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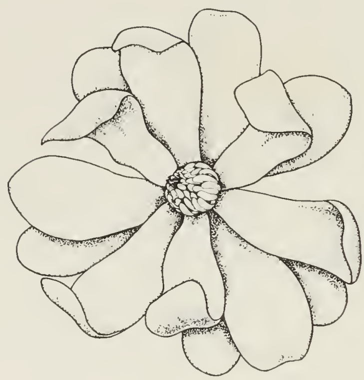

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To those who have led the search for BETTER BALANCE

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1976–1987

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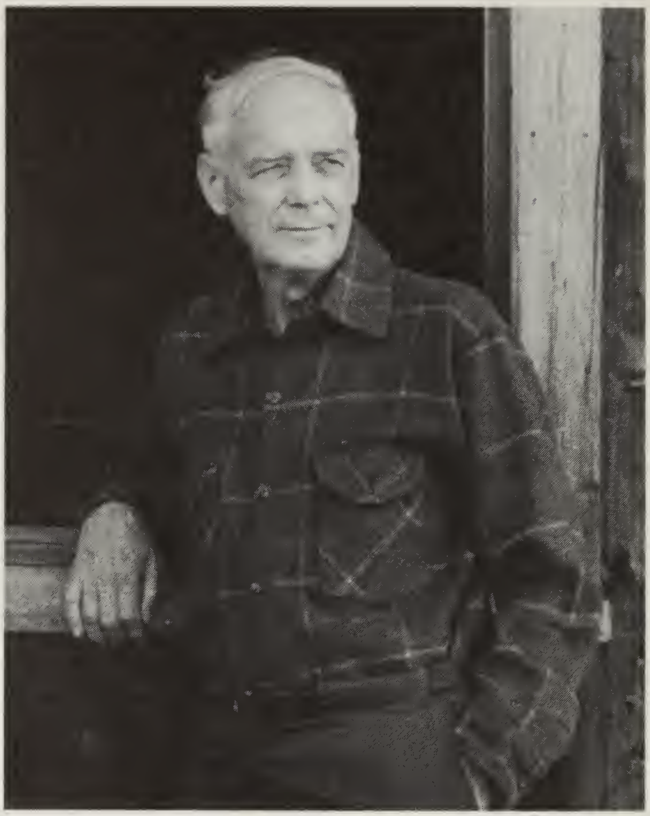
Hon. Francis L. Kellogg
Hon. Elmer L. Andersen
Donald G. Padilla



Richard W. Brown, Photographer

Charles A. Lindbergh

The Charles A. Lindbergh Fund: The First Decade—1978–1987

Reeve Lindbergh Tripp

The Lindbergh Grants are the heart of The Charles A. Lindbergh Fund. As Vice President and Chairman of the Grants and Awards Committee and a member of the Lindbergh family, I think the grants are a perfect way to remember and honor my father. These projects deal with activity, with life and with risk.

Each year, the Fund makes grants of up to $10,580—the cost of the "Spirit of St. Louis"—to individuals whose projects reflect my father's conviction, "The Human Future depends on our ability to combine the knowledge of science with the wisdom of wildness." Since the Program began in 1978, more than $1,600,000 in grants have been awarded to 90 men and women from the U.S. and thirteen other countries; all carry the central purpose of creatively resolving conflicts between technological growth and conservation of our environment.

Formal applications are first screened by an independent, technical Review Panel, which results in the recommendation of about thirty finalists. The Grants and Awards Committee of the Fund Board of Directors then reviews the thirty and designates those it feels best meets the appealing and unusual grant criteria. The final selection of Lindbergh Grant Recipients and the new category of those deserving Honorable Mention are made once each year by the Board of Directors.

Past Lindbergh Grant Recipients have come from the following fields of study:

- Aeronautics
- Astronautics
- Aviation
- Agriculture
- Arts and Humanities
- Biomedical Research
- Conservation of Natural Resources
- Health and Population Sciences
- Intercultural Communication
- Oceanography/Water Resource Management
- Waste Disposal Management
- Wildlife Preservation

- The Jonathan Lindbergh Brown Grant in Adaptive Technology or Biomedical Research which seeks to redress imbalance between an individual and his or her environment.

We believe that the Washington Academy of Science's publication of this cross-section of work will stimulate more publicity and create a wider public forum for the work of the recipients.

My entire family wishes to thank The Charles A. Lindbergh Fund leaders, Board of Directors and staff for their personal commitment to the Grants Program; Gen. James H. Doolittle, Neil Armstrong and the Explorers Club for planting the original seed of this international organization; the community of Little Falls, MN for opening their homes and their hearts to host our first Grant Recipients Reunion; the Washington Academy of Sciences for publishing the results of the work to date, and all sponsors, contributors and volunteers over the past ten years who have enabled the Fund to serve as an appropriate channel for the expression of my father's ideas and deepest convictions.

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Note: For further information regarding the Lindbergh Grants Program, please contact Gloria S. Perkins, Editor of the Lindbergh Grants Publication, at the above address.

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"Working with Charles Lindbergh"

Richard J. Bing, M.D.

Huntington Medical Research Institutes, and Huntington Memorial Hospital, 100 Congress Street, Pasadena, California*

Fate and personality determine the course of a life's event. Personality shifts the vector of fate.

It was my interest in biology, tissue culture in particular, which brought me in contact with Charles Lindbergh. As a medical student I had worked with Rhoda Erdman in Berlin on tissue cultures and was impressed by the behavior of cells in cultures. I believed that nature revealed its inner workings in cell division and cell movements. Because of this interest I joined in 1934, at the age of 25, the Carlsberg Institute for Biology in Copenhagen. When the World Congress for Cell Biology was held in Copenhagen that year, both Charles Lindbergh and Alexis Carrel visited the Institute.

When it was decided in Copenhagen that someone should learn the method for the culture of whole organs, and I was chosen to go to the Rockefeller Institute in New York City, I was overjoyed. Carrel arranged a Rockefeller grant and in 1934 I sailed for New York to work with Carrel on the perfusion of whole organs. I was then 25 years old. My first close contact with Charles Lindbergh occurred on the trip to America, when I stopped in England and visited the Lindberghs in Seven Oaks, Kent. It is strange how *one* brief encounter can deeply engrave itself on ones memory. The few hours spent with the Lindbergh's made a deep impression on me, not because I was "pre-programmed", but because I found a resonance for my youthful scientific enthusiasm in Charles Lindbergh's response to me and to my ideas. I learned then, that he never made light of other people's ideas, but respected originality and ideas even from the young and inexperienced. Both Mrs. Lindbergh and Charles were gracious enough to take me serious. I was even introduced to a super dog with superior training. (Was its name Thor?), who had been taught to perform supercanine tricks.

At the Rockefeller Institute in Carrel's department I began to work on "the pump" as it was called. Carrel was a benign chief, he overlooked any weakness as long as he could detect some strength. Thus, I, a complete novice, was privileged to be trained in the perfusion of whole organs by Carrel's staff and Carrel's co-workers had also worked with Lindbergh and were his friends. What is the "pump"? It is a perfusion system made out of glass, which permits sterile perfusion of individual organs such as the thyroid gland, the pancreas or the kidney outside the body, and allows obser-

* Lecture presented at the first Lindbergh grant Recipients Reunion, Little Falls, Minnesota, June 20, 1987

vations of the effects of different perfusion fluids on survival and biological behavior of these organs. The ingenious part of this device was Lindbergh's introduction of floating glass valves, which separated individual chambers, through which the perfusion fluid coursed, exposing the organ to any desired perfusion pressure and rate. This became important 40 years later when I became interested in the uptake of cholesterol by the arterial wall. Sterility was maintained by sterile cotton plugs, through which the gas mixture passed to exert its pressure on the perfusion fluid.

During my time at the Institute, Lindbergh was rarely present since the developmental phase had terminated. I learned soon from my colleagues that the relationship of Charles Lindbergh to his co-workers was one of his great attributes. He treated them as equals as he treated me, the young physician, with consideration. This, I have no doubt, was also one of the sources of his success in the building of the "Spirit of St. Louis". Whether it was the airplane mechanic in San Diego or the glass blower at the Rockefeller Institute, he treated them as equal and with respect. He himself had come up from the ranks and knew what it was to start at the bottom.

The idea of the pump was conceived by Charles Lindbergh who wanted to develop an instrument which would make operations on the human heart possible. He asked the crucial question, why a mechanical pump could not be devised for circulating blood through the body during the period of operation on the heart? Why could one not bypass the heart and operate on it by shunting the blood around it? This idea, in the early 1930's, represented a novel intellectual concept in open heart surgery; not until 1953 was this feat accomplished by John H. Gibbon, Professor of Surgery at Jefferson University in Philadelphia. His life and work are deserving of a special chapter. During his surgical residency at the Massachusetts General Hospital, Gibbon had to stand helplessly by while a patient with a pulmonary embolus died because the operation on the heart or its blood vessels was not possible. For years afterwards, Gibbon and his wife worked on the idea of the heart lung bypass, discouraged by most, encouraged by few; he accomplished his goal, the building of a heart lung machine, with the first successful operation on May 6, 1953.

It was Carrel who reorientated Lindbergh's goal away from the idea of replacing the heart in the body and creating a bypass. He did so for practical reasons: the building of such a machine presented tremendous problems of oxygenation of blood; because in order to operate on the heart emptied of blood the lung had to be bypassed as well. Thus the perfusion system developed into a tool that fitted Carrel's idea, his wish to study the interplay between organ, blood and tissue fluid. An intellectual disciple of Claude Bernard, Carrel was interested in the internal environment through study of the interplay between tissue fluid and organ.

In retrospect, Charles Lindbergh's original concept was much broader and of far greater importance: to operate on a bloodless heart while the rest of the body was supplied with blood.

Lindbergh's approach to this as well as to the other problems was to me, a young scientist, fascinating. I had grown up in European medical schools and laboratories with the idea that there were excellent reasons for scientific hierarchy. Unquestionably the professor knew more than the associate professor who was a wise man compared to the assistant professor who knew slightly more than the instructor; the medical student was not permitted to have original ideas. Unfortunately this system has also survived in this country in some places. Lindbergh taught me otherwise, namely that a fresh, from the ground approach can be more rewarding than to place just another mosaic stone into an almost completed picture. It is important, and necessary to read and familiarize oneself with the work of others prior to beginning any project, but to be overwhelmed by the thought of others is detrimental to original thinking. A good scientist sees the woods as well as the trees. An original thinker has the capacity for simplicity of thought, of cutting through the plethora of verbage and to arrive at a simple conclusion.

My relationship with Lindbergh grew after I had left the Rockefeller Institute. When I joined Columbia University and the College of Physicians and Surgeons in New York under Allen Whipple I worked again with the "pump"; my main goal was to find an artificial fluid which, unlike blood, would not deteriorate during long perfusion. I conceived an outlandish idea, the use of hemocyanin, the respiratory pigment of the blood of horseshoe crabs and squids as a blood substitute. These animals living in the ocean have evolved this copper containing pigment to carry oxygen at relatively low temperatures. It was indeed a curious sight to see blue blood streaming through á mammalian organ! Alas these organs had to be maintained at relatively low temperatures, since both squid and horseshoe crab are cold blooded animals. It was a good try! Lindbergh came quite often to the College of Physicians and Surgeons to watch what I was doing.

I then went to Bellevue Hospital and hence to John Hopkins and my scientific interest shifted and during the war we lost contact. I was in the army medical corps and later at various university medical schools and it was not until I came to Pasadena in 1969 that we saw each other again because I began to use the pump to study cholesterol uptake by arteries.

When Lindbergh visited me here in Pasadena I took him to my laboratory; it was for both of us a journey into the past. You see, the pump has a special audible rhythm, as air enters and escapes the valves, not unlike the rhythmic idling of a locomotive. Lindbergh on entering my lab listened to this rhythm of the past and both of us thought of the early times at the Rockefeller Institute. Carrel, friend of both of us, had gone and so had many others and for both of us the memory began to play its nostalgic tunes. As Lindbergh wrote me then, "It is as if the time had fallen away and we were both still working with Carrel at the Rockefeller Institute". He stayed with me while he visited our home and enchanted my then youngest teenage daughter, (my wife had met him before). He gave a talk at our hospital staff meeting. When it was time to take him to the airport, my rented car would not start. Lindbergh opened the hood and juggled a few wires and the thing went off. This was our last meeting but it had a special patina which only advancing age and past remembrance can give.

Since that time I have often reflected upon my work with him. I wondered what made him, a flyer search for science, while I, a physician and scientist, became quite a musician and composer. I do not know whether I have the answer, but in Lindbergh's case, the search for the secrets of life and its processes were a personal fulfillment. As a flyer he was meticulous. Very little was left to chance, every possibility was considered and taken into account. In his excursions into the field of biology it was a search for the unknown, for the secrets of nature. Here a flight plan could be only very tentative, because in the search for nature's secrets one must often change ones course. This approach intrigued Charles Lindbergh, because he was fascinated by the poetry of life and by the mysteries of evolution. For me, a scientist devoted to music this was easy to understand. I too am fascinated by the sublimation of biological processes and of life into the world of art.

What a wonderful thing memory can be. It brings into harmony different cords and emotions of the past. My work with Charles Lindbergh has become a treasured part of my life.

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Warren Y. Brockelman, Ph.D., Dept. of Biology, Faculty of Science, Mahidol University, Bangkok, Thailand. "Conservation of the Pileated Gibbon in Thailand"

Michael Huston, Dept. of Ecology & Evolutionary Biology, University of Michigan (Ann Arbor). "Nutrients and the Regeneration of Tropical Forests"

Theodore I. Malinin, M.D., Director, Surgical Research Laboratories, University of Miami (FL). "Development of The Lindbergh Organ Perfusion Laboratory"

David C. Oren, Ph.D., Ornitologia Museu Paranse Emilio Geoldi, Belem, Brasil. "Area Requirements for Species: A Problem For Conservation"

Donald C. Rundquist, Ph.D., Director, Remote Sensing Center, University of Nebraska (Lincoln) and Jeffrey S. Linden, Ph.D., Manager, Peterson & Associates, Lincoln, NB. "Toward a Digital Classification of Wetlands in the Nebraska Sand Hills Region Using Landsat MSS Data"

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Peter Brosius, Dept. of Anthropology, University of Hawaii (Honolulu). "The Zambales Negritos: Economic Responses to Deforestation"

Richard D. Gilson, Ph.D., Chairman, Dept. of Aviation, Ohio State University (Columbus). "Development of a Prototype Device for Visual Flight Simulation"

Noel Peyton Greis, Center for Environmental Studies, Princeton University (NJ). "Drought Management in Eastern Rivers: A Case Study of Water Management in the Delaware Basin"

Stephen Risch, Division of Biological Sciences, Cornell University, Ithaca, NY. "Effect of Growing Corn, Beans, and Squash in Monocultures and Polycultures on Populations of Pest Beetles: A Strategy for Pest Control in a Tropical Agroecosystem"

George M. Woodwell, Ph.D., Director, Ecosystems Center, Marine Biological Laboratories, Woods Hole, MA. "Technology and Nature: A Lecture Series on Balance" (Refunded in 1981)

"Technology and Nature: The Search for the Balance"

Lectures in the Series

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ADAPTING TO UNCERTAINTY IN AN UNFORGIVING SOCIETY July 16, 1980	Dr. C. S. Holling Institute of Resource Ecology University of British Columbia Vancouver, Canada
SHOULD WE WORRY ABOUT THE EXTINCTION OF OTHER SPECIES? July 30, 1980	Dr. Paul R. Ehrlich Bing Professor of Population Studies Department of Biological Sciences Stanford University Stanford, CA
MANAGEMENT OF RESOURCES IN THE COASTAL ZONE: June 24, 1981	Dr. Kenneth Mann Director of the Marine Ecology Laboratory Bedford Institute of Oceanography Dartmouth, Canada and Adjunct Professor of Biology Dalhousie University Halifax, Canada
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Apisit Eiumnoh, Ph.D., Asst. Professor, Dept. of Soils, Kasetsart University, Bangkok, Thailand. "Effects of Leucaena (**Leucaena leucocephala**) Planting on Soil Environments and Its Economics"

Karl T. Weber, M.D., Asst. Prof. of Medicine, University of Pennsylvania (Philadelphia). "The Influence of Pulsatile and Nonpulsatile Blood Flow on Autoregulatory Behavior of the Coronary Circulation"

