interestingly, this oil did not accumulate in downwind sediments; Sites O, P, and Q had levels of 0.05 to 0.07% by weight, based on samplings a month apart. Therefore, a thorough study of the compounds in both water and sediment, along with laboratory experiments on weathering and sediment interactions, will be necessary for understanding sediment burdens in relation to inputs.

N. Mil, p23, 4 km, NORTHERN BASIN
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 area a few kilometers offshore, west of Mayagüez. The primary effects...

The potential effects of resuspension of bottom sediments, which can be brought up into the water column during the construction phase, are being studied. Initiated in January 1976, the study is expected to last one year. The major aspects of the study are briefly described below:

1. Determination of Sediment: This aspect involves determining the amount of material that would potentially be disturbed by the construction. An initial approach will be to conduct a literature search. If this doesn't provide the necessary data, sub-bottom profiling will be considered.

2. Physical Properties of Sediment: The size distribution, shape of the particles, and if possible, their origin and mineral content will be determined. This will involve taking and analyzing cores as a function of depth into the sediment. Sediment surface samples will also be secured throughout the basin for analysis. A review of related literature will be carried out.

3. Benthos: The bottom-living organisms will be sampled across the basin for identification and population analysis. Literature will be searched for information on the effects of resuspending the sediment. The study may be extended to adjacent areas if necessary and time permits.

4. Trace Metals: Resuspension may lead to an increase in potentially toxic trace metals. Therefore, their concentrations in the sediment and water at specific locations will be determined.

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

6. Projected Trajectory: The probable path the resuspended sediment will take is projected based on 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, and the program schedule has been determined. A significant change in the program duration, which was reduced to one year, resulted in the restriction of work to the Northern Basin of the Platform (Figure 1). Two cruises have been made into the study area. The first cruise took place on March 25, 1976.

The text was made aboard the R/V Pelumbo (PRINCI), with the aim 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 US 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.

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 of less than 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.

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 (‰)

---Rest of the table content is not provided in the text---

My 121 EE EE 7

Table 2: Cabo Rojo Platform Benthos, April 1976

Station Number Station:

CEO i fam, Maldanidae
Uncen: pune NEL
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NEI Holophiobalone
NEI Halophite bailoni
Trigoniocardi santloram
Anyida lum dendriticum tom.
Orbinida (Polyeh) (am, Callander
1 Phacoides marictu
Chione mice, Polychaete piece
Unigene. ipenelids

5-1 Holophiebalons
Ascidiasyndneiensis tam, Potyonide fm, Didemnidae
SEN Halophita aionie tm
Acoetdae Nt
Balima euricincte mint
Polychaete Nat ta, Maldon tam.
Aphrodite Unigene, Polychaete
NAN unident. Polycacte piece

511 Holophit Batons
S11 Molgua occidentale
Nereis Wt
Polycora sponiaite (Chama forse
Syemon vcherst fam
Xanthine olicione Wt
Holictons WAN
Chasmocarcinuseplindrius
Halton Alpheus
Smleene Polychaete

04 Tein SW: Halophia ballon fom.
Amphiwridae m3
nian puneulid niger.
Polychaete

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, the 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.
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

Men were recruited from the town of Boqueron, to construct and operate 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 Rincén, 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, tied up, and repaired. It was put into Puerto Real Bay with 20 cultch plates on 8 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 64 and 48 oysters per plate for the two rafts.

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	$138.75
Raft 2	118	10	128	$96.00

Both rafts yielded a mean of 46 oysters/frame, and the stated selling price was $0.75 per dozen. The gross income is somewhat low because not all oysters were sold; some of those from the first

raft were taken for personal consumption, and approximately 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 $228.00. Eleven man-hours were needed for construction and another hour for assembly and emplacement. Maintenance is estimated to cost about $36.00 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 early March 1976, it was obvious that growth was very slow, few oysters being >15 mm 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 Rincon 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 on hand for the preparation of a pamphlet in English and Spanish. This pamphlet, written in layman's terms, describes how to build and operate an oyster raft. It includes lists of materials for the raft and cultch, and photographs and drawings of the various stages in construction and harvesting, etc. The pamphlet, scheduled for printing in August 1976, will be Volume VIII, No. 1, of the Agricultural and Fisheries Contribution of the Puerto Rico Department of Agriculture. It will be distributed by the PRDA Commercial Fisheries Laboratory.