David Western, Ph.D., Resource Ecologist, New York Zoological Society (Nairobi, Kenya). "The Significance of Herbivore Migrations in the African Savannahs to Their Conservation and to Livestock Development"

Jerome L. Wright, Solar Sail Project Director, World Space Foundation, South Pasadena, CA. "Development of a Prototype Solar Sail and Spar System"

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Marluce Fernandes de Lacerda, Chemical Engineer, State Foundation for Environmental Engineering (FEEMA), Rio de Janeiro, Brasil. "Utilization of Slum Wastes for Production of Biogas for Community Use"

Robert S. O. Harding, Ph.D., Associate Professor, Dept. of Anthropology, University of Pennsylvania (Philadelphia). "Outamba-Kilimi: The Impact of a New National Park in Sierra Leone on Shifting Agriculturists"

Graham S. Hawkes, President, Deep Ocean Technologies Inc., Oakland, CA. "Development of a Lightweight Hull for Maximum Ocean Depths (Project Deep Rover)"

C. Wayne Martin, Ph.D., Professor of Engineering Mechanics, University of Nebraska (Lincoln). "Nitrogen Fixation with Wind Energy"

Mario A. Rueda, Honorary Administrator of the Natural Park for the Gray Whale in Laguna Ojo de Liebre, Mexico, B.C. a Sur, Mexico. "Development of a Permanent Refuge for the California Gray Whale in Baja, California"

George G. Soares, Jr., Ph.D., Institut National de la Recherce Agronomique, LaMiniere, Guyancourt, France. "*Tolypocladium cylindrosprum*, A Naturally Occurring Pathogen of Mosquito Larvae with Potential for Use in Integrated Pest Management (IPM) of Human Diseases Vectors"

1982

John Fryxell, Ph.D., Research Fellow, Animal Research & Conservation Center, New York Zoological Society (Bronx). "Remote Sensing and the Analysis of an African Savanna Ecosystem in Southern Sudan"

James L. Luteyn, Ph.D., Curator of Botany, New York Botanical Garden (Bronx). "The Establishment of Permanent Study Plots in Two Ecuadorean National Parks"

Roderick Nash, Ph.D., Professor of History and Environmental Studies, University of California (Santa Barbara). "Air Travel and Wilderness Preservation in Alaska"

Pamela Parker, Ph.D., Section of Ecology and Systematics, Cornell University. "Local Extinction and Sustained Co-Existence of Domestic and Native Fauna (Brookfield Conservation Park, South Australia)"

Lawrence R. Parsons, Ph.D., Asst. Professor, and James P. Syversten, Ph.D., Asst. Professor, University of Florida Agricultural Research and Education Center (Lake Alfred). "Low Volume Irrigation: A Way to Preserve the Balance Between Agriculture and Florida's Unique Ecology"

Bruce E. White, Consultant, Presidential (Philippines) Committee for the Conservation of the Tamaraw, and Daniele Perrot-Maitre, Natural Resource Economist, The Haribon Society, Manila, Philippines. "Establishment of Socio-Economic Links Between Traditional Upland Mangyan People and Efforts to Protect the Endangered Tamaraw (Bubalus mindorensis) in the Philippines"

Albert Mukasa Wilson, Student, Art Design Center College of Design, Pasadena, CA. "Development of an Efficient African Charcoal Stove" (Refunded in 1986)

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Tim W. Clark, Ph.D., Wildlife Research Institute, Victor, ID. "The Meeteetse Black-Footed Ferret Conservation Studies"

Ricardo B. Jacquez, Ph.D., Dept. of Civil Engineering, New Mexico State University (Las Cruces). "Combining Nutrient Removal with Protein Synthesis Using a Water Hyacinth-Freshwater Prawn Polyculture Wastewater Treatment Process"

Aaron A. Jennings, Ph.D., Dept. of Civil Engineering, University of Notre Dame (IN). "Regional Hazardous Waste Management Planning to Minimize Risk"

Gilberto Silva Lopez, Asst. Biologist, Centro de Investigaciones Biologicas, Universidad Veracruzana (Mexico). "Rainforest Exploitation in Mexico and Efforts to Protect the Endangered Spider and Howler Monkeys (*Ateles geoffroyi* and *Alouatta villosa*).

David MacInnes, Ph.D., Chemistry Dept., Guilford College, Greensboro, NC. "Lightweight Plastic Batteries"

Robert E. Ricklefs, Ph.D., Dept. of Biology, University of Pennsylvania (Philadelphia). "Growth Performance of Sooty Tern Chicks: A Bio-Indicator for Tropical Marine Fisheries"

Cindy K. Stupp, Dept. of Biology/Chemistry, Mount Senario College, Ladysmith, WI. "Removal of True Color From Paper Mill Effluent by a Biological Process"

J. Edward Sunderland, Ph.D., Head, Dept. of Mechanical Engineering, and Aleksandar B. Brancic, P.E., University of Massachusetts (Amherst). "Seasonal Earth Thermal Storage System"

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Richard J. Bing, M.D., Director, Experimental Cardiology & Scientific Development, Huntington Medical Research Institute, Pasadena, CA. "The Use of a Newly Developed Perfusion System in the Study of the Reaction of Coronary Blood Vessels"

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Ann M. Fallon, Ph.D., Asst. Professor of Microbiology, School of Osteopathic Medicine, University of Medicine and Dentistry of New Jersey (Piscataway). "Genetic Basis for Insecticide Resistance"

Scott Farrow, Ph.D., Asst. Professor, Dept. of Engineering and Public Policy, Carnegie-Mellon University (Pittsburgh). "Recycling Scrap Titanium: Economic, Environmental and National Security Impacts"

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Kevin L. Sullivan, Wayzata, MN. First Recipient of The Jonathan Lindbergh Brown Grant. This grant supports projects in adaptive technology or biomedical research which seeks to redress imbalance between an individual and his or her environment.

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Jonathan A. Sandor, Ph.D., Assistant Professor, Agronomy Department, Iowa State University (Ames). (This Lindbergh-Guggenheim Grant in Anthropology has been made possible by a grant from the Harry Frank Guggenheim Foundation) "Comparison of Soils in Ancient and Modern Peruvian Agricultural Terraces"

Hans Schuessler, Professor, Department of Physics, Texas A&M University (College Station). "Utilizing Laser Spectroscopy to Determine Plutonium Levels in Radioactive Waste Management"

Robert L. Staehle, President, and Mark Bergam, Solar Sail Project Director, World Space Foundation, Pasadena, CA. "Solar Sail Project Engineering Development Mission"

Susan Yensen, Teaching Assistant, Dept. of Food Science and Nutrition, University of Arizona (Tucson), and Nicholas Yensen, Ph.D., President, Salt Weeds Inc. (Tucson). "Utilization of a Rare Halophyte Grain and Forage for Returning Salt-Ruined Farmland to Productivity"

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Henrik Balslev, Ph.D., Associate Professor, Botanical Institute, University Aarhus, Risskov, Denmark. "Conservation of *Attalea colenda*, a Threatened, High-Yielding, Oil Palm From Western Ecuador"

Kathleen Crane, Ph.D., Dept. of Geology and Geography, Hunter College (New York, NY). (This Lindbergh/Noble project in Oceanography/Water Resource management has been made possible by a grant from the Edward John Noble Foundation, Inc.) "Seafloor Mineral and Geothermal Resources Video Tape Production to Promote the Education of High School Students"

Holly T. Dublin, World Wildlife Fund, Nairobi, Kenya. (This Lindbergh/Weyerhaeuser project in Conservation has been made possible by a grant from the Carl A. Weyerhaeuser Charitable Trusts) "Ecological Monitoring in the Mara Reserve: Balancing Local Needs, Agricultural Advances and the Preservation of a Natural Ecosystem"

Paul Gepts, Asst. Professor, Dept. of Agronomy and Range Science, University of California (Davis). "Biogeography of Genetic Diversity in Wild Common Beans (*Phaseolus vulgaris* L.)"

Thomas J. Goreau, Dept. of Geological Sciences, University of Miami (Coral Gables). (This Lindbergh/Newton project in Oceanography/Water Resource management has been made possible by a grant from James D. and Eleanore F. Newton, Ft. Myers Beach, Florida) "Deciphering Environmental Records From Caribbean Corals"

Mark E. Hay, Ph.D., Asst. Professor, Institute of Marine Sciences, University of North Carolina (Morehead City). (This Lindbergh/Lutheran Brotherhood project in Agriculture has been made possible by a grant from The Lutheran Brotherhood) "Marine Natural Products as Ecologically-Sound Agrochemicals and Oncologic Drugs"

J. Donald Hughes, Ph.D., Professor, Department of History, University of Denver (CO). (This Lindbergh/Fried project in The Arts and Humanities has been made possible by a grant from The Fried Foundation) "Human Ecology in History: The Search of Mankind for a Sustainable Balance Between Technology and Environment"

Virginia Knowlden, Ed.D., R.N., Saint Joseph College, West Hartford, CT. (This Jonathan Lindbergh Brown Grant project in Adaptive Technology/Biomedical Research has been made possible by contributions to the Jonathan Lindbergh Brown Grant Endowment) "Caring in Nursing: Is It Surviving in High Technology Health Care Settings?"

Mariella Leo, M.A., The Peruvian Association for Conservation of Nature -APECO- (Peru). "Natural Resources Conservation and Management Workshop for Key Persons and Teachers of the State of Amazonas-Peru"

Daniel L. Pardieck, Dept. of Hydrology and Water Resources, University of Arizona (Tucson). "Restoration of Waters Contaminated with Persistent Organic Compounds by Stimulating Natural Microbial Populations"

Allyn MacLean Stearman, Ph.D., Associate Professor, Dept. of Sociology and Anthropology, University of Central Florida (Orlando). (This Lindbergh/Guggenheim project in Anthropology has been made possible by a grant from The Harry Frank Guggenheim Foundation) "A Long-Term Study of Adaptation and Social Change in Two Lowland Bolivian Foraging Societies: Strategies for Technological Innovation and Rational Land Use"

In 1987, The Board of Directors of The Charles A. Lindbergh made a special designated grant to:

Daniele Magda, Laboratoire IBEAS, Pau, France. "Colonization of Disturbed Habitats by the Plant Species, *Lathynus sylvestris*, In Aid of Stabilization of Soil"

Project DEEP ROVER: A complete description of this Lindbergh Grant can be found in The Journal of the Washington Academy of Sciences: Vol. 76, No. 1, pp. 82–87.

Honorable Mention—This category of recognition carries full and deserving merit of the work proposed, but due to a lack of funds available at the time of grants selection, carries no monetary support. The Charles A. Lindbergh Fund wishes to bring public attention to these exceptional individuals and their work so that prospective Sponsors will accept this endorsement and take the opportunity to provide personal financial support for continued work in 'better balance.' Contributions of all or a part of the funding requested are enthusiastically solicited by The Charles A. Lindbergh Fund and will be appropriately acknowledged.

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Martin T. Katzman, Program in Environmental Sciences, University of Texas at Dallas. "How Market Incentives Can Balance the Environmental Risks and Benefits of High Technology: Lessons for Success." Requested Funding: $9,950

Ulrich Jorg Krull, Department of Chemistry, University of Toronto, Mississauga, Ontario, Canada. "Artificial Chemoreception for Environmental and In-vivo Selective Chemical Sensing and Contaminant Control." Requested Funding: $6,000

Natividad T. Nacianceno, Office of Research and Institutional Studies, University of the City of Manila, Metro Manila, Philippines. "An Alternative Solution to Problems of Waste Disposal and Environmental Sanitation in the City of Manila, Philippines." Requested Funding: $9,478

David Stock, Biology Department, Stetson University, DeLand, FL. "Radiation-Damaged DNA Plasmids in Insect Cells: Potential Use of Radiation as an Alternative to Chemical Insect Control." Requested Funding: $10,580

Michael S. Switzenbaum, Department of Civil Engineering, University of Massachusetts, Amherst. "Anaerobic Treatment of Domestic Wastewater in Tropical Municipalities with Special Reference to South America." Requested Funding: $7,200

Anitra Thorhaug, Greater Caribbean Energy & Environment Foundation, Inc., Miami, FL. "Testing the Balance Between an Oil Spill Clean-up Technology (Various Disperseants) with Critical Fisheries Nursery Habitat Seagrass." Requested Funding: $9,500

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Human Ecology in History: The Search for a Sustainable Balance Between Technology and Environment

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ABSTRACT

The project is a world environmental history that will focus on the relationships between human beings and the natural environments that they inhabit. It will be an investigation of how technological development, and attitudes toward nature, have affected treatment of human habitats. The methodology adopted is that of environmental history, now a recognized historical sub-discipline. Part of the project that has already been completed and published, i.e. the relationship between human attitudes and practices affecting the natural environment in the Mediterranean basin in ancient times. The environment suffered severe damage in this period from processes such as deforestation, overgrazing, and erosion in spite of the generally positive and respectful attitudes of the ancient peoples toward nature. This can be explained by the rudimentary level of the understanding of nature in general, and of ecological science in particular, along with a Greek philosophical position that placed all natural entities in the service of mankind, and a policy of the Roman government that ignored or discouraged research.

This project is a world environmental history that will focus on the relationships between human beings and the natural environments that they inhabit. It will be an investigation of how technological development, and attitudes toward nature, have affected treatment of human habitats. Because it will embrace the history of humankind around the whole earth, it must be an interpretive survey, and cannot claim to be exhaustive. Within each society and period discussed, it will attempt to answer several questions. What were the typical attitudes expressed toward nature in literature, philosophy, religion, the materials of popular culture, etc.? What knowledge did they have of the workings of natural systems or the principles of the science of ecology? What was the ability of their technology to make major changes in the environment? Did they possess the social control necessary to channel their environmental impacts? What was the level of the population and how did this influence the kind and extent of these impacts?

In order to achieve the balance we seek, it is necessary to understand what the past human experience of technological growth and environmental change has been. The problems of human ecology existed in one form or another in previous periods. An historical study can make a valuable contribution of perspective in considering the ways in which human relationships to the natural environment altered their form and intensity through time, as well as varying degrees of human awareness of and understanding of the processes involved. The natural world is not just the background for human events, but an active participant (actually a numerous portion of the cast of participants) that helps to shape, color, and direct those events. This is not merely a novel way of looking at history, but a recognition of the actual order of things, in that human beings do in fact exist within ecosystems. Environmental history can arouse a shock of recognition: this is what human beings have been doing in, with, and to their world all along, and this is what nature, in turn, has been doing to them. Those who grasp this concept may well find themselves transcending a narrow humanism in the sense of indifference to the environment, and expanding their conceptual limits to a new humanism that recognizes and embraces the claims of all life, including, alongside, and in relationship to human beings.

As a newly-designated Lindbergh Grant Recipient, yet to complete the proposed research, I will here describe a part of this project that I have already completed and published in my book, *Ecology in Ancient Civilizations*. In 1817, inspired by a description of the ruins of the Ramesseum in Egypt, Percy Bysshe Shelley wrote the poem *Oxymandias*, which contains these lines:

> "And on the pedestal these words appear: 'My name is Ozymandias, King of Kings: Look on my works, ye Mighty, and despair! Nothing beside remains. Round the decay Of that collossal wreck, boundless and bare, The lone and level sands stretch far away."

Tourists who visit ancient ruins in the Mediterranean area today are familiar with the kind of scene Shelley described in this poem, if their vision is broad enough. Shattered statues and broken columns of vanished societies stand inside other ruins so vast we often do not see them: the ruins of the natural environment that these very civilizations depleted, causing their own destruction in the process.

The once-prosperous cities of Mesopotamia are now mounds in the desert, and the famous "Fertile Crescent" that supported them is a shrunken remnant, as revealed in photographs taken from space. There is a close interconnection between ruined cities and ruined land. Their association with each other is not an accident of history, but a pointed, ironic lesson in ecological imbalance.

The lesson is ironic because we would not have expected it to happen, given the attitudes of ancient people toward nature. The Greeks recognized mankind's oneness with nature and worshipped nature in the guise of gods who embodied aspects of it, such as Zeus, who guarded mountain tops, and Artemis, who protected wild creatures. They preserved natural areas, groves around springs in particular being considered sacred to the gods, and forbade hunting, fishing, cutting of trees, and cultivation within the precincts. We might call these sanctuaries the earliest national parks. But they were isolated islands in a denuded, eroded landscape.

The Romans had a genuine love of nature, celebrating fields and forests in

Latin Literature, but the Romans treated the actual landscape as a conquered province. Evidently good attitudes alone were not enough to maintain the balance of human societies with nature. Ecologically, the road to hell was paved with good—but inadequate—intentions.

The Greeks saw what was happening. In the *Critias*, Plato vividly described changes suffered by his homeland in two generations, including deforestation, erosion, and the drying up of springs. But Plato's constructive suggestions were ignored, and the despoiling of the land went on. Aristotle closely observed nature, but placed the world within a rational framework, assigning to minerals, plants, and animals a highest purpose, which was the service of mankind. His thought, authoritative for centuries in the Arabic countries and Europe, helped justify the cavalier use or misuse of nature according to human whim.

Where the Greeks were philosophical about the treatment of nature, the Romans were practical—but not consistently so. While they parceled out forests and rangelands to private syndicates for exploitation, they failed to see the possibilities of advances in technology, and they stifled research that might have enabled them to understand nature better. Emperors supported orators but ignored or persecuted researchers in the sciences, theoretical or applied. Romans also failed to use older knowledge they possessed. Knowing from experience how to treat land to guard its fertility, they nevertheless reacted to political and military crises by using wasteful methods that failed to support nature, and as a direct result nature was unable to support the Romans. Erosion, exhaustion of resources, debilitating pollution in several forms, diseases, food shortages, and ruinous inflation resulted and interacted with other forces to assure that the Empire would disappear or be changed beyond recognition. The decline and fall of Rome had an ecological dimension.

Thus our modern ecological crisis has roots in ancient times. In order to achieve the balance we seek, it is necessary to understand what the past human experience of technological growth and environment change has been. While it is the purpose of my project to describe what has happened rather than to offer recommendations, it is nonetheless likely that we can learn from the ecological successes and failures of earlier societies as we look to the future.

We need to find ways to use our technological abilities to minimize the destructive impact of our civilization on the natural environment, so that the balance can be sustained. History is a warning and a challenge to our attitudes, our ability to understand, our technical competence, and our willingness to make far-reaching decisions.

My new study will expand the geographical field of concern from the Mediterranean basin to the world, and the time frame from the ancient world to the sweep of human history. When I wrote *Ecology in Ancient Civilizations* and *American Indian Ecology*, I became familiar with earlier societies and how they handled technology in their habitats. Now I will follow the same themes on down to the present. My experience as editor of *Environmental Review* introduced me to environmental historians who work all over the world. The Lindbergh Grant, and a sabbatical, will help me travel to places where I can find the materials for historical research and become familiar with the environments in which the historical processes occurred. For example, I plan to go to the Soviet Union in August as part of a group that will meet with environmentalists and ecologists, and visit ecological study centers and nature reserves. Much of the period of the grant will be spent in libraries and research centers that have collections essential for this subject.

I hope the book, when finished, will be of value to people working in the fields of environmental studies, conservation, land use, resource management, and ecological science. I trust it may be useful in college courses in any of these subjects. But above all, I intend that it will be one that anyone concerned about achieving a balance between the preservation of our natural environment and a sustainable technology will find readable and interesting.

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Microsprinkler Irrigation—A Way to Conserve Water and Protect Crops

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ABSTRACT

Agricultural irrigation is one of the largest users of water in Florida. Because of Florida's sandy soils and irregular rainfall, agriculture needs water to optimize production. Microsprinkler irrigation offers a way to increase the irrigation efficiency for citrus, Florida's main economic crop. Instead of wetting the entire orchard floor as do higher volume overhead systems, microsprinkler irrigation conserves water by wetting only the soil surface under the tree. Compared to overhead sprinkler systems, it is estimated that properly managed microirrigation systems can save 10% of the irrigation water needed for citrus. This is estimated to be a potential savings of at least 6.5 billion gallon per year. Besides increasing irrigation efficiency, microsprinkler irrigation can also provide partial frost protection. By aiding in water conservation, microsprinkler irrigation helps maintain a viable agricultural system in balance with the natural ecology of a rapidly growing state.

Florida is one of the most rapidly growing states in the United States. Florida's population has quadrupled between 1950 and 1987, and Florida will soon become the fourth most populous state in the nation. This rapid population growth has already had an impact on Florida's fragile ecology of rivers, lakes, and wetlands.

Agriculture plays a major role in Florida's economy. Next to tourism, agriculture is the second largest generator of income in the state. Florida produces more citrus than any state in U.S. and is a major producer of vegetables and ornamental plants. Florida's soils are generally sandy and will hold very little water. Even though Florida normally receives over 1200 mm of rain, these low water holding soils make supplemental irrigation necessary for optimum yields. On an annual basis, most citrus groves in Florida do not use much more water than natural vegetation. However, during critical stages, erratic rainfall is not always sufficient for optimum growth. Hence, irrigation is needed during certain times of the year. Much of the water that is not used by the crop returns to the groundwater.

Largely because of Florida's low water holding capacity soils and erratic rainfall, agricultural irrigation is the largest user of water in Florida. There are 624,492 acres of citrus in Florida, and it is the state's major economic crop. Until the 1970's citrus was normally irrigated by flood (seepage) or overhead sprinkler irrigation. Permanent overhead irrigation was 75 to 90% efficient, while flood and volume gun irrigation was less efficient.

Microsprinkler irrigation is a relatively new form of irrigation that shows promise for conserving water. This form of irrigation was introduced into Florida in the early 1970's and has been found to be 90 to 95% efficient. By improving irrigation water use efficiency, more water can become available for Florida's natural rivers, lakes, wetlands, and ground water supplies.

Microsprinklers are small plastic emitters that deliver from about 5 to 26 gal/hour (20 to 100 liters/hour). With citrus, usually one microsprinkler emitter is used per tree. Depending on the capacity of the emitter and tree size, microsprinklers water part or all of the area under the tree canopy. This is where the majority of the roots grow. With mature trees, relatively little area outside the canopy zone receives water. Hence, microsprinklers can conserve water by covering the area of major root density, not 100% of the orchard floor.

The water saving advantages of microsprinklers are particularly apparent with young trees that have limited root systems. At a common spacing of 345 trees/ha (140 trees/acre), a 38 liter/hour (10 gallon/hour) microsprinkler can irrigate trees well. With 3 applications of 2 hours each per week, microsprinklers would use 8400 gallons week^{-1} whereas overhead sprinkler irrigation would use 20,000 to 27,000 gallons week^{-1}. With young trees, this means that microsprinklers could save 58 to 70% of the water applied by overhead irrigation. With mature trees, properly managed microsprinklers could save 10% of the water used by overhead systems.

Total acreage of microsprinkler and drip irrigation has increased rapidly since 1979 from 70,000 acres to over 200,000 acres to present. The normal annual amount of irrigation water needed for citrus is approximately 305 mm (12 inches) which is usually required in the dry spring and fall months. Because the citrus industry consists of both young and mature groves, one can estimate that 200,000 acres of microirrigation systems can save 10 to 20% of the water used by overhead or flood systems. This amounts to a potential savings of 6.5 to 13 billion gallons of water per year.

By using microirrigation, these several billion gallons of water could be available for other uses that would alleviate pressures on lakes, rivers, wetlands, and ground water recharge areas. At present, irrigation scheduling programs are being refined to improve management of microirrigation systems.[1,2]

When properly managed, microsprinkler irrigation has advantages for conserving agricultural water use during the growing season. Yet in winter, microsprinkler irrigation has an additional advantage—frost protection. From grower experience during a frost in 1977, it was suggested that microsprinklers might provide some frost protection. However, as late as 1980, it was debated if microsprinkler irrigation would provide any protection and a number of growers and scientists remained sceptical.

An unusual series of four severe freezes hit Florida between 1981 and 1985. These freezes were unprecedented in the exten-

Fig. 1. Example of microsprinklers used for frost protection of young citrus trees.

siveness of the damage they caused. Over 223,000 acres of citrus were killed. The only other comparable period was in 1894–85 and 1899 when several freezes caused major damage to Florida citrus. Freezes occurred in January, 1981, and January, 1982. Two even more damaging windy freezes came in December, 1983 and January, 1985. Since the turn of the century, freezes had not hit Florida in this unprecedented "back to back" manner. Total acreage dropped by 26% to 624,492 acres. Over 102 million boxes (4,196,680 million metric tons) of oranges were lost between 1979–80 and 1984–85. Direct economic losses were estimated to be over 2 billion dollars for the 1983 Christmas freeze and 472 million dollars for the 1985 freeze. Other major indirect sociological losses occurred such as unemployment of pickers, truckers, and other citrus related workers.

During these four freezes, the University of Florida initiated active research investigations into the effectiveness of microsprinkler irrigation for citrus frost protection. During that period, it was found that microsprinkler irrigation could indeed provide partial protection of young and mature trees. Amount of warming at different heights was determined,[3,4] effectiveness with young trees was shown to be improved with tree wraps[5] and covers,[6,7] and necessary precautions during windy freezes were noted.[8] An example of microsprinklers used for frost protection of young trees is shown in Fig. 1. Although microsprinkler irrigation does not provide complete mature tree protection, it does provide partial protection and is more affordable than traditional oil heating. Because of its effectiveness and cost advantage, microsprinkler irrigation has become the most commonly used form of frost protection in Florida citrus in just 5 years.

In conclusion, microsprinkler irrigation is an improved form of irrigation that can conserve water during spring, summer, and fall and provide partial frost protection during the winter. Because of these advantages, this form of irrigation continues to grow in popularity. By helping to conserve water, microsprinkler irrigation helps maintain a viable agricultural enterprise in balance with the natural ecology of a rapidly growing state.

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Antarctic Ice Volume and Global Sea Level: Will Their Balance Survive?

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ABSTRACT

The Antarctic ice sheet is devoid of life and free of permanent human inhabitants. It nevertheless plays a crucial role in the balance between mankind's activity and the global environment. Warming of the earth's climate as a result of mankind's inadvertent modification of atmospheric CO_2-content (accomplished by the burning of fossil fuel and through tropical deforestation) may release ice volume stored in the Antarctic ice reservoir. This release could raise sea level world wide, by over 6 m (20 ft.) in several centuries and prompt severe environmental stress as coastal populations retreat to new homelands.

Introduction: Geologic Perspective on Global Change

The vast mantle of Antarctic continental ice differs from all other portions of the earth's surface in two respects: (i) it is barren of indigenous life, and (ii) human populations on its surface are limited by international treaty (and the extreme conditions) to transient bands of scientists and the occasional adventurer. It is thus surprising to realize that Antarctic ice is part of the ever-present competition between human activity and the environment. Our surprise, in fact, exemplifies man's far-reaching capacity to produce unmediated change on a global scale.

The Antarctic ice sheet today, as in the geologic past, serves as a natural regulator of global sea level. When an imbalance exists between snow accumulation on its surface and glacial return flow at its seaward margin, water is either extracted from, or returned to, the world ocean. Ice-volume fluctuations in the past have been quite dramatic and have had a profound effect on the coastal habitats of the world. Eighteen thousand years ago, for example, global ice volume of the great ice age lowered global sea level by approximately 120 m (390 ft.). This low stand created the land bridge between Asia and North America that permitted early man to enter the Western hemisphere.

In the absence of man, future fluctuations of the Antarctic ice reservoir would proceed according to the slow pace dictated by the earth's orbital wobbles that modulate the reception of solar energy. Global ice volume would slowly increase over the next 80,000 years until the earth becomes shrouded in an ice age similar to that of the past. Rising levels of atmospheric CO_2 produced by man's use of fossil fuel (oil, coal, and natural gas) and tropical deforestation threaten to produce a *greenhouse* warming of the global climate. In this circumstance, man's activity may upset the natural, slowly paced progression of the ice ages and threaten to cause global sea level to suddenly rise.[1]

CO_2-warming in the Antarctic is expected to be greater than in temperate or tropical latitudes, in part, because of a postulated *ice-albeado feedback.* This feedback allows greater absorption of solar energy as the highly reflective snow cover is melted. Warming by as much as 6°C (12°F) could be expected by 2050 A.D. A possible consequence of this warming is the collapse of the western half of the Antarctic ice sheet that presently rests on bedrock that is depressed below sea level. If this collapse occurs, sea level would rise by as much as 6 m (20 ft.).

While we do not know the likelihood of such an ice-sheet collapse scenario, or how rapidly sea level could rise, the consequence of such a possibility mandate continued research on Antarctic ice-sheet stability. If sea level were to begin to rise by the middle of the next century, one could envision dramatic shifts of human populations that currently live within 6 m of sea level. Most of the heavily populated regions of Florida, for example, would be slowly inundated over a time period of 1 or 2 centuries (Figure 1). Initially, ill-fated coastal engineering projects designed to save real-estate investments would undoubtedly disrupt marine ecology and coastal sedimentation patterns. As the sea eventually becomes irresistable, population fall-back to higher ground would disrupt the previously unpopulated, agricultural habitats of the hinterland.

My role as a scientist, and the purpose of the grant provided by The Charles A. Lindbergh Fund, is to assess the impact of CO_2-warming on the Antarctic ice reservoir. My ultimate objective is to provide

Fig. 1. Florida as it would exist after a hypothetical sea-level rise of 6 m (20 ft.).

a forecast of global sea level rise in response to possible ice sheet collapse.

Research Activities: Seeking the Wisdom of Wildness

To forecast the future behavior of the Antarctic ice sheet five steps must be completed. First, one must identify the fundamental physical laws that govern balance between snow accumulation on the ice-sheet surface (ice input) and discharge by glacial flow into the ocean (ice output). This ongoing task is the concern of theoretical physicists, and is subject to constant updates and improvements due to interplay with the other three steps. Second, the physical laws must be incorporated into a computer model that simulates Antarctic ice-sheet evolution under prescribed climatic conditions. Third, the model must be tested and improved by comparison with observations of ice-sheet drainage. These two steps are my principal concern, and constitute the bulk of my ongoing research. Four, the simulation model is run with CO_2-warming as prescribed input to produce a forecast of ice-sheet behavior. Finally, the fifth and last step is to assess the level of uncertainty inherent in foreeasts of complex behavior.

Over the last four years I have focused primarily on steps two and three by constructing and testing a model capable of predicting change in parts of the Antarctic ice sheet most sensitive to CO_2-warming: the Ross and Filchner/Ronne ice shelves. This model was tested by comparison of its prediction for current conditions with glacial ice-flow measurements performed by myself and a West German colleague (Dr. Manfred A. Lange of the Alfred-Wegener-Institut für Polar- und Meeresforschung) during several Antarctic expeditions over the past five years.[2]

While comparison between model and field observations is providing insight into the natural mechanisms that regulate ice-sheet drainage, model performance is not yet sufficiently accurate to proceed with a forecast. Perhaps five to ten more years of research by myself and colleagues will be required before model performance will be sufficiently tuned to be a reliable forecast tool.

Conclusion: Implementation of Values

Perhaps the most difficult task for a scientist is to be patient with the slow rhythm of research. In this world of fast paced events, it is tempting to circumvent many of the quality-control steps in the forecast of environmental impact for the sake of a tantalizing headline. Fortunately, most scientists working in this field realize that such action would be disastrous: misinformed action can often lead to greater environmental damage than uninformed action. Quality in science thus depends in part on the personal values which guide each individual scientist.

Values guide scientists in other ways as well: choosing research topics, selecting appropriate methods, and disseminating results. For me, exposure to people brought together by the Charles A. Lindbergh Fund has helped to solidify my values (a process not required in most Ph.D. programs) on the relationship between science and mankind's general struggle to prosper on this limited planet. I have learned through discussions with scientists in other disciplines (who I would not normally meet) and with supporters of The Charles A. Lindbergh Fund that we have a great deal in common, and that often, this common thread concerns the perception and value of balance between man and nature.

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Solar Sail Engineering Development: Interplanetary Transportation with Environmental Benefits

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ABSTRACT

"For I dipp'd into the future, far as human eye could see,
Saw the vision of the world, and all the wonder that would be;
Saw the heavens fill with commerce, argosies of magic sails. . ."