Discussion

Oyster culture has been developed to a very limited commercial scale in Puerto Rico. A method has been developed, modified, tested, and tried by local fishermen which can 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 proven capable of producing oysters on a commercial scale. Other areas, like Puerto Real, show promise for obtaining spat, but the 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 are even more unpredictable. 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 worthwhile.

Also, there is no guarantee that the existing workforce can be persuaded 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 due to the high level of subsistence support available (primarily food stamps), which encourages part-time work.

The text corrected:

The 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 culture 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 workforce exists to carry on the 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 the 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.

TERRESTRIAL ECOLOGY

The main effort of the Terrestrial Ecology Division has been redirected to a comprehensive study of the Espirit Santo Drainage Basin located in northeastern Puerto Rico. The general objectives 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 database. At present, little is known about the inner workings of a complete, integrated system such as a drainage.

Basin: A literature survey of the main research areas outlined in PRNC-198 confirms that, although many individual ecologically-oriented studies have been carried out in a tropical environment, few if any provide the database required for environmental management. In light 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 project to enhance the interdisciplinary approach to clarifying the ecosystem dynamics in a tropical rainforest. 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 rainforest. To this end, the following studies were initiated during the report period: Upper Espiritu Santo Precipitation Distribution (B. Holben, J.A. Colén, M. Canals, F. Santos, and R.G. Clements). A storage rain-gauge 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...

Element Analysis of Precipitation (B. Holben, A. Block, R.G. Clements, F. Santos, J.A. Colén, 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 precipitation amounts. Samples are taken biweekly from each of the 20 storage rain gauges. They are analyzed by atomic absorption for Na+, K+, Ca++, and Mg++. No results will be available until after the storage rain-gauge study is finished in February 1977.

Temperature and Humidity Profiles Modeling in a Tabonuco-type Forest (B. Holben and F.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.

Both variables move in the same direction. The afternoon temperature maximum appears to occur slightly below the canopy crown. These results and other findings will be confirmed or refuted as the analysis continues.

Insolation Modeling (B. Holben and R.G. Clements): A computer model is being used to simulate the insolation characteristics of the Earth's surface. This model will provide a first approximation of the solar energy input in the Upper Espiritu Santo forest ecosystem. Solar energy is a principal component in ecosystem dynamics. As there is no data available for the Upper Espiritu Santo watershed, this model may reveal some interesting relationships with plant distribution and precipitation. The model simulates insolation on square cells of land in a grid, covering the entire watershed. Each cell represents the slope and orientation characteristic of a specific area and location of land. The model simulates insolation for land with 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 knowledge of the topographic characteristics of a portion of the Earth's surface. A 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 shows that variability for any given grid density is independent of changes.

In slope, the 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 measurements 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 time for completion, and the data obtained will be used in planning limnological research in the basin. The studies now underway, and the preliminary data obtained, are reported below.

Water Quality Parameters of the Rio Espiritu Santo River System by W. Bhajan, M. Canals, A. Colén, and R. G. Clements. In November 1976, a survey began 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, pH and temperature increase from higher to lower elevations, and dissolved oxygen decreases.

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 O2 values were 3.90 and 4.60 mg/liter, respectively.

The data on planktonic invertebrate larvae are presented in Table 2, along with preliminary results for decapod crustaceans, molluscs, and fish. The crustaceans Atya lanipes, Xiphocaris elongata, and Macrobrachium carcinus were observed in both fresh and estuarine waters. The upper altitudinal limit for the first two species was 780m, but M. carcinus was not specified.

"Not found above 623m. 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.)

Bioassay of Some Decapod Crustaceans for Salinity Tolerances. (W. Bhajan, M. Canals, J. Colén, and R. G. Clements). Very little is known about the ecology of the ten species of decapod crustaceans found in the Espiritu Santo River System. Chase and Hobbs, Bul. 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 juveniles of this species exhibit 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 the 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 done and data reduction, analyses, and reporting are expected to be completed soon.

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.

Theses include:

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

2. Biogeographic 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 species.

3. Influence of Land Use Changes on Water Quality (B. McCormick)
4. Economic Valuation of the Forest Sinks (C. Pease)
5. Protein Efficiency Ratios for Livestock Production and
6. Indices of Primary Productivity in Acumen Forests (A. Verge)

7. Advanced Studies on Angiosperm Life Cycles (T. Thorne)
8. Factors Affecting the Distribution of Caracol Snails (F. Cements)

Further thesis abstracts will follow in the next section.

The third chapter focuses on a systematic revision of the American species of the genus Alsophila. Speciation in the Cyatheaceae is perceived as an ecogeographic process, and the taxonomic revision applies the conclusions from the previous chapters to the problems of species classification. An unanticipated 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 Palicourea riparia Bentham (Rubiaceae) by Maria Luz Lebron emphasizes the current accelerated rates of destruction of tropical rain forests, leading to renewed attention on the process of secondary succession in these areas. Despite numerous studies on this topic, our understanding of the behavior of ecologically important species participating in this process is limited.

This 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 significant in disturbed areas in terms of density, and it is also present under mature forest conditions, albeit at reduced levels. Studies on seedling seasonality show that there are no significant variations in periodicity in the forest in terms of frequency or density. Germination studies indicate that, regardless of the 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.

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 µmol m-2 s-1, and that increases in light intensity consistently enhance photosynthetic rates.

The present study provides an...

The text presents an important contribution towards the understanding of ecologically important species in lowland tropical rain forest areas. Based on 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 greatly benefit from forest disturbances (Baur, 1964).

"Changes in Water Quality as Influenced by Land Use Patterns" is a study by Elvira Cuevas. Biweekly 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, 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. CO2 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 standards for drinking water.

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.

In "Some Aspects of the Ecology of the Freshwater Shrimps in the Upper Espiritu Santo River at El Verde, P.R." by 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 heterachirus, and Atya innocous. Selected physical and chemical characteristics of the stream were measured to describe the habitat of the species.

Each species and their effects on the distribution were observed. The physical parameters which affected the habitat selection and the distribution were water flow, 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 were 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, residing under rocks and in low-flow conditions. Selected anatomical characteristics were measured.

Rainfall data were used to measure the Santo Basin in the upper Espr.

MATERIALS SCIENCE

The Materials Science Division is engaged in research on the 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 Triglyci 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;~7.-AT, and 7, =T,). From this, the

The ideal efficiency (me Le) = Ee where '4' is the mean field coefficient, 'M' is the temperature derivative of the squared spontaneous polarization, '»' is the density, and 'AC' and 'C' are the ferroelectric and total (ferroelectric plus “background”) average specific heats respectively. 'ATs/Te_' is the Carnot factor, which puts an upper thermodynamic limit to the ideal efficiency. This is the factor determining conversion performance '1 /e¢". 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 '7p' and an electric relaxation time '1'. Optimum power output is obtained when the load resistance is equal to the internal resistance and the ratio of the thermal to the electric relaxation is unity. The optimum thickness of the ferroelectric plate is given by 'Sulfate (J. A. Gonzalo 4 = Were? const. x (r,/8T9)" where 'r' is the thermal conductivity of the ferroelectric plate and '+ = x7. = tee'. In other words, it is determined by the maximum range 'a7', over which the performance factor 'm' remains at its maximum value.

From here it is possible to determine the specific power output per unit mass, which can be expressed as '(PR) (BY'. If a single-stage converter is used between the extremes of 100K and ambient temperature, taking '(3M/C’) as 0.25, which is a not unreasonably high value in light of experimental data (Gonzalo et al.) for ferroelectrics with variations above room temperature, we come up with a figure in the 1% range.

Specific power output estimates for these types of ferroelectrics, for which transport parameter (ke) is known, appear to compete with those typically obtained with other conversion thermoelectric materials. Furthermore, ferroelectric converters do not require a single crystal plate, working equally well with polycrystalline material having preferred orientation along the ferroelectric axis, which can probably be produced more economically.

To obtain more power by thermocycling, one must keep the single-domain state of the crystal and maintain a larger fraction of the dipoles aligned in one of the two possible directions.