Alfred Lord Tennyson [1842]

Exploration of the Solar System and rational use of its resources for our expanding civilization requires methods of space transportation which are low in cost, high in capability, modest in the amount of resources consumed by the transportation system itself, and which have a long useful life. The solar sail is a space vehicle which is uniquely outstanding in these areas. Rather than expendable propellants, a solar sail utilizes sunlight reflected by a large, lightweight metallized plastic sheet as a means of propulsion.

The faint pressure of sunlight is adequate to propel a spacecraft made with modern materials to and from a variety of destinations in the Solar System. Light pressure has been utilized to stabilize and control the orientation of a few spacecraft, but none have been built with the necessary configuration and controls to harness sunlight as a direct force for primary propulsion and orbit change.

With assistance from The Charles A. Lindbergh Fund, the Jet Propulsion Laboratory and others, the World Space Foundation is preparing for the first orbital test of a solar sail spacecraft. Preliminary designs have been completed, unique prototype hardware has been fabricated and tested, and some flight hardware is in storage. Project plans have been delayed by the loss of the Shace Shuttle *Challenger* and the resulting limitations of launch vehicle capacity. Highest priority is now placed on arranging a launch agreement.

Many missions have been identified which are either enabled or significantly enhanced through the use of solar sails. These include the exploration of several asteroids with a single spacecraft, returning samples from Mercury's surface, supporting expedition crews on Mars, and perhaps even carrying high-level nuclear waste far beyond the reach of the biosphere.

In addition to the engineering advantages inherent in their high performance, distinct environmental advantages may accrue to the Earth's atmosphere, the Van Allen radiation belts, and even in interplanetary space, from the use of solar sails instead of certain competing techniques. In addition, there is a certain appeal in a propulsion technique which only reflects sunlight, rather than extracting large quantities of chemical propellants from one environment where they are common and depositing them in another environment where they are rare.

Development of solar sailing represents an application of the concept of balance between technological advancement in space propulsion and limiting humanity's impact on potentially fragile natural systems upon which our descendents may depend.

In 1979, the World Space Foundation (WSF) established the Solar Sail Project with the objective of developing solar sailing as an advanced space propulsion technology.

Even with today's most advanced technologies, moving from one orbit in space to another requires massive quantities of propellant. This propellant cannot be obtained in space, and so must be brought at great expense from the surface of the Earth or another celestial body. Sunlight however, is abundant in the inner Solar System, and its energy can be harnessed with a large, kite-like solar sail to move scientific probes, expedition supplies, and eventually even commercial cargo among the planets and asteroids.

The WSF is constructing the first solar sail spacecraft for testing in Earth orbit. This working prototype of larger sails is expected to pave the way for such missions as in-depth exploration of mutiple asteroids with a single spacecraft, a close-in observatory of the Sun's polar regions, logistical support for expedition crews going to Mars, and others.

Light applies a very slight pressure on any illuminated object. In 1924, Fridrikh Tsander and Konstantin Tsiolkovskiy* noted that in the vacuum of space, a large, sail-like sheet of reflective material illuminated by the Sun could propel a spacecraft without propellant. Beginning in 1973, the U.S. National Aeronautics and Space Administration (NASA) sponsored a full evaluation of solar sailing, confirming its feasibility and unique advantages. Budget pressures forced the Agency to suspend development in 1977.

Prototype Design and Testing

Beginning in 1979, the Foundation's Engineering Mission spacecraft and its subsystems have been designed. After successful ground testing (Figure 1), a full-size prototype sail was completed in 1983. A full-size sail may be unfurled aboard the Space Shuttle in a final dress rehearsal for the Engineering Development Mission (Figure 2).

Engineering Development Mission

A fully-controllable solar sail spacecraft is targeted for launch into high Earth orbit for an engineering demonstration. Larger than a baseball diamond, the square sail may propel the spacecraft by the Moon on its way to escaping the bonds of Earth. Tests of attitude control, orbital maneuvering, electrical charging and ground control procedures will be valuable in designing solar sails of the future.

Asteroid Rendezvous Mission (ARM)

The most numerous bodies in the inner Solar System, asteroids, have never been visited. The EDM has been designed as a prototype for the Asteroid Rendezvous Mission, which, borne by a sail the size of two football fields, could lead exploration of near-Earth asteroids. Because its sail will require no propellants, the Asteroid Rendezvous spacecraft will be able to move from one asteroid to another in an open-ended survey. Rendezvous with

*It is almost certain that one of two men was the inventor of solar sailing.

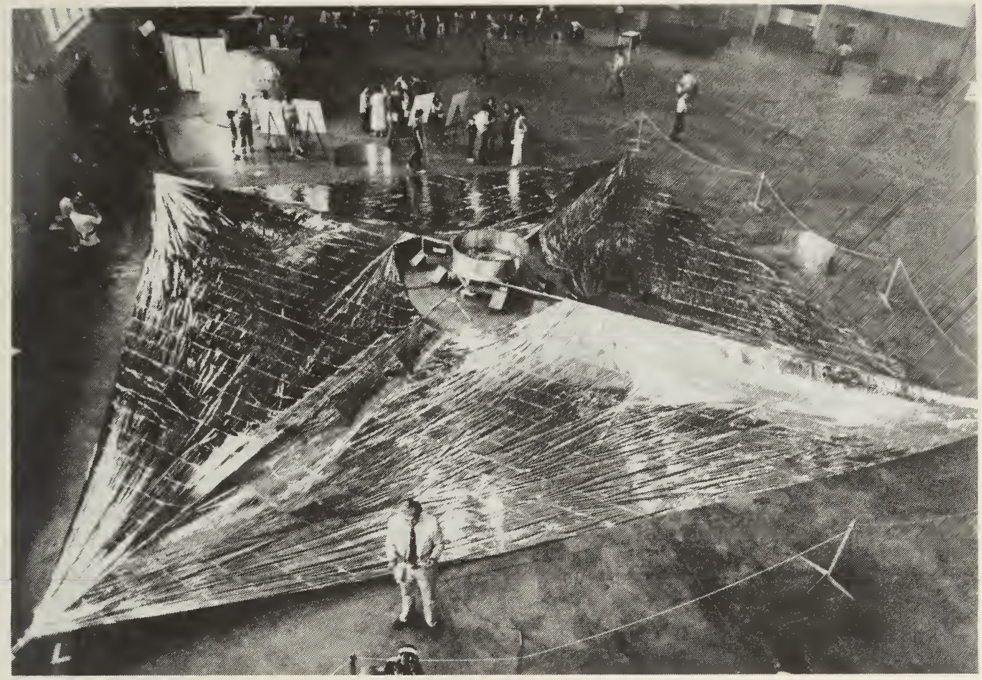

Fig. 1. The first solar sail ever made was deployed in a ground test by the World Space Foundation during 1981. Shown here is that half-scale prototype. Photo by Richard Dowling, Metavision.

a comet could also be added to the itinerary. Use of a solar sail allows one spacecraft to do a job which would require many using conventional propulsion.

Clipper Ships of Space

Just as sailing vessels enabled early maritime exploration and commerce, solar sailing vessels which could be built in space are uniquely suited to supporting expedition crews at Mars, the asteroids, and other destinations. Unfurling to nearly two miles on a side, a single "solar clipper" could carry about the same load as an "eighteen-wheeler" truck (30 tons) to Mars in four years, and return empty in two. A fleet shuttling between here and Mars could support the first permanent outpost on Mars. Like gleaming beads on an invisible string to Mars, the nearer clipper ships would be visible to the eye, with those near Mars visible using a modest telescope.

Nuclear Waste Disposal

Extensive stockpiles of nuclear waste have been built up since development of the first atomic weapons and the advent of nuclear power. A small fraction of these nuclear by-products termed "high level wastes" are highly radioactive and must be isolated from the biosphere for 100,000 years or more. While many methods of geologic disposal have been proposed, there is some question in each case of the permanency of isolation from groundwater and other elements of the biosphere. Space disposal has been proposed by a number of means, all of which require higher initial capital outlays than terrestrial disposal. The distinct advantage of space disposal, whether on the Moon, an asteroid, ejection from the So-

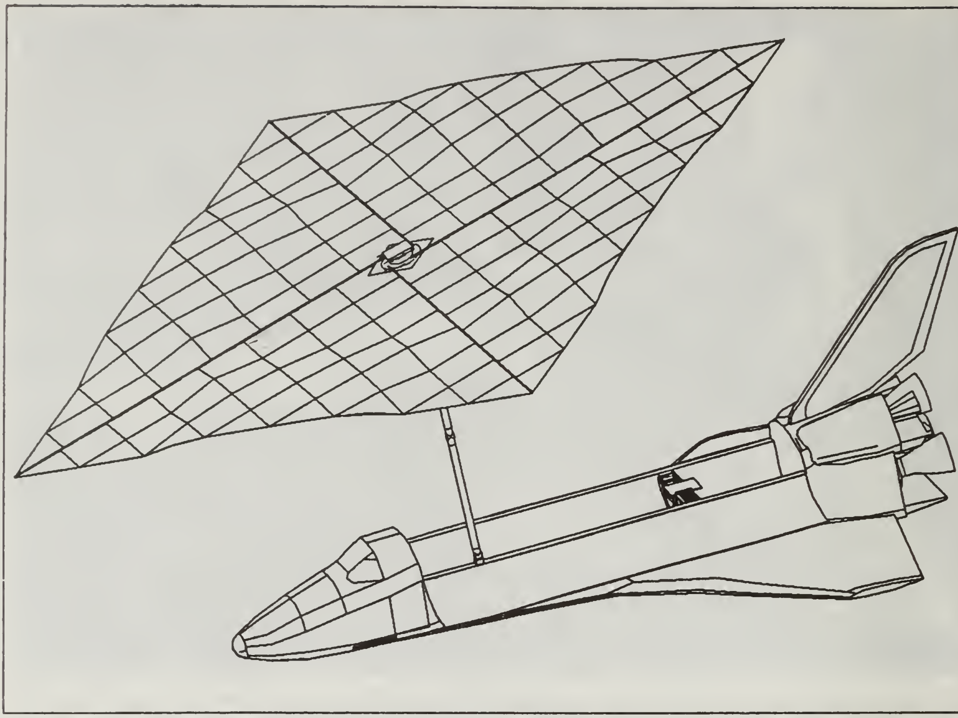

Fig. 2. Full-size test sail after deployment from the cargo bay.

lar System, or incineration by the Sun itself, is that the opportunity for natural reintroduction of significant quantities into the biosphere is eliminated. While no such proposal has been carried beyond the conceptual stage, transport beyond Earth orbit using Solar Sail Cargo Vessels, such as those examined for supporting expeditions to Mars, offers an opportunity for significant savings in launch mass from Earth, rocket traffic through the atmosphere, and risks associated with vehicle loss during ascent.

Other Applications

Numerous other applications have been proposed for solar sails. Sails offer the possibility of placing significant scientific payloads into orbit around Mercury with a modest launch vehicle and moderate flight time. Once in Mercury orbit, such spacecraft could then thoroughly map the planet, or even carry a lander which would go to the surface, pick up rock samples, and return to the waiting sail in orbit. The sail could then carry the sample back to Earth for analysis.[1] A similar sail could carry a scientific instrument package into close orbit around the Sun. Using the sail, the plane of the orbit could be slowly rotated, eventually taking the spacecraft repeatedly over the Sun's poles. The solar poles cannot be seen from Earth, but because of interactions between the solar magnetic field and the varying rotation rate of the Sun's outer layers, it may be expected that phenomena unseen on the visible portion of the Sun are waiting to be discovered. Sails have been proposed for missions in the other direction, i.e., for rapid escape from the Solar System to measure the properties of interstellar space. Sails may also find commercial use in affording more slots for communications spacecraft in stationary orbits above the Earth.[2] Descendants of solar sails propelled by massive orbiting banks of lasers or microwave transmitters could even traverse the distance to the nearest stars within less than a lifetime. Such laser (or maser) sails thus become candidates to carry the first tendrils of human civilization into neighboring star systems, perhaps beginning their journey within our own lifetime.[3]

The next fundamental step to be taken on the path to comprehensive utilization of sails in space is the test of a solar sail in orbit. Just as the first sailing vessels must have been something like a raft with a skin or cloth erected on a tree branch, and just as the distance covered during the first flight of the Wright Flyer was less than the length of modern airliners, the first solar sail is likely to appear crude by comparison with the vessels whose creation it fosters.

Future Plans

Shuttle Sail Deployment Experiment (SSDE)

During initial SSDE design, it was decided that disposal of the flight hardward in orbit after completion of the experiment resulted in the least overall cost to the Project, reduced risk of hardware failure, and the best simulation of actual EDM flight equipment. Consequently it is not necessary to be concerned with committing EDM equipment to the SSDE. The EDM could fly on nearly any launch vehicle, whereas the SSDE requires the presence of a crew to be most useful.

Preliminary design of the EDM is complete, and the detailed design process has been mapped out. Most detailed work is "on hold" until a launch vehicle is selected because the configuration may vary depending on launch loads and how the EDM package is attached to the booster and other payloads. A solid propellant upper stage motor (FW-5, manufactured by United Technologies Chemical Systems Division and donated to the Foundation by Hughes Aircraft Co.) will be used if the selected launch vehicle places the EDM in low Earth orbit. If a launch is available to geosynchronous transfer orbit or another high orbit, the FW-5 will be released for use on another Foundation mission.

The Foundation has enlisted the assistance of the Radio Amateur Satellite Corporation (AMSAT) for the provision of certain communications and electrical equipment, and for assistance in the establishment of a ground tracking network. AMSAT has built and flown a number of successful spacecraft. Optical tracking may also be provided by amateur astronomy groups, including France's Société d'Astronomie Populaire. Pasadena City College has provided valuable assistance in test and fabrication of parts, and will presumably be available once a final hardware design is selected to match a launch vehicle. Technische Universität München has offered assistance with the pre-deployment attitude control system.

In addition to The Lindbergh Fund, assistance has been received from California Institute of Technology's Jet Propulsion Laboratory (spars, thermal vacuum testing and control analysis), the University of California's California Space Institute (spacecraft charging study), the law firm of Silvestri and Massicot (negotiations and contracts), Morton Thiokol Corporation (solid rocket motor handling), United Technologies Corp./Chemical Systems Division (solid rocket motor inspection), E. I. du Pont de Nemours & Co. (Kapton for EDM sail), as well as Solar Sail Project Subscribers and Associates of the World Space Foundation.

Preliminary work continues on considering applications for solar sails. The Foundation co-sponsored The Case for Mars III conference during July, 1987 in

Boulder, which continued the process of defining how the first expeditions to land people on Mars might be performed. Solar sails could play an important role in such an expedition.[4,5,6]

As we stand gazing up at the stars or contemplting the thousand million miles to the outer planets, most people consider space an indomitable and unthreatened environment. The portion of space in which we reside, referred to as our Solar System, is in fact an environment existing in a balance established over five billion years of cosmic evolution.

Environmental destruction of newly-inhabited frontiers has often resulted from the simple lack of forethought on the part of early settlers. Frequently a handful of people speak for environmental awareness and protection, but awareness of space as a natural environment which could be subjected to regrettable human damage is not common in the field of astronautics. Only recently has the problem or orbital debris been perceived by space mission planners.[7,8,9] Formulated in 1979, one of the twelve objectives which guide World Space Foundation activities is to, "Encourage maintenance of space in its natural state and preservation of substantial undisturbed areas on celestial bodies commensurate with carefully planned exploration, resources utilization and settlement activities."

Conclusion

Solar sails are best suited for applications where multiple trips are to be made between two or more locations with bulk cargo having little sensitivity to trip time. The situation is analogous to present-day ocean shipping. Solar sails may make a substantial contribution to exploration by sending expedition supplies ahead of Mars-bound explorers with reduced cost and environmental impact at launch sites. Numerous other applications have been described in the astronautics literature. Nearly all of the applications noted can be accelerated by the early test of a solar sail spacecraft in Earth orbit. The World Space Foundation's Engineering Development Mission has been designed for just such a test, and is about as small as a sail could be while still providing useful day-to-day orbit changes which can be measured to verify different maneuvers and control techniques.

One mission class which could be aided by solar sailing has particular environmental and technological relevance; this is the disposal of high-level nuclear wastes. Space disposal is the only proposed disposal method (besides transmutation, which may require more energy than was generated with the original nuclear fuel) which provides absolute assurance of removing dangerous wastes from the biosphere for the required period of time. Space disposal draws this confidence from celestial mechanics theory, observation and practice over the past three centuries. In comparison, geologic disposal must rely on complex and still-evolving theories of terrestrial processes. Solar sails could provide transportation for high-level nuclear wastes from Earth orbit to whatever disposal sites might be selected.

While not a universal space propulsion technique, solar sailing does seem likely to play a major role in some future space transportation markets because of its economic attractiveness. Because sails typically reduce the launch mass required to take a given payload to a destination, launch vehicle traffic through the atmosphere may be reduced. When compared with several space propulsion techniques requiring mass expulsion, solar sailing compares favorably with regard to its impact on the space environment. Environmental impact in space is only a dimly-perceived concept at this time, but a historical perspective suggests that considerable long-term regret can be avoided through near-term awareness of possible environmental sensitivities of space itself.

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Titanium Recycling

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ABSTRACT

Motivated by the apparently low recycling rate of obsolete titanium scrap, indicating a social and technical system potentially out of balance, we assess the quantities of obsolete titanium scrap recycled. A materials cycle model is constructed and after addressing the inherent uncertainty of the equations in the model we conclude that the quantities of obsolete titanium scrap recycled are greater than what is reported. This indicates the recycling system may be in balance but that defense stockpiling activity based on the lower reported numbers is likely to be out of balance.

We were concerned that the reported small quantities of obsolete titanium scrap recycled indicated a system that was out of balance; a system that depended on energy intensive primary production instead of the more environmentally benign process of recycling. We hypothesized that the low reported quantity might be due to the newness of the metal or due to external factors such as pollution which both producers and recyclers might ignore.

The U.S. Bureau of Mines estimates that the quantity of obsolete titanium recycled annually is between 100 and 400 tons per year.[1,2] When compared to the current consumption levels of titanium, the apparent recycling rate for obsolete titanium scrap is quite low, approximately 2 percent. This is of special significance in the case of titanium, considered to be a strategic metal because: (i) titanium is a critical input in many sophisticated aerospace applications, (ii) the short-term lack of substitutes for titanium, and (iii) because the U.S. relies heavily on imports for the raw materials input.[3] The Federal Emergency Management Agency therefore stockpiles both titanium metal as well as rutile, the preferred ore from which to extract titanium. Because recycling acts like an internal flywheel in the materials system and consequently reduces the need for imports, an underestimate of the quantities recycled could result in an unnecessarily large and costly stockpile. The cost of acquiring a ton of titanium for the stockpile is approximately $11,000 which at an interest rate of 10 percent translates into an annual cost of $1,100 per additional ton stockpiled. Ensuring an optimal level of recycling thus has broad policy implications in addition to the trade offs in energy use and environmental disruption between primary sources and recycled sources of titanium.

One impediment to a high recycling rate might be that titanium is a relatively new metal, having been in use a little over 25 years. The market for obsolete scrap is even newer and thus may not be operating at a long term stable level. A second impediment might be due to external effects, factors such as pollution which affect parties other than the immediate buyer and seller. Differential external costs between primary production and recycling could arise because recycling requires less extraction of both ore and energy resources (so there would be a differential externality if the amenity value of wilderness is not considered) while less pollution may be generated by the recycling process itself.

These issues motivated us to determine: (i) how much obsolete scrap is available, (ii) how much obsolete titanium scrap is recycled, and (iii) what is the "true" recycling rate? The true recycling rate (the quantity recycled as a ratio of available obsolete scrap) must be distinguished from the apparent recycling rate (quantity recycled as a ratio of current consumption) which is often reported. The true and apparent recycling rates can be quite different in the case of new materials like titanium whose consumption has been changing over time and where the product, such an airplane, has a substantial product life.

In order to evaluate the true recyclng rate, we first estimated the availability of obsolete scrap. We adopted a time dependent systems approach to reflect the interdependence of recycling on production, fabrication and consumption. To this end we constructed a materials cycle model of the titanium industry.

1. The Titanium Materials Cycle

A materials cycle traces the path of titanium from its extraction to its disposal. In the case of titanium, the important subsystems that interact to form the overall materials cycle include the extractive sector, the manufacturing sector (facilities that convert raw titanium into usable products), end users (consumers of titanium and its alloys), and the secondary sector (facilities that salvage, reuse, process and dispose the waste generated by end users).

The properties of titanium that make it attractive to end users are its high specific strength, exploited in aerospace applications, and its high corrosion resistance, also of importance in chemical processing applications.[4] The consumption of titanium can be classified into:

- Aerospace uses: in airframe structural components and jet engine compressor blades. The restricted number of users makes obsolete scrap from these sources the least expensive to collect.
- Industrial uses: in pressure vessels, heat exchangers, etc. Such users are more spread out geographically and hence collection of obsolete scrap is more expensive.
- Alloying uses: principally as a deoxidant and grain refiner in steels, and as an alloying addition to aluminum and magnesium. This use, as opposed by the others, is dissipative in nature; because the titanium is dispersed in low concentrations (about .1%) in other complex materials, it is practically irrecoverable. There is no recycling of such obsolete scrap with the intention of recovering titanium.

Conceptually, of the total titanium sponge available in a year (the porous titanium that is produced from ore), a portion is made into ingots, a fraction of which is subsequently made into products for use in the aerospace sector and in the chemical industry. So called new or prompt scrap produced at the earlier stages is typically recycled at a high rate. Obsolete scrap results when the final products are retired at the end of their useful life. In any given year, some of the obsolete scrap generated is recycled, with the rest leaking away from the system.[5,6] The physical system described can be represented by a series of equations each of which quantitatively defines a processing step or use.[7]

Table 1.—Predicted Obsolete Scrap Recycled.

Year	Obsolete Scrap Recycled (tons)
1985	1200
1986	1950
1987	2000
1988	1400
1989	2000

2. Model and Results

We developed two models of the titanium system based on two sources of coefficients for the equations in the materials cycle. One source was from the published literature. The second source was based on responses to a survey of 45 experts in the titanium industry. As the results from each model were qualitatively similar we focus below on the first of the models.

The most likely predictions of obsolete scrap that would be recycled for the period 1985–89 are summarized in Table 1. These should be compared to the estimate reported by the Bureau of Mines for 1985 of between 100 and 400 tons of obsolete scrap recycled. Our estimates predict that the supply of scrap will almost double over the next five years.

We also investigated the effect of different coefficient values on the predicted level of recycling, in part because the experts surveyed indicated a range of values between .25 and .9 for the proportion of obsolete scrap that is recycled. Predictably, certain coefficients were found to have greater influence on the quantity recycled than other coefficients. The results of the sensitivity analysis, ranked in order of the absolute value of their effect, are presented in Table 2.

These results may be interpreted to represent either the effect of inaccuracy in the estimation of each parameter, or alternatively, the effect of technological advances in that field of processing. The effect is quantified by the value of the elasticity reported in column 3 of Table 2. The elasticity measure is the percentage change in the quantity of obsolete scrap recycled due to a one percent change in the coefficient. We find that the product lives have the largest elasticities and the next largest factor is the recycling rate itself.

The results of the model indicate that, if recycling of domestic titanium scrap in the aerospace and industrial product sectors is taking place at the 80 percent level, then the quantities of scrap recycled are about six times higher than the estimates of the Bureau of Mines. Given all the simplifying assumptions of the model, and the fact that the Bureau of Mines estimates are constructed from surveys as well, it may seem that the estimates are sufficiently close. However, the difference may be unacceptably high if the model were to be used as a tool in policy making decisions regarding primary and secondary production, or with respect to stockpiling. In particular, the difference be-

Table 2. Sensitivity of Results to Variations in Input Parameters.

Variable	Base value	Elasticity*
Life of aerospace products	20 years	−2.1
Life of industrial products	20 years	−1.6
Fraction of obsolete scrap recycled	.80	1.2
Exports of aerospace products	.60	−.7
Leakage during ingot-making	.20	−.6
Scrappage, aerospace fabrication	.75	−.6
Ratio, aerospace ingot/total ingot	.90	.5
Scrappage, industrial fabrication	.35	−.4

*Percentage change in the amount of obsolete scrap recycled due to a one percent change in the coefficient value.

tween our estimates and those of the Bureau of Mines can be said to imply the following: if the quantity of obsolete scrap is between 100 and 400 tons (the range given by the Bureau of Mines) then the rate of recycling would have to be between 7 and 27 percent for product lives of twenty years. This contrasts with the lowest estimate given by the experts in our survey of 25 percent and the highest estimate of 90 percent recycling of domestic scrap from the aerospace and industrial products sectors.

3. Conclusions

There is considerable uncertainty in the values of how much obsolete titanium scrap is available and how much is being recycled. Elsewhere we investigate a range of estimates instead of focusing on the most likely case as here. In spite of the inherent uncertainties, the results indicate that the amount of obsolete scrap recycled is likely to be quite higher than the figures reported by the Bureau of Mines. This suggests that the market for obsolete titanium scrap is not as immature as one would be led to believe from the reported quantities and implied recycling rates. The interaction between social and technological systems seems to have led to a reasonable balance between primary sources and recycled sources of titanium. However, the larger estimates of the quantity of titanium recycled here indicates that the policy for titanium stockpiling may be out of balance; large supplies available from recycling imply a reduced role for the National Defense Stockpile.

Acknowledgments

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Wild Ancestors of Crop Plants—A Neglected Resource

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ABSTRACT

The wild ancestors from which our crop plants were domesticated 7,000 to 10,000 years ago constitute an underutilized and threatened natural resource. Wild ancestors are easily crossed with their cultivated descendants, and they contain significant levels of genetic diversity of potential use in genetic improvement. They are threatened with genetic erosion partly caused by the introduction of advanced cultivars which undermine their genetic foundation. This situation calls for increased conservation efforts both *in situ* and *ex situ,* thus establishing a balance between the conservation of a natural resource and its economic use in crop improvement.

Introduction

Some 7,000 to 10,000 years ago, humanity underwent one of the most significant changes in its existence: hunters and gatherers started growing crops and herding animals. This new activity would lead to a more sedentary lifestyle and would increase food supply and thus allow a significant portion of the population to engage in activities other than food production, such as industry and commerce. The beginning of agriculture in a number of independent areas (e.g., Fertile Crescent of the Middle East, Mesoamerica, and the South American Andes) was also a prelude to the appearance of large cities in these areas, such as Ur, Nineveh (Middle East), La Venta, Tres Zapotes (Mesoamerica), and Chavin de Huantar (Andes).[1,2]

Through deliberate cultivation, wild plants have been subjected to selection pressures which have led to marked changes in their morphological, physiological, and genetic constitution. Selection pressures resulted from planting and harvesting practices, as well as the introduction of plant materials into different environments. For example, seed planting led to a reduction of seed dormancy to achieve rapid and even germination.[2] Certain modes of harvesting required a suppression of natural mechanisms of seed dispersal. Plants were therefore selected with nonbrittle rachises as in cereals (e.g., wild barley: *Hordeum spontaneum;* wild maize: *Zea mays* ssp. *parviglumis*) or nonshattering pods as in legumes (e.g., wild common bean: *Phaseolus vulgaris* var. *aborigenius* and var. *mexicanus*). It is this set of radical changes induced by cultivation in wild plants which constitute plant domestication. The domestication process has led to a symbiosis between humans and plants: whereas humans have to rely on plants for food and other uses, cultivated plants have to rely on humans for their continued existence and propagation. Cultivated plants cannot survive in the wild.

Since its inception at the beginning of the 20th century, plant breeding has relied primarily on the genetic diversity provided by cultivars. Little or no use has been made of the wild ancestors of crop plants. According to Harlan,[3] this can be attributed to several causes, among which an inadequate taxonomy, insufficient collections and rampant genetic erosion within collections (see also further). Yet, in recent years, interest in the wild relatives has been on the rise, albeit timidly. In the next paragraphs, I will outline some of the advantages and disadvantages of using wild crop relatives as a source of genetic diversity, and will then discuss the need for both *in situ* (on-site) and *ex situ* (off-site) conservation approaches, with particular reference to the common bean (*Phaseolus vulgaris* L.).

Advantages of Wild Crop Relatives as a Source of Genetic Diversity

There are two main advantages to the use of wild relatives as a source of genetic diversity. First, contrary to "truly" wild species, wild crop relatives are conspecific with the crop to which they gave rise. As a consequence, they can be easily crossed with cultivars and the progeny is viable and fertile.[4] Gene transfer from wild relatives to crop plant should therefore be quite easy, unlike gene transfer between different species which can be faced with serious problems of viability, fertility, and linkage blocks.[5]

The second advantage of wild relatives is their store of genetic variability. Examples exist of genetic diversity for agronomic traits which has been transferred successfully (or could be so) from wild progenitors to crop derivatives.[6,3,7] Modern sugarcane cultivars incorporate additional chromosomes from wild relatives carrying resistance to virus and fungal diseases. Wild relatives of tomato have contributed genes for resistance to viruses, fungi, bacteria, and nematodes. In common bean, Gentry[8] and Brucher[9] mention the existence of genes for resistance to anthracnose, *Fusarium* sp., and bacterial diseases in wild common bean. Van Schoonhoven et al.[10] have identified wild common bean populations of Mexico which have high levels of resistance against seed weevils (*Coleoptera: Bruchidae*). Resistance against this pest is found only among wild beans and is correlated with the presence of a protein in the seeds.[11]

Wild relatives have also provided the male-sterility inducing cytoplasms and fertility-restorer genes needed for hybrid seed productions in barley (*Hordeum vulgare*).[12] The wild *arundinaceum* race of sorghum (*Sorghum bicolor*) is photosynthetically more efficient at low light intensities than cultivated sorghum.[13] Diploid wild wheats have a higher photosynthetic potential than cultivated wheat.[14,15] The nutritional value of oats could be improved by transferring high protein levels from wild to cultivated oats (*Avena sativa*).[16]

Through appropriate breeding schemes, wild crop relatives can (and in certain cases have indeed) been a source of increased yields, for example in oats,[16] pearl millet (*Pennisetum americanum*) (L.) Leeke:[17] and chickpea (*Cicer arietinum* L.: 18).

Disadvantages to the Use of Wild Crop Relatives as a Source of Genetic Diversity

In spite of these obvious advantages, little use has been made of the wild ancestors of crop plants. I would suggest here that one of the major reasons for this is the important morphological differences separating the wild ancestors and cultivated progenies as a consequence of the domestication process. Plant breeders have been reluctant to use as progenitors any material which would threaten to nullify the long evolutionary process from which our modern advanced cultivars have emerged. Yet, traits separating wild and cultivated types are usually controlled by a limited number of genes or else are highly heritable. For example, in common bean, the difference between climbing growth habit (characteristics of wild beans) and bush growth habit (found in cultivars) is coded by 3 major genes.[19] Seed size is generally considered to be a polygenic trait; however, Motto et al.[20] have shown in wild x cultivated common bean crosses that seed size has a high heritability (approx. 0.8). These two examples indicate that it would require little effort to recover a cultivated phenotype in wild x cultivated crosses.

A second aspect hampering a substantial use of wild relatives in genetic improvement is the limited availability of wild forms in germ-plasm collections. The *Phaseolus* world collection at the Centro Internacional de Agricultura Tropical in Colombia contains some 30,000 cultivated common bean accessions but less than 1,000 wild common beans.[21] The actual distribution area of wild common beans is still being identified as shown by recent findings of Nabhan[22] in Chihuahua (Mexico; the northernmost accession of wild *P. vulgaris*), of Gepts and Debouck;[23] the first description of wild common beans in the Sierra Madre Oriental of Mexico), and Brucher (9; the first descriptions of wild common beans in Costa Rica and Panama). Only recently are wild *Phaseolus vulgaris* (and wild *Phaseolus* species) being collected systematically through the efforts of the International Board of Plant Genetic Resources.[24,25] Undoubtedly, the reduced presence of wild forms in gene banks is related to their perceived limited practical importance. However, wild crop relatives have been found to harbor significant genetic diversity and the breeding methodology is available to transfer it to cultivated types. In addition, genetic resources of wild crop relatives (as well as of landraces) are threatened by genetic erosion.[3,2,26] Part of this genetic erosion is paradoxically due to the introduction of advanced cultivars, which therefore undermine the very genetic foundation on which they are based. More extensive conservation efforts are needed, therefore, to fully utilize the potential of wild crop relatives.