Directions can be done in several ways. Unapparently, gyration can be maintained using any radiation. In some instances, by applying a permanent shear stress to the earth over a long time in the proper direction. Reported here are preliminary measurements of efficiency and specific power output in single cases of triglycine sulfate (TGS), with radiation-induced preferred direction for the spontaneous phase (Okade, Gono, and River, Phys. Chem. Sol., 25, 1967). TGS crystals were chosen to test the theory, not because they were the best possible candidates for energy conversion, but because of the easily achievable fine temperature and availability of irradiated samples with a net nonzero polarization along one preferred direction.

Experimentally, the samples were old, irradiated TGS single-crystal plates with areas between 0.25 and 1 cm^2 and thicknesses between 0.6 and 2.5 mm, cut normal to the electric 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 irradiated (with 2.5 Mad) 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 P1 and P2 being the heights of the larger and smaller loop respectively, the effective fraction of the spontaneous polarization was = (P1P2) / (P1 + P2) = 0.34.

Note that at a given temperature, P1 + P2 gives the total spontaneous polarization. The value obtained for the resistivity (Rt) is 1.07 x 10■ ohm. The thermal relaxation time of the sample holder with the crystal was about 20 sec, a value larger than that estimated for a thin plate, rp (pc"iklé®), which, for d ~ 1 mm, gives t ~ 2 sec; this indicates that the thermal resistance of the air between the cylindrical container and the sample.

The heat transfer factor was more limiting than that of the sample itself.

Figure 1 depicts Cag X10" Dynes em HO.

Results and Discussion: The comparison of the measured and experimental values of efficiency gives 0.82, indicating a reasonably good agreement between calculation and experiment. The comparison for the specific power output isn't as straightforward. This is because the calculation (as per Gonzalo) has been carried out completely only for the case when Fo ty = eqs, which requires a specific sample thickness determined by the electrical resistivity value for a given ATs. Nevertheless, if zp and r, are unequal but of the similar order of magnitude, the specific power output calculated by Gonzalo could serve as a useful estimate. The ratio of experimental to calculated power output was 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. Vazquez and J. A. Gonzalo): By using the Brillouin scattering technique, 10 of the 13 elastic constants of deuterated tryglycine sulfate (DTGS) have been obtained. They are (in 10"* dynes/em? I): C11 = 5.08, Cz = 2.04, Cy = 2.05, Ca = 3.51, Cys = 2.40, Co = 1.10, Cy = 1.21, Cus = 0.73, and Cay = 0.03. The temperature dependence (30°C to 80°C) of some of these elastic constants has been studied, with emphasis on the transition temperature region.

Raising the temperature through T 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, where o Tey with +~* is proportional to O7 = 7, ~ 7, was achieved.

"A value of 7! = (44 + 0.4) x 10!°(r,-7), is used for TGS. However, the results could not be fitted with Equation (1) for 7 close to 7. Careful measurements with 7, - T<0.1°C showed that the transition starts rather abruptly. This indicates that the simple relaxation formula, Equation (1), does not completely explain the behavior of DTGS. The topic of Elastic vs. Polarization Energy in TGS Near the Phase Transition was discussed by J. A. Gonzalo and F. Vazquez. They examined the elastic energy of ferroelectrics. 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 this, 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 is obtained. The transition's temperature and pressure dependence can also be obtained. A 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. R. S. Singh discussed the Phonon Raman Spectra of Crystals Under High Pressure. A high pressure pump to generate hydrostatic pressure (10kbar) has been procured and the pressure cell is currently being built. The systems will be tested soon. A few selected crystals will be studied under hydrostatic pressure. R. S. Singh and O. Matos discussed the Phonon Raman Spectra of TGS and OTGS in Ferroelectric and Paraelectric Phases. Both TGS and DTGS are ferroelectric at room temperature and belong to the C3-Ps, 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) +."

The text should be:

12A(R) + 108(T) + 128(R), which are all IR as well as Raman active. In the paraelectric phase, both belong to the Ciy~ Ps, 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) + 5A4(T) + 6A4(R) + 48(T) + 6B(R). Only g-types are active in Raman and u-types in IR. Polarized phonon Raman spectra 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. Vazquez) 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 the lattice modes unambiguously and may shed further light on the mechanism of phase transition. Brillouin Scattering of DTGS Around the Transition Temperature. (F. Vazquez). 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.

The dynamics of the second-order phase transition are being analyzed and related to the results obtained with TGS. Data have been taken for the elastic constants and are currently being computed.

EDUCATIONAL ACTIVITIES

Thesis Research: M.S. theses being conducted under the auspices of the Materials Science Division are listed below. All students are from Puerto Rico unless otherwise noted:

- Radiolysis of Aqueous Solution of Sulfur-Containing Amino Acids by Luz del Mar Garcia (supervised by Dr. R. A. Lee; completed 11/75).
- Raman Scattering of Hydrogen-Bonded Ferroelectric Crystal by Osvaldo Matos (supervised by Dr. R. S. Singh, Physics; completed 12/76).
- Phonon Raman Spectra of TGSe, DTGSe, and TOFBe by Fernando Noriega from Guatemala (supervised by Dr. R. S. Singh).
- Study of Phase Transition in Crystals by Light-Scattering Techniques by Luis Mera Romero from the Dominican Republic (supervised by Dr. R. S. Singh).
- Dielectric Constants in TGS and DTGS With Uniaxial Pressure by Jorge Ortiz (supervised by Dr. F. Vazquez, Physics).
- Infrared Studies of the Bromine-Benzene Complex by Roberto Torres (supervised by Dr. T. C. Jao, Chemistry).
- Raman Scattering of Ribosomal RNA, Ribosome, and Some Antibiotics by René S. Vieta (supervised by Dr. Jao).
- Raman Scattering of Some Polyamino Acids, Peptides, and Proteins by Gloria O. Marquez (supervised by Dr. Jao).
- Phase Diagram and Shift in Curie Point for Doped $NaNO_2$ by Mario Rojas from Colombia (supervised by Drs. Jao, Vézquez, and M. I. Kay, Neutron Diffraction).

Special Training: Mrs. Claribel Velez has an ORAU undergraduate fellowship and is working on the project, "Radiation Chemistry and Radioprotection of Biologically Important Compounds (Purines)," under the supervision of 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. Gomez, J. A. Gonzalo, and M. I. Kay. They managed both the scientific program and the local organization, and are currently editing the proceedings. Sponsorship was provided by...

UPR, ERDA (via PRNC), the International Union of Pure and Applied Physics, and the American Physical Society were the main sponsors of the event. Funding was provided by the National Science Foundation and the Office of Naval Research. The 150 physicists in attendance hailed from the U.S, USSR, Japan, Europe, and Latin America.

Visitors included Dr. J. B. Cohen, Head of the Materials Science Department and Frank C. Engelhart Professor at Northwestern University. He visited PRNC for two weeks, from March 21 to April 4, 1976, to initiate an experiment on diffuse scattering from TGS, which is currently underway at PRNC. The goal of the experiment is to study the details of correlation through the phase transition. Dr. Michael Butler of Sandia Corporation visited the Division on June 11, 1976, and presented a seminar.

Neutron Diffraction Program, funded by the National Science Foundation (Grant

OMR-71-01785-A02), investigates the structural changes in materials undergoing ferroelectric and antiferroelectric transitions. The microscopic molecular structure of crystals, which defines their lattice vibrational and molecular spectra, determines their response to imposed fields. Hence, the crystal structure and its changes through phase transitions provide essential information for predicting and interpreting transition mechanisms via their dynamics.

Ferroelectric, antiferroelectric, or more generally ferroic materials have been utilized as optical gates, infrared detectors, transducers, and optical memory devices. The application of these materials, via the pyroelectric effect, as potential solar energy converters, is discussed earlier in this report. It is worth noting that the study of most materials and their interactions with various force fields invariably leads to "energy conversion." Certain solids have long-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 by M.I. Key. 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 scatterer than hydrogen and has a lower incoherent cross section, a crystal whose exchangeable hydrogen atoms were deuterated (DTGS) was used 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= 2|F - F2|/2F, 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-D1 bond remains about 1.00 A and for the D-O2 increases from 1.52 to 1.58 A above transition.