In situ and *ex situ* Conservation Efforts

Genetic conservation of wild crop relatives can be achieved by *in situ* and *ex situ* conservation efforts, both of which have advantages. The advantages of *ex situ* conservation (i.e., conservation in cold storage in gene banks outside of the natural ecosystem) are the immediate availability to users, the potential for extensive evaluation, and a reduction of the threat of gene losses due to pests and diseases and destruction of the habitat. The advantages of *in situ* conservation (i.e., conservation in the natural ecosystem) are the continued adaptive evolution in conjunction with pests and diseases and the maintenance of the natural ecosystem *per se* as a source of other products (forage, fiber, fuel), for watershed maintenance, etc.[26] Continued adaptive evolution with pests is illustrated by wild common beans and seed weevils in Mexico. A study of weevils in wild bean populations has revealed that weevils are subject to a number of hyperparasites which presumably may contribute to some form of biological control of weevils in these natural populations. The wild bean-weevil-hyperparasite triangle could become a model for pest management in cultivated ecosystems.[27] Therefore, the hyperparasites of the seed weevils also constitute a valuable genetic resource in need of protection.

In the case of the common bean, conservation efforts, both *in situ* and *ex situ,* represent a particular challenge as the geographic distribution is quite large: it extends from Chihuahua (Mexico) over Central America into the Andes and ends in northwestern Argentina (9, 27; and references therein). In order to devise efficient conservation strategies, an understanding is needed of the biogeographic pattern of genetic diversity. This understanding should help us identify areas of high or unusual variability which could become primary targets of conservation efforts. Patterns of genetic diversity are best analyzed using molecular or biochemical markers, such as seed proteins, isozymes, restriction fragment length polymorphisms, as these markers provide a good assessment of genetic similarity of distinctiveness.[28,29] This approach has already provided interesting results in the case of the common bean. Based on phaseolin seed protein diversity, it has been possible to postulate multiple domestications along the distribution area of wild beans: two major ones (Mexico, southern Andes) and the minor one (Colombia).[30,31]

Conclusion

Wild relatives of crop plants have been neglected as a source of genetic diversity, in spite of the fact that useful traits have been identified among them, and that these can be transferred relatively easily to the cultivated descendants. One reason for the infrequent use of wild relatives is their limited number in gene banks. A more active conservation effort directed towards these wild populations is needed, especially in light of the threat of genetic erosion, brought about in part by the introduction of modern, high-yielding cultivars. The identification of areas of high or unusual genetic diversity in wild crop relatives for *in situ* and *ex situ* conservation efforts will help maintain a balance between technology and the environment, as advocated by C. Lindbergh: these genetic resources will be preserved for the future while at the same time being made available for the breeding of improved cultivars.

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Natural Energy for Nitrogen Fixation

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ABSTRACT

Nitrogen fertilizer is essential to continued high-level production of most cereal grains which are major sources of food worldwide. During the energy crisis of the 1970's, there were shortages and prices increased rapidly. This situation could recur in the 1990's, with the most severe shortages in countries lacking indigenous gas supplies.

Wind turbines and photovoltaic cells are alternate sources of energy which can provide power input to the electric arc process for nitrogen fixation. These systems provide an opportunity to use very sophisticated technology in a synergistic way that is totally in harmony with the environment. The process uses only air, water and limestone. The technology can be implemented at small scale, and there is no pollution.

Some results of operation of an arc reactor with a wind turbine and also by direct connection to solar cells are described. It is shown that both are feasible. However, research to improve the efficiency of the arc process is needed to make the systems more economically attractive.

1. Introduction

Nitrogen fertilizer is essential to continued high-level production of corn and most cereal grains, which are major sources of food worldwide. In the United States, nitrogen fertilizers account for about 28% of the energy input to agriculture. It has been estimated that the increased energy content of grains producd is 2.76 times the energy input from the fertilizers.

During the energy shortage in the 1970's, companies which producd ammonia (the most common nitrate fertilizer) from natural gas were, for a time, unable to make new contracts for gas. Supplies of ammonia were inadequate, and price increased rapidly. Interest in alternate energy sources and alternate processes for fertilizer production became intense. This situation could recur in the 1990's, with the most severe shortages in countries lacking indigenous gas supplies.

Among the most promising alternate energy sources are wind turbines and photovoltaic cells. These sources share the characteristic that energy supply is not easily matched to demand. Some form of energy storage is needed, e.g. batteries or super-flywheels, if power is to be continuously available, and storage becomes a significant part of system costs. Wind, in most locations, has very high energy peaks for short durations and significant periods when little or no energy is available.

The electric arc process for nitrogen fixation is interesting because the reactor has a very low cost, but can absorb large amounts of energy, and the product can be stored indefinitely. It provides an alternate use for a power source whose primary load is intermittent, e.g. irrigation pumping. Also the arc reactor can be used as a variable load to limit speed of the wind turbine, probably at much less cost than other methods of speed control such as variable-pitch blades.

This system provides an opportunity to use very sophisticated technology in a way that is totally in harmony with the environment. The process uses only air, water and limestone or phosphate rock. It can be decentralized and small scale. There is no pollution.

This paper describes some results from operation of the arc reactor by a wind turbine and also by direct connection to solar cells. It is shown that both modes of operation are possible.

Research to improve efficiency of the electric arc process is needed to make it economically attractive under currently forseeable economic conditions. Also, more work is needed on speed control algorithms for wind turbines with fixed blade pitch.

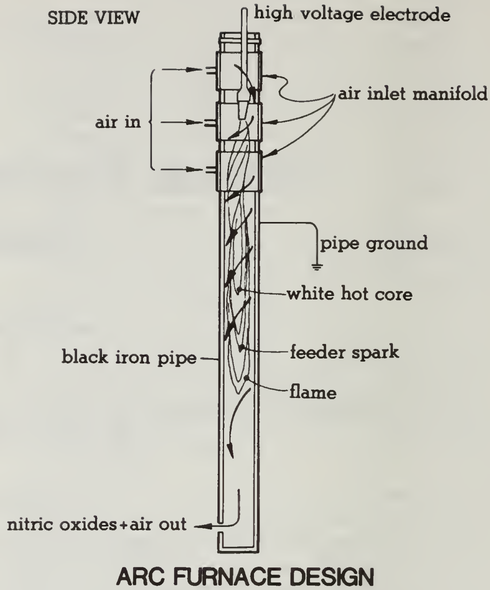

Fig. 1. Kettering arc reactor.

2. The Arc Process for Nitrogen Fixation

The electric arc process for nitrogen fixation was first used commercially[1] in a plant designed by Bradley and Lovejoy at Niagara Falls in 1902. A small plant designed by Birkeland and Eyde was built in Norway in 1903. By 1930, this had grown to be Norway's greatest industry,[2] but the Haber process[1] had lower costs, and soon after replaced the electric arc process.

Considerable research and experimentation on the arc process was done during the 1920's. Among the most notable is a series of 4 papers by Steinmetz.[3] In 1927, Colin and Tartar[4] reported that the best yield they had found was 90g of nitric acid per kwh, which corresponds to 48000 kwh per metric ton of nitrogen captured, and the highest equilibrium concentration observed in closed-circuit experiments was 14.4% nitrogen oxide (NO).

Some investigators have argued that formation of NO in the electric arc is a purely thermal process, no different from heating air with a flame. The equilibrium concentration of NO in air ranges from 0.123 at 4000°K to nearly zero at room temperature, and the rate of decomposition is very high. Consequently, it is only by very rapid cooling that the NO can be retained at low temperatures. According to Gilbert,[5] 4860 kwh/ton (of N) is required to heat O_2 and N_2 to 4000°K and form NO. Since the equilibrium concentration of NO in air is only 0.123 at 4000°K, an infinite cooling rate would re-

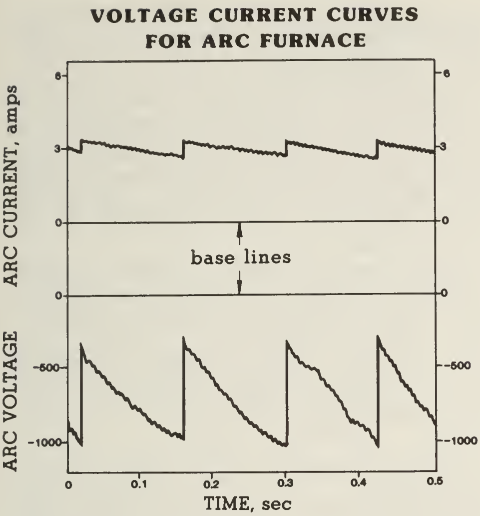

Fig. 2. Typical voltage and current records for the arc reactor.

sult in 4860/0.123 = 39,512 kwh/ton. This accounts for 82% of the 48000 kwh/ton observed in laboratory experiments. If thermal ionization is the only phenomenon involved, there is little hope of greatly improved yield.

Another view of the arc process is that ionization is caused by electrical phenomena in the arc and ions recombine randomly so that, if gasses could be instantly cooled, the fraction of NO would be about 0.33 in air. However, after leaving the arc, the NO decomposes at a rate which decreases as temperature decreases. Steinmetz[3] (p. 457) hypothesized that yields of 33% NO could be obtained from an arc operating at 1400°K. He also suggested that the temperature of the arc depends on the boiling point of the cathode material.

A serious study of nitrogen fixation in arcs, with modern instrumentation and knowledge of plasmas might be very rewarding. If concentrations of NO approaching 0.33 could be achieved at arc temperatures around 1400°K, it should be possible to reduce the energy required for nitrogen fixation by the arc by a factor of 10. This could have great economic significance.

Treharne and associates[6] at the Kettering Foundation began work on the electric arc process in late 1974. Their interest was in developing a "small scale" process which could be used in less-developed countries where a small amount of nitrogen could have a large impact on food supply. An arc reactor designed at Kettering was installed at the University of Nebraska Field Laboratory in late 1979. Operation of the reactor by utility power and by photovoltaic power processed through batteries and an inverter has been described by Rein *et al.*,[7] who found that it required about 60,000 kwh to fix one metric ton of nitrogen. A sketch of the Kettering arc reactor is shown in Figure 1.

3. Direct Photovoltaic Power

The electric arc reactor at the University of Nebraska Field Laboratory has been operated at power levels from about 0.7 kw to 5.3 kw by direct connection to panels of photovoltaic cells. This system is elegant in its simplicity. It involves no batteries, no transformers, and no control system. The voltage across the Kettering arc reactor has the characteristic "sawtooth" pattern, shown in Figure 2, because the arc is blown down the tube by a spiral stream of air; breaks off and reattaches near the electrode. Power drawn by the arc varied by a factor of two at frequencies of up to 10 hz, but caused no perceptible problem in operation. Clouds passing between the sun and the solar panels caused power variations by a factor of 5, but the arc continued to operate.

Data from these experiments were used to develop equations describing the relation between airflow rate, arc current and arc voltage. By various connections, it was possible to obtain open circuit voltages of about 1000 or 1200 volts, and short circuit currents of about 2, 4, 6 or 8 amperes. An additional parameter which was varied was the amount of air flowing through the arc. Current from the solar cells is self-limiting, and they can be directly connected to the arc reactor without any control system or other current limiting device.

Arc welding in space should be possible with a similar system.

4. Wind Power

A computer simulation model of a wind turbine and arc reactor was developed[8,9] which includes all essential features of the system. Major components of the model are: generations of wind velocity from power spectra, wind-rotor interaction, drive-train dynamics, electrical load of the arc reactor, and an elementary control system. Some conclusions from the simulation are:

(a) The electric arc reactor can be operated with fluctuating power of a wind turbine.
(b) The arc reactor can act as a variable load which controls speed of the wind turbine so that variable blade pitch is not required if a simple feedback control system is included.
(c) Significant mechanical vibrations can be induced by the "sawtooth" wave form of the arc load. An arc reactor with constant arc length would be much preferred for use with wind turbines.

Predictions of the computer simulation have been confirmed by successful operation of the arc reactor at the UNL Field Laboratory with a wine turbine. A schematic of this system is shown in Figure 3. A typical record of power available from the 18 ft-diameter wind turbine and power consumed, is shown in Figure 4. The 3-

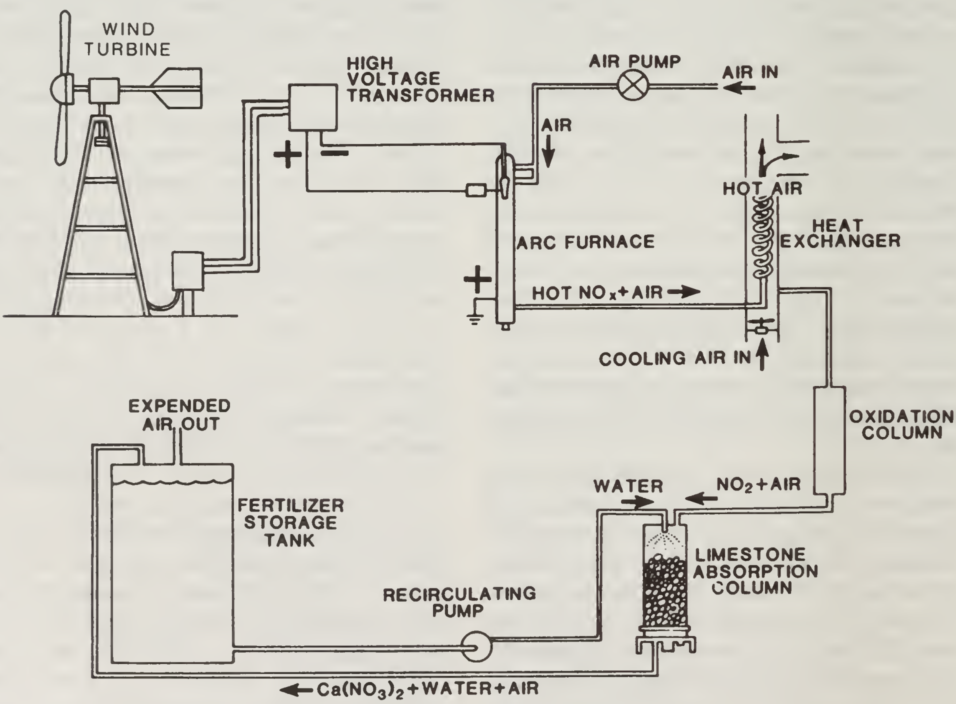

Fig. 3. Wind powered nitrogen generator system.

phase AC generator in the experimental system is designed for 240 volts at 1800 rpm. It has a voltage control which makes output voltage proportional to frequency. The high-voltage transformer has surplus inductance in its primary side, which limits current. Arc current remained between 2.0 and 2.5 amperes for a wide range of generator speeds.

The "available wind power" in Figure 4 is the total power in the airstream. The average of the mechanical power in the figure is 3.3 kw. Since the power coefficient of the wind turbine is about 0.3, the curves are in good agreement. Rated power output of the generator is 5 kw, and its efficiency is not very good at the low power output shown in the figure.

The experimental wind turbine is protected from rotor overspeed by a mechanism which is activated by fly-weights to change blade pitch. A safety system is needed to protect the turbine when the electrical load is disconnected, even though it is not necessary under normal operating conditions.

Significant mechanical vibrations have been observed under some conditions, as predicted by the simulation. The fundamental frequency of the "sawtooth" voltage wave form of the arc may vary from less than 1.0 Hz to at least 10 Hz, and it contains strong harmonics at frequencies at least 5 times the fundamental frequency. Consequently, significant excitation of mechanical vibration can occur at frequencies ranging from less than 1.0 Hz to at least 50 Hz.