Page Break

Table 1: Hydrogen Bonds (Ferroelectric Phase in Parentheses) (r1= donor to hydrogen distance; r2= hydrogen distance)
From Glycine I:
Angle O-D-O1, 1.01 (1.00) 80501 (rc)
N-D1-O, 1.02 (1.06) 91899 (teu)
N-D2-O1, 1.05 1.01 202196) 196 4136)
From Glycine II:
Paes tot, 1.10 6208 200) 190 161)

From Glycine II: NM,

"(pg) 200) On N= Page 205 (pg) 10 Mo, ‘098 (pg) as of equivalent Gy interface page “The average H-H distance in the ammonium group is 1.01 A below the transition and 11.00 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 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,-0 II bond with polarization reversal is probably correlated with the O II 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), With Standard Deviation in Parentheses.

Table 3: Short Hydrogen Bond Geometry

All parameters Ru RwlF 0.037 084 131 σt = 0.08 = 0.25 U, = 0.28 0.11 t0 0-0 bond is “8 x

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 by M. I. Kay. Ammonium Dihydrogen Arsenate"

(ADA) is isomorphous with the phosphate. The material is antiferroelectric below its transition temperature of -87°C. It transitions from I-42d to P2,2,2,. The tetragonal lattice parameters are a = 7.69 and c = 7.72 as given by Kahn and Baur (Acta Cryst. B28, 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 or 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 OK0 reflections in DTGS to examine correlated motions through the transition. Mr. Mario Rojas is carrying out exploratory work on the KNO3-NaNO3 work and because of possible uses of NaNO3 in energy conversion.

Table 1: Experimental and Predicted Argon-41 Concentration Search

NUCLEAR ENGINEERING: The Nuclear Engineering Division is engaged in both teaching and research. Staff members teach both graduate and undergraduate courses at the UPR Mayagiez Campus and direct the thesis work of nuclear engineering students. They conduct research on their own projects and assist the staff of other PRINC divisions as the need arises. The scientists on the

The staff of the Division all hold joint appointments at PRNC and UPR, and they constitute the faculty of the UPR Nuclear Engineering Department. The head of the PRNC Division also serves as the Chairman of the UPR Department. The Division provides the classrooms, offices, laboratories, equipment, and most of the administrative personnel required for the education and training of 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 Argon-41 in unrestricted areas be reduced by a factor of 60, to 8 X 107 µCi/ec. The objective of this work was to develop a simple and accurate procedure for Argon-41 measurements in unrestricted areas when its concentration is significantly below the newly recommended allowable concentration.

The purpose of these measurements is to provide verification of results obtained from prediction models for the spatial variation of the concentration of gases released from a source. The ability to measure Argon-41 at a concentration less than 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 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-inch-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 Argon-41 concentration in the off-gas system was zero. In Run 2, the concentration could be measured but not predicted since the model does not apply when the wind frequency is low. The average difference between the experimental

The predicted concentrations for the last four runs was 25%. The concentration in the off-gas system was approximately 10.3 x 10 Ci/ee at the 1000-kw power level. The radiation detection system determined a ground level of 6.0 X10 Cilce, which is less than 10% of the new

recommended allowable concentration and indicates an attenuation factor of 2x 10.

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 1950s, several systems were described in which raw waste was mixed with a large anaerobic biological mass maintained in the digester for a 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, via 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 the 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 is typically fed to the aerobic digester. The bench-scale unit had several disadvantages. The mixer had to be filled at time intervals depending on the operation's liquid flow rate. Additionally, it lacked control over 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 could clog the bellows-type metering pump. Due to 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 time when gas production does not change greatly from one day to another. When 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. Sasser and F. Ferrer)

A major attraction of ocean thermal energy conversion (OTEC) systems is that they use the ocean for energy storage and can produce power at a constant rate. An OTEC plant operates on the temperature difference between the surface water and the deep water, which seldom exceeds 40°F, even under ideal conditions. Therefore, it has a low thermal efficiency that increases rapidly with an 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. These issues raise doubts about their engineering and economic feasibility, justifying the investigation of alternatives. One proposal is to locate OTEC facilities on land in shoreline areas near deep ocean water. This approach would not only be more feasible but also would allow judicious integration with a conventional plant. This integration 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 are integrated with conventional ones. The tropical waters around Puerto Rico maintain a year-round surface temperature of 75° to 85°F. Within 1.5 to 5 miles from the shore, water of 40° to 45°F is found at a depth of 2000 ft. Consequently, a secondary objective is to assess the feasibility of using Puerto Rico for field testing Ocean Thermal Energy Conversion (OTEC) components. This could possibly be 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 is Punta Higuero, located on the west coast of Puerto Rico, near Rincon. The second is Punta Tuna, in the southeast, near Yabucoa, and the third is Barrio Islote, on the north coast, near Arecibo. The distance from the shore to the source of 40°F water at a depth of 3000 ft is 5 to 7 miles for Punta Higuero, 1.7 miles for Punta Tuna, and 10 miles for Barrio Islote.

The 28 mills kW-hr quoted by Carnegie Mellon University (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 theses are summarized below.

"Population Exposure to Natural Radiation in Puerto Rico" by Antonio J. Gonzalez- Rodriguez (under Dr. A. E, Gilead). 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 127 - 53:8 mrem/yr per person, ranging from 108-216.

In Ciales, the value was 3425, whereas in Carolina and Ponce, the personal dosimeters worn by four volunteers gave an average value of 5428. The cosmic component of the dose equivalent (DE) within the surveyed municipalities was found to vary by only 3.3 mrem/yr per person, hence, the DE variation was assumed to arise from the terrestrial component. The natural background activity level in Puerto Rico is among the lowest known, being 20% lower than in "normal" areas and 59% lower than the average of all countries reported by UNSCEAR in 1962.

A cost-benefit analysis was done on condenser-cooling systems for nuclear power plants in Puerto Rico, authored by Juan M. Cajigas under the supervision of Dr. K. B. Pedersen. The systems analyzed included once-through cooling, cooling pond, wet cooling towers, and dry cooling towers.

Computer programs were used to design these different alternatives, optimizing for minimum cost. The general environmental impact was also studied. The results indicate that the once-through system is the method best suited to the cooling needs of Puerto Rico's future nuclear power plant. Its design total system cost was calculated to be 0.076 mill/kW-hr less than that of the closest competitor, mechanical draft wet cooling towers, and its environmental effects are within tolerable limits.

Carlos Andreu Vi, under the supervision of Dr. D. S. Sesscer, aimed to determine the yearly average maximum concentration required for verifying the model used for calculating the attenuation factor between the off-gas stack outlet and ground level. The model utilizes 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. This calibration was satisfactorily done, with a probable error of +/- 0.5%. The system used allowed for the measurement of Argon-41 dose at the PRNC site boundary.

The text has a ground level concentration lower by a factor of 6.75 x 10^0 than the concentration in the off-gas stack, or to 1.6 x 10^-11 Ci/sec. 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 x 10^-11 Ci/m^2, 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" by Frank Ferrer Almodovar (under Dr. O. 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 Tune.

"Methane Gas Production From Returned Activated Sludge Using the Anaerobic Filter" by Angel Luis Rivera (under Dr. K. S. 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 187.6 ml/min resulted in fairly good gas production, 1.58 ft^3 (at STP) per pound of total.

"Suspended solids were removed on average. However, 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/tt.

A study on the population dose due to the transportation of irradiated fuel from two nuclear power plants in Puerto Rico was conducted by Luis Reyes Medina, under the supervision of 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 x 10 mem.

Another study titled 'Atmospheric Transport of Gaseous and Volatile Radioactive Effluents from the PRNC Mica Reactor' was conducted by Rolando Pérez Ortiz under the supervision of 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-FLP research reactor, using actual operating parameters and local meteorological data. The code is written in Fortran IV and executed on the PDP-10 computer of the UPR Mayagüez Campus.

Using 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 input parameters such as position coordinates, source intensity, and climatic data, with allowance made for effective stack height, reflection at the ground surface, and depletion by ground deposition and radioactive decay.

In terms of educational activities, UPR, in close cooperation with the PRNC Nuclear Engineering Division, offers a Master of Science degree in Nuclear Engineering. In 1975, 12 graduate students were enrolled in this program. The seven theses completed are summarized above. One student, Dick Carrero, is primarily engaged in thesis work."