It appears that arc reactors for use with wind turbines should be designed to have an arc length which does not change rapidly with time. One possibility is to use a magnetic field to spin the arc. This might achieve the rapid arc movement which ap-

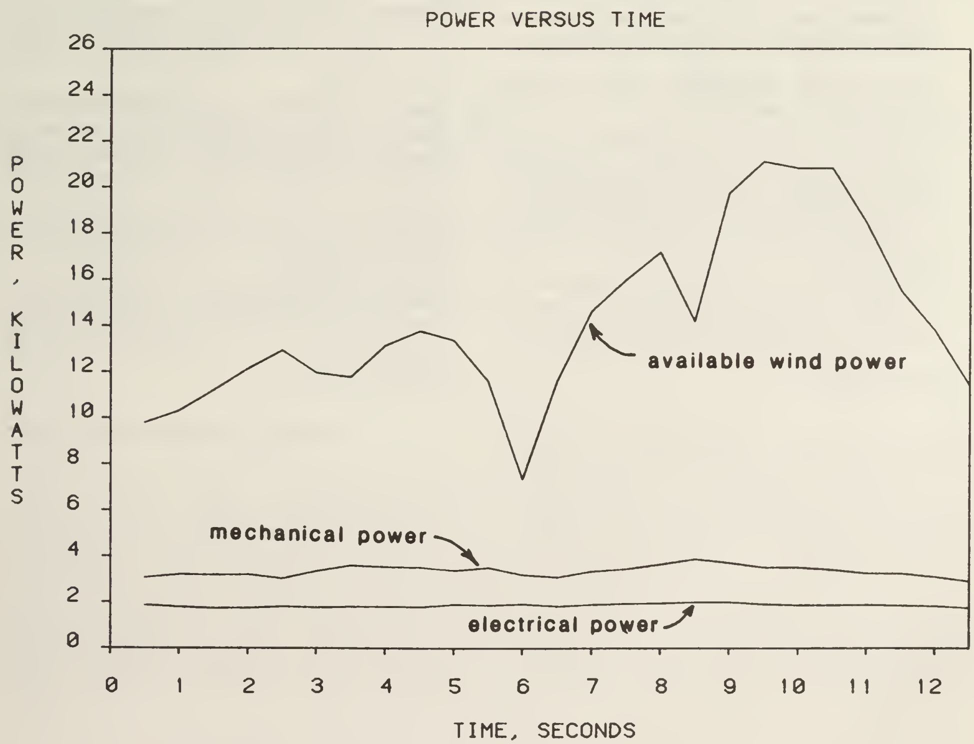

Fig. 4. Power-time curves with the electric arc in moderate winds.

pears necessary for formation of NO, while avoiding periodic fluctuations in arc voltage which can excite mechanical vibrations.

5. Conclusions

The conclusions of this study are the following:

1. The arc process for nitrogen fixation can be operated with power from direct connection to photovoltaic cells or with power from a wind turbine. Operation with power from photovoltaic cells is remarkably simple. These systems are totally in harmony with the environment. The process uses only air, water and limestone. There is no pollution.
2. Practical operation of the arc process with power from a wind turbine appears to require an arc reactor with constant arc length. Some work on voltage regulation and startup controls is also needed.
3. An effort should be made to improve yield of electrical processes for nitrogen fixation, utilizing contemporary theory and experimental capability.
4. More work on optimum design of wind turbine systems should be done, in anticipation of the next energy crisis.

6. Acknowledgements

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"Communicating with an Endangered Culture: The Maasai Mara Expeditions"

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ABSTRACT

"Each day that we camped made the jungle more real and, at the same time, civilization stranger, until I understood the Maasai questioning our values."(Charles A. Lindbergh, *Autobiography of Values*, page 381)

The Maasai are on a collision course with modern society in Kenya. Their land has been slowly and systematically eroded by tourism under the guise of nationalizing game reserves and by various land management schemes that are, in theory, designed to benefit the Maasai population as a whole, but in reality benefit only a small number of politically astute individuals.

Maasailand once covered virtually all of Kenya, Tanzania and Uganda. Today, their nomadic lifestyle is restricted to an ever decreasing area of southern Kenya and northern Tanzania. Consequently, the Maasai are tenaciously holding on to a way of life against all odds. They are a nomadic people who do not feel compelled to assimilate or absorb external cultures. Hopefully, it is not too late to preserve the culture and identity of the Maasai people. By studying their language, nomenclature and color preferences we can learn how the Maasai see, feel, think and communicate—on their own terms. By developing empathy with and for the Maasai culture we can better understand the problems they face and we can look for solutions wihtin a Maasai frame of reference. For the only chance the Maasai have for survival is to learn, once again, to control their own destiny.

The Maasai Mara Expeditions

The Maasai Mara Expeditions were conceived as a means of producing an intercultural communications handbook about the Massai. Named for the language they speak, Maa, a distinct and unwritten African tongue, the Maasai of Kenya still live much as they did thousands of years ago. Today, communications with the 300,000 inhabitants of Maasailand is frequently diffused and misinterpreted because the Maa language and cultural frame of references are totally ignored.

A failure to communicate with the Maasai was first brought to my attention by Thane Riney who, at the time, was

Chief of Wildlife and Forestry in Africa for the Food and Agricultural Organization of the United Nations (FAO). Mr. Riney recognized that English and Maasai, lacking a common frame of reference, lost a great deal through translation in yet a third language, Swahili. Even two refined languages such as English and Russian can be difficult to translate. For example, the phrase "out of sight, out of mind" translated from English to Russian and immediately back into English translates as "invisible maniac". And we have a great deal in common with the Russians compared with a total lack of knowledge of the Maa language and Maasai attitudes and perceptions. Therefore, it should come as no surprise that FAO projects encompassing health, education and welfare, programs for legislating land, programs for increasing crop yields and improving cattle range land—all failed, wasting enormous amounts of time, energy and financial resources.

The specific aim of the Maasai Mara Expeditions is to develop a communications handbook that defines Maasai words, graphics, symbols, color associations and preferences. In the execution of communications materials for Maasai projects in the past, the use and importance of color has been overlooked entirely. If we want a positive reaction to our communications efforts, knowing which colors produce a positive effect is extremely important. That this is true is evident and easily substantiated by the millions of dollars spent by manufacturers and advertising agencies researching product and package design. We know a great deal about how people or groups of people react to color. For example, Americans rank the following colors in order of preference; (1) blue, (2) red, (3) green, (4) white, (5) pink, (6) purple, (7) orange, (8) yellow. Cooler colors are preferred by people in cooler climates, warmer shades are preferred in the warmer parts of the country. More importantly, colors are not used only for aesthetic reasons; they are loaded with meaning. Color communicats, suggests,

evokes associations—and therefore creates feelings and brings back memories.

We also know that color is emotional, not rational, and the appeal is largely subconscious. There also seems to be a collective subconscious and, as a consequence, all individuals belonging to the same culture seem to react in a similar way when exposed to color. For example, black and orange have become traditional colors for Halloween just as red and green have become traditional colors for Christmas. Additionally, color creates very definite psychological feelings. Medically, it has been found that red can effect blood pressure and respiration. Blue, on the other hand, is a psychological sedative. Yellow produces the sensation of sunlight and warmth, yet the slightest change in yellow will render it warm or cold, soothing or irritating. Our color research with the Maasai found that black, a negative color in the west, ranked first as it represented the sky before it rains, which translates into abundant water for their cattle.

Other areas of visual comprehension that need to be explored include magnification, perspective and foreshortening. These visual phenomena, along with the mental concept of anticipation, are all relative abstractions in a literal culture.

Maasai Mara Expedition I was sponsored by The Explorers Club and funded by Discover Magazine. Conducted in March, 1982, two tented base camps were established in the Maasai Mara Game Reserve and in the Loita Hills near the Tanzania border. The research team consisted of six participants and six camp crew. Research was, for the most part, deductive, starting with a specific premise and arriving at a logical conclusion. Expedition members systematically photographed the color and graphic design of beaded jewelry and clothing, documented color preferences and associations in relationship to culture and environment, photographed cattle branding, recorded oral traditions and collected material culture for future references.

Maasai Mara Expedition II was sponsored by The Explorers Club and funded by Discover Magazine and Rolex Watch USA. Conducted in January, 1983, a single base camp was established on the Mara River within the Maasai Mara Game Reserve. The project team consisted of four participants, eight camp crew and six film crew. Expeditions members systematically photographed color and graphics in beaded jewelry, documented color associations and recorded nomenclature of common objects. Additionally, due to a government ban on the importation of beads and on the formation of warrior manyattas (camps), no material culture was collected and the Maasai warrior camps have been forced into hiding in the deep bush country. Our objective was to locate a secret Maasai warrior camp, perhaps the last manyatta in Maasailand, and document the tenacity of a proud people holding on to a way of life against all odds. British television produced a half hour, prime time network documentary of the expedition for worldwide distribution. This film has since been aired in the United States on the Discovery Channel. It is hoped that public awareness of the Maasai plight will reduce government pressure.

Massai Mara Expedition III was funded entirely by The Lindbergh Fund. Conducted in December, 1984 and January, 1985, by two of the original team members, a series of interviews were arranged and recorded to balance our predisposed point-of-view in favor of the Maasai. In addition to interviewing businessmen, politicians, and Maasai Game Wardens, funding allowed us to continue photography of material culture and illustrations of common objects for a dictionary of Maa nomenclature.

Maasai Mara Expedition IV will be conducted in October and November, 1987 to review the final manuscript for accuracy and to incorporate the current state-of-affairs to Maasailand. Manuscript will be ready for publication in the spring of 1988.

A brief review of previously published material on the Maasai falls into a number of different categories including historical, autobiographical, ecological, ethnology and social anthropology.

One of the earliest and most interesting accounts is Joseph Thomson's "Through Maasai Land". Published by E. F. Loftus as part of the Early Travellers in East Africa series. Joseph Thomson was the first white "European" to enter Maasailand in January, 1883 and reported in great detail on the trials and tribulations of exploring unkown territory and his first encounters with the Maasai, establishing notions of savage primitivism for the next twenty years. Autobiographical works written through the early part of this century and up through the present day tell quite a different story. "Barefoot over the Serengetti" and "Waters of the Sanjan" by David Read, "African Saga" by Mirella Ricciardi and "Maasai" by Sonia Bleeker all speak of the friendly, honest, intelligent nature of a proud and independent people.

It would be fair to say that ninety percent of all books publishd on the Maasai are somewhat repetitive, beginning with Gunther's "Inside Africa" and ending with the latest tourist guidebook. These books range from a modest review of cultural highlights, such as "Kenya Past and Present" published by the Kenya Museum Society, to expensive "coffee table" books with magnificent color plates, such as "Maasai" by Carol Beckwith and Tepilit Ole Saitoti. Other visual presentations of the Maasai culture include "Vanishing Africa" by Leni Riefenstahl, "Africa, A Continent Revealed" by Rene Gordon, "Massai" by Salvadori and Fedders, "Maasai the Magnificent" by Ada Wincza (a private edition of 500 copies). "The Maasai" by S. S. Sankan, and "The Herd & Spear" by Solomon Ole Saibull. These books are quite beautiful to look at and are comprehensive regarding the daily lifestyle and cultural traditions of the Maasai.

"Maasai Grammer" by Tucker and Mpaayei, "Maa" and "Maasai Mara" by Fr. Frans Mol, "Rangeland Management and Ecology in East Africa" by D. J. Pratt and M. D. Gwynne, and "The Lonely African" by Colin Turnbull, though concerned with the Maasai in contemporary society to a much greater degree, still fail to offer any solutions.

If solutions are not found soon, the Maasai will be increasingly disenfranchised and alienated from Kenyan society by the end of the century. It is startling to realize that two percent of the world's population are nomadic peoples, yet they inhabit nearly fifty percent of the available land surface. They are the most neglected group where international assistance and health services are concerned, partially due to the extremely low density of their numbers in the vast areas through which they roam. Often their cultures and values are little or not at all known to us, necessitating new approaches to communication. Nomadism is the consequence of long historical adaptation by groups to particular climatic and ecological circumstances. Technological progress in Kenya is creating pressure on the natural environment, the vast area of Maasailand, and the Maasai themselves are forced into the matrix. Nomads forced to leave their natural environment and their tribal, migratory lifestyle to settle into community life results in deculturation, establishment of slum existence and severe psycho-social disturbance. They will tend still to rely to some extent on their traditional principles, so that intercultural projects must win local cooperation of the tribe.

One of the most celebrated peoples of Africa, for centuries the Maasai have roamed the land and ignored the national boundaries that sprung up around them. But today, they are finding themselves increasingly restricted and misunderstood by the modern Africa that now encircles them. The Maasai Mara Expeditions is a completely original investigation dealing with the Maasai point-of-view; their perception and frame of reference in regard to language, color and graphics. In the end, the preservation of the Maasai's natural environment depends not on knowing how to speak to them, but rather, in learning how to listen.

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Environmental Benefits and Possible Applications of Excited Impinging Jets in the Jet Engine Industry

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ABSTRACT

The development of advanced heat transfer techniques is of significant importance to the environment and the growing jet engine industry as the impetus towards reductions in aircraft fuel consumption and by-product pollutants present in aircraft exhaust. By studying how the application of excited flow fields can change the cooling characteristics of a jet engine turbine blade, it may be possible to optimize cooling techniques which will allow gas turbine engines to be operated at higher temperatures. In experiments conducted by the authors, a curved plate (used to simulate the inner leading edge of a blade) was subjected to a jet flow field with an induced periodic disturbance. This disturbed flow was found to be less efficient at cooling the blade than that of an unexcited field. Through interaction with the jet engine industry, there will be an opportunity to develop new research programs investigating the suppression of any harmonic disturbances in the impinging jet cooling techniques presently used in modern day aircraft engines. If new methods of blade cooling can be developed which allow engines to operate at higher temperatures (and thereby consume less fuel), it will be possible to positively effect both industry and environment through the production of more cost efficient yet less polluting aircraft. (Figure 1)

A major problem facing the gas turbine industry involves developing a way to increase fuel efficiency by allowing the production engine to operate at higher temperatures. Present metallurgical limitations restrict the operating temperatures to approximately 1,300°C. For this reason, an increase in gas temperatures

Fig. 1. A Gates 35/36 Learjet, typically used for corporate executive transport. This is an example of the type of aircraft which would benefit from the development of more efficient engine cooling techniques.

require the development, optimization, and implementation of more effective heat transfer techniques.

Turbine blade cooling is often accomplished through the use of a jet flow impinging on the blade's inner leading edge (Figure 2). The air used for cooling is bled off of the engine's compressor. This air, by the very nature of its origin, is not acoustically stable. In certain cases, acoustics will enhance heat transfer by strengthening vorticies in the flow field. In other instances, excitation will suppress turbulence and flow field vortices, thus reducing heat transfer. In the latter case, overall engine performance is reduced.

For this experiment, a curved plate mounted in a thermally insulated box (Figure 3) was subjected to an impingement jet emanating from a rectangular nozzle mounted at an adjustable height. Upstream of the nozzle was a settling chamber containing a 25 cm speaker which provided harmonic excitation to the flow field. The plate temperatures were measured by thermocouples using a computer controlled data acquisition facility. When the flow field was excited, plate temperatures were found to increase by as much as 10%. To understand this, one must examine the structure of the flow field itself.

As a jet of air exits a nozzle, it sheds a train of vorticies from each nozzle lip which advect downstream before eventually breaking up into a fully turbulent jet flow. When excited, these vorticies coalesce, or "roll-up" into large discrete structures. Since these structures are generated in pairs, there exists a high induced velocity field between them which, under ordinary circumstances, would be expected to enhance heat transfer. However, it is believed that, due to the confined fluid field within the curvature of the plate, these vorticies re-entrain the already warmed air. Since a smaller tem-

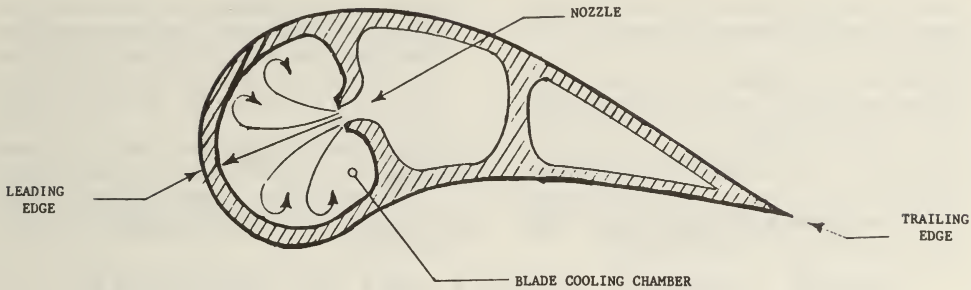

Fig. 2. Turbine blade cooling process.

perature difference exists between the blade and the plate, less heat is transferred from the blade, and the cooling efficiency of the jet is reduced.[1,2,3,4,5,6,7]

It would appear that these preliminary tests warrant a more comprehensive study of excitation effects. By working with the jet-engine industry, we plan to acquire experimental data on the frequency and amplitudes of periodic disturbances present in modern gas turbine engines. These conditions will then be reproduced in the present experimental facility to determine if it is possible to squelch the dominant frequencies and optimize heat transfer. As heat transfer is increased, the amount of air spent from the compressor is reduced. This reduction, in turn, increases the overall fuel efficiency of the engine. By raising efficiency, the average fuel consumption is reduced, as is the over-all pollution emitted by the engine.

In the long run, it is hoped that, by developing and optimizing systems which reduce flow field disturbances, a significant contribution can be made towards increasing turbine performance. By pursuing the study and reconceptualization of such mechanisms as impinging jet cooling, we may ultimately and positively effect the quality of life on Earth through more efficient use of its natural resources and enhancement of the atmosphere and environment.

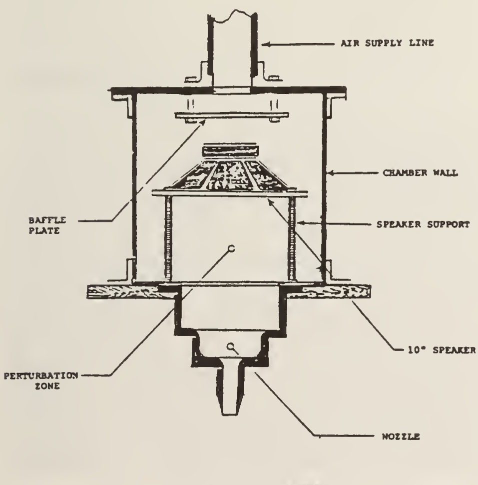

Fig. 3. A Typical Jet Engine.

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Soil Conservation and Redevelopment of Agricultural Terraces in the Colca Valley, Peru

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ABSTRACT

Ancient farming sites offer an opportunity to learn about the long-term effects of agriculture on soils and landscapes. An understanding of these effects is essential in the search to balance intensive agricultural land use with the conservation of soil resources. In this study, soils terraced and farmed for at least 1500 years in the Andes of southern Peru were investigated to evaluate their productivity and to observe soils cultivated over a long time period. While over half of the agricultural terraces are abandoned, many are still in use. The government of Peru is interested in redeveloping abandoned terraces to increase food production for a growing population. Field and laboratory research suggests that soils in both presently cultivated and abandoned terraces have physical and chemical properties favorable for agriculture. Properties indicative of good tilth and fertility in topsoils include: thick loamy topsoils, granular structure and abundant macropores, slightly acid to neutral pH, and relatively high amounts of organic matter and nutrients such as nitrogen and phosphorus. These data suggest that traditional management practices in the region support a sustainable agricultural system that is well-adapted to the mountainous environment and that the potential productivity of abandoned terraces is high.

Introduction

This study of soils in ancient agricultural terraces in Peru has focused on two problems relating to agricultural land use and soil conservation. The first problem involves the long-term effect of agriculture on soil. While much research has been directed toward evaluating the relatively recent effects of agricultural practices on soils, less is known about the effects of agriculture on soils after centuries of use.[1,2] The Colca Valley provides an excellent opportunity to study soils cultivated during the past 1500 years or more.

A second concern in this study is the abandonment of over half of the traditional agricultural terraces in Peru, most of which were built before the Spanish conquest.[3,4] In the Andes and other Mountainous regions, agricultural terraces are an important source of arable land. Mountain terracing, involving the construction of nearly level fields upslope of a series of stepped walls built across hillslopes, creates stable fields in terrain otherwise unsuitable for farming because of steep slopes and shallow soils (Fig. 1). It is estimated that terraced fields constitute one million of the 2.6 million hectares of cultivated land in Peru. The extensive disuse of terraces thus constitutes a significant loss of farmland at a time of increased need for food production with rising population, and at a time when many rural people are losing self-sufficiency by migrating to overcrowded cities. This situation has prompted the Peruvian government and certain U.S. government agencies to become interested in restoring abandoned terraces and associated irrigation systems.[5] Information about the current and potential productivity of terraced soils would help to provide a basis for redevelopment of abandoned terraces.

Both problems addressed in this study relate closely to Lindbergh's concept of a balance between technological growth and conservation of natural resources. First, many who are involved with agricultural and environmental sciences are increasingly aware of the need for agricultural systems that are not only highly productive, but that also conserve, rather than degrade, soils and other natural resources.[1] Knowledge about traditional agricultural systems and a longer time perspective on the effects of agriculture on soils may help in the search for a balance between the intensifying land use accompanying modern agricultural technology and the need for resource conservation. Because soil is essentially a non-renewable resource on a human time scale, monitoring soil changes induced by cultivation, cropping, and other agricultural practices is an integral part of the effort to conserve soil.

Second, agricultural terraces of the Andes and other regions themselves comprise a valuable resource with a long history. Many who have observed these terraces recognize the extraordinary engineering and agricultural skills involved in their creation and use. In essence, extensively terraced areas such as the Colca Valley represent agroecosystems well-adapted to a mountainous environment

Fig. 1. Agricultural terraces in the Colca Valley, Peru. Abandoned agricultural terraces in foreground.

(Fig. 1). This research suggests that both presently used and abandoned terraced soils in the Colca Valley are agriculturally excellent because of careful terrace construction and good soil management practices. Redevelopment of abandoned terraces represents a sound way to increase agricultural production without environmental degradation.

Methodology

This study, begun in 1984, involved both field and laboratory phases. Fieldwork consisted of describing[6,7] and sampling soil profiles in a variety of geomorphic settings to characterize the range of cultivated and natural soils. Data on uncultivated soils gave information on selection of sites for agricultural terracing and also provided a reference against which soil changes resulting from agricultural practices could be assessed. Also, many samples from 0 to 15-cm depth were collected along transects in presently cultivated terraces, abandoned terraces, and uncultivated areas to characterize topsoils more intensively. Volcanic rock and organic deposits were sampled to develop a chronology of natural soil development and the history of agricultural soils. Stream water samples were collected to examine the possible long-term effects of irrigation water on the soils. A general soil/surficial geology map of part of the Colca Valley was also prepared.

Laboratory analyses relevant to evaluating the productivity, fertility, and other properties of the soils were also conducted. Properties measured to assess tilth, water retention, water movement, and aeration include texture, bulk density, and available water capacity. Properties measured to assess soil fertility include organic carbon, total nitrogen, total phosphorus, availability of selected nutrients (e.g., phosphorus), carbonate, pH, cation exchange capacity and exchangeable bases, and mineralogy. Details and references for sample preparation and analyses of these properties are given elsewhere.[8,9] Methods for analyses reported in Table 1 include: soil texture (pipette method), bulk density (clod method), total nitrogen (semimicro Kjeldahl method), and pH (1:1 soil to water, glass electrode). Chemical analyses of irrigation water, acidified in the field to less than pH 2, were determined by the University of Minnesota Analytical Research Laboratory using ICP. Radiocarbon dating was done by Beta Analytic, Inc. and potassium/argon dating was done by the Laboratory of Isotope Geochemistry at the University of Arizona.

Results

Information gathered to date about natural and terraced soils in the Colca Valley is summarized in this section. Please refer to Sandor[8,9] for a more detailed presentation.

A perspective on the relatively rapid and profound soil changes resulting from agriculture can be gained by considering that many of these soils had been forming naturally for thousands of years before agriculture and human existence in the semiarid region. During that time, subsoils layers with accumulations of clay, silica, and carbonate developed in stable landscape positions. Dark-colored, organic matter-rich topsoils were mostly less than 0.5 meter thick. Volcanic rocks underlying a moderately developed soil within the main Colca Valley was dated in this study by the potassium/argon method at 172,000 ± 14,000 years. This means that many of the natural soils were several hundred thousand years to perhaps several million years old before they were farmed.

Soils in the Colca Valley have been greatly changed from their natural state by agriculture, especially their upper layers. The long history and continuity of soil use is indicated by radiocarbon dates and

Table 1.—Summary of laboratory data for 1986 soil samples (0–15 cm depth) collected along transects at 5 meter intervals in the Colca Valley, Peru.

Transect type	Number of samples	Sand	Silt	Clay	Bulk density	pH	Total Nitrogen
		----------------%----------------			$Mg\ m^{-3}$		$g\ kg^{-1}$
Cultivated Agricultural Terraces	34	42(6)	37(3)	20(1)	1.33(0.10)	6.4(0.2)	1.72(0.22)
Abandoned Agricultural Terraces	34	42(4)	40(5)	19(3)	1.35(0.10)	6.7(0.4)	1.57(0.51)
Uncultivated Areas	30	47(6)	32(5)	21(5)	1.38(0.09)	7.2(0.5)	1.17(0.30)
$LSD_{0.05}$		3	2	1.5	0.05	0.2	0.18

Notes: 1. Data are means with standard deviations in parentheses.
2. Samples from two cultivated and abandoned terrace transects, and three uncultivated area transects, are combined in this table.
3. $LSD_{0.05}$ = Least significant difference at the 0.05 level.

archaeological evidence which show terrace agriculture continuing from over 1500 years ago to the present day.[8,9] Soil changes are most pronounced in topsoils and include: thickening, texture changes, distinctive soil structure and pores, irregular trends of organic matter and other chemical properties with depth, decreases in pH, and increases in nitrogen and phosphorus. In several properties (clay and silt content, pH, total nitrogen), cultivated soils are more uniform than topsoils in abandoned terraces or uncultivated areas (Table 1). Subsoils beneath terraced surfaces have generally remained intact, although there is evidence for their chemical alteration by downward movement of ions in solution. The specific changes in soil physical and chemical properties discussed below are largely the result of agricultural practices such as terracing, cultivation, fertilization, and irrigation. These soil properties are important determinants of soil productivity.

Probably the most visible soil physical change is topsoil thickness increase, ranging from 0.3 to 1.3 meters, brought about by terrace construction.[9] Also, a comparison of topsoils from cultivated terraces, abandoned terraces, and uncultivated areas indicates a modest increase in silt and a corresponding decrease in sand in terraced soils (Table 1). This is likely the result of particle-size sorting during the accumulation of sediment upslope of terrace walls. Terraced topsoils have distinctive structure and pores. The compound structure is medium subangular blocky parting to fine subangular blocky and granular.[8] Macropores, often tubular in shape, are abundant, as are earthworms in presently cultivated soils. The favorable tilth exhibited by these soils is further shown by moderate bulk density, which tends to be lower in terraced vs. uncultivated topsoils (Table 1).

Several soil chemical properties have also been transformed by agricultural practices. Organic matter and total nitrogen (Table 1) contents of terraced topsoils are generally high, but often are irregular with depth,[9] probably because of periodic additions of dung and other amendments (e.g., ash from burned vegetation) added to the soils over the long duration of agricultural use. Similar buried organic matter-rich layers were reported in Andean agricultural terraces by Wright[10] and Keeley.[11] High concentrations of phosphorus occur in presently cultivated and abandoned terrace soils.[9] These high phosphorus levels reflect residual accumulation from long-term fertilization. This study has also documented significant movement of agricultural phosphorus into subsoils, notable because soil phosphorus is usually considered relatively immobile.[12] These data add a longer time perspective to research on modern U.S. agricultural soils which indicates phosphorus movement in association with manure additions (e.g., Tisdale et al.[13]). The pH of terraced topsoils is usually slightly acid to neutral, a range generally considered optimal for nutrient uptake by plants. The transect data reveals a trend of decreasing pH from uncultivated soils to soils in abandoned and cultivated terraces (Table 1). A possible reason for this is increased nitrification in terraced soils with higher organic matter contents. Leaching of soils by irrigation water may also play a role in pH decrease; however, irrigation water also adds significant quantities of bases such as calcium, magnesium, sodium, and potassium to terraced soils.

Discussion

While much work remains to be done on the issues of restoration of abandoned terraces and soil changes caused by agriculture, progress has been made on both problems in this study. The emerging picture is that topsoils in both cultivated and abandoned agricultural terraces seem to be agriculturally excellent in most respects. In terms of physical condition, the granular structure, friable consistence, abundant macropores, earthworm activity, and extensive root permeation indicate good soil tilth.[9] The structure and porosity result in favorable permeability and aeration, and the moderate bulk densities show that the soils have not been compacted from tillage. These features combine with the loam texture and thick topsoil to produce a high available water capacity. Relatively high organic matter levels also promote aggregate stability and good tilth. Soil retained behind terrace walls provides a deep rooting medium. Soils in the terraces, even those on steep slopes, are generally stable, except in some landslide areas. Factors such as careful construction and close spacing of terrace walls, as well as subsoil properties that seem to favor low erodibility (e.g., silica cementation is one possibility being explored), may contribute to the soil stability. Both cultivated and abandoned terraced soils seem generally fertile, having received additions of organic fertilizers over a long time period. The majority of soils have levels of organic matter and the macronutrient nitrogen comparable to fertile soils in the Midwest U.S. These relatively high organic matter levels, dominance of smectitic clays, and slightly acid to neutral pH, indicate high cation exchange capacities and base saturation percentages. The soils are generally rich in total and available phosphorus.

This study suggests that soil is not a limiting factor with regard to the potential for redeveloping abandoned agricultural terraces in the region. Why, then, is terrace redevelopment such a difficult undertaking? Treacy,[5] who has worked closely with farmers in the study area, identified several social and economic barriers to terrace reconstruction. These include problems of land ownership, water rights, labor relations, and securing new markets for new production. Until progress is made on these issues, terrace restoration projects such as that begun in the study area in 1986[5] will have difficulty making headway. Even so, these initial efforts that are fraught with difficulties may open possibilities for future success. In terms of this study, basic data about the soil resources in the agricultural terraces are being made available to government agencies of Peru and the U.S. involved in terrace reconstruction. Further testing of initial results and research into questions about phosphorus, soil stability, and indigenous soil knowledge in the Colca Valley are continuing.

Agricultural practices over the past 1500 years or more have clearly altered the soils of the Colca Valley. Most of these changes are interpreted as having a beneficial effect in terms of soil productivity, in contrast to the degradation incurred by many modern or some other prehistoric agricultural soils.[2] These terraced soils are similar in some respects to plaggen soils in Europe and elsewhere, which have been built up over centuries of use by additions of amendents.[6] Researchers striving today for agricultural systems that maintain soil quality as well as production can look to the Colca Valley terraces as an example of sustainable agriculture. Traditional management practices in the region such as terracing, fertilization, crop rotation/fallowing, and low-impact tillage form the basis of an agricultural system that conserves soil and is well-adapted to its mountainous environment.

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Utilization of Seafood Wastes as a Source of Nutrients for Agricultural Crops

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ABSTRACT

The U.S. Seafood industry generates large quantities of wastes and an acceptable solution to dispose of the wastes within the boundary of federal and state laws is urgently needed. The prohibition of indiscriminate dumping of the wastes into oceans, streams, and lands has placed a severe burden on the industry and threatened its survival. The proposed plan to use the wastes as a source of nutrients for agricultural crops fertilization will lessen environmental contamination and confer upon the wastes an economic value when used as a fertilizer. Such usages would help (a) to preserve the health and integrity of the seafood industry and the cleanliness of our environment, and (b) to provide a better understanding of the biological and chemical relatedness between marine and plant organisms.

Introduction

The practice of using seafood as a source of nutrients for crop growing is an ancient one. A popular Thanksgiving story relates how the early American Indians put a fish in each "hill of corne" and saved the Plymouth Colony from starvation by teaching the Pilgrims to do likewise. Although the authenticity of such a practice and the origin of the idea of utilizing fish as a fertilizer are uncertain,[1] it is generally recognized that seafood contains nutritional qualities beneficial for crop growth. The general perceived beneficial aspects of seafood on crop growth, however, are based upon casual observations rather than methodological experimentation. Such percep-

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tions of the desirable usefulness of seafood on crops can perhaps be readily appreciated when one considers the chemical composition and ingredients present in such materials. Both organic and inorganic substances necessary for crop growth are present in varying amounts and kinds in seafood. Despite the ancient practice of using seafood and its byproducts for manuring crops, a proper scientific understanding of the real value and biochemical action and properties of seafood on plant growth is still to be sought.

The literature pertaining to seafood and its byproducts on plant growth is relatively scarce because few scientific investigations have been conducted on the subject. However, interest is gradually growing because ecological (environmental), economic, and legal concerns dictated attention to dealing with the seafood