The following individuals specialize in research and academic coursework: Edmundo Martinez, César Pérez Arenas, Manuel Lépez, and Milton Soto. Special Courses are available, offering short courses (ranging from one week to three months) on various topics related to nuclear engineering. These are offered approximately once a year for scientists, engineers, and other interested persons.

In June, a one-week Summer Workshop on Energy and the Environment was offered for high school science teachers. This was jointly sponsored by ERDA, RNG, the UPR Mayaguez Campus, and the Puerto Rico Water Resources Authority. The workshop aimed to provide these teachers with sufficient background knowledge to guide their students and communities towards a more factual and less emotional consideration of the trade-off between energy and the environment. 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. They also taught eight undergraduate sections in the Mechanical Engineering and Electrical Engineering Departments. The courses included:

- Math 675 - Math of Modern Science
- NuEg 605 - Elements of Nuclear Engineering
- NuEg 621 - Reactor Theory
- NuEg 603 - Nuclear Reactor Measurement and Instruments
- NuEg 699 - Research
- ME 340 - Thermodynamics
- EE 311 - Electrical Engineering

- NuEp 622 - Advanced Reactor Theory
- NuEg 625 - Nuclear Reactor
- NuEg 626 - Reactor Laboratory
- NuEg 616 - Seminar
- NuEg 699 - Research
- NuEg 551 - Introduction to Nuclear Engineering
- ME 381 - Thermodynamics
- EE 311 - Electrical Engineering

The Tropical Agro-Sciences Division has two primary functions: conducting research on the impact of air pollution on tropical agriculture and providing 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 Guayanila-Peñuelas region, which has 8 fossil-fuel power plants, 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-Ruiz). At the beginning of this fiscal year, trips were made to Guayanila-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 originally planned. The preliminary monitoring indicates an irregular daily SO2 distribution pattern differing at the two locations. In general, a heavy SO2 influx lasting 1 to 4 hours 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 SO2 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. SO2 Effect on Leaf Fresh Weight and Net Photosynthesis in Phaseolus vulgaris seedlings (F. K. S. Koo, J.

"Cuevas-Ruiz, and J. Garcia-Villalobos conducted experiments on the effect of SO2 on 10-day-old bean seedlings (Phaseolus vulgaris L.). Seedlings in a sealed 12.5x9.5x12 in. glass chamber were exposed for 1 hr to concentrations of SO2, generated by heating 10 ml each of 2.0M HCl and 1.0M K2S2O5 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.

The injury is caused by acute SO2 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

increased to 29%. Net photosynthesis, measured immediately after exposure and 24 and 48 hr later, showed a marked decrease as the SO2 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 more than 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 was researched by 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: Cd 190, Co 0.18, Ni 231, Cu 1.80, Pb 7.35
Mangifera: Cd 283, Co 23.70, Ni 1226, Cu 85.12, Pb 12.18

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

The Availability of Methionine for Synthesis of Different Protein Fractions in Soybean Seeds During Development was studied by B. F. de Riesco and F. K. S. Koo. The quantitative changes in nitrogen and 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 base research activities.

During FY 1976, Division staff members holding joint or honorary 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

Student: Professor 614 New Teenie in Boge. Remark D4. ComeRu an A for Monge 618. Yep 3 LA Feestone 020. Ramesh 1 Rcwsenotaonee (05 Nov). Techie in Angel Research 3. Come at 'Ao 418 Seco in Aaonay 1 RRS. Kee Hort 085. Grows Reps in Agere 3A. Caatontsdonsso Bio 608. Rene 1 Res. ee Bot 698. Renee 1 La Fereratong.

Thesis Research During FY 1976, three undergraduate students were doing thesis research in the Division of Cytogenetic Effect of Insulin on Human Chromosomes:

1. Alice Ortiz, Puerto Rico (for MS. in Biology under Dr. J. A. Ferrer-Monge).
2. Carmen Asencio, Puerto Rico (for MS. in Biology under Dr. A. Cedefo-Maldonado).
3. Blanca Riesco, U.S. (for MS. 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 trainees (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

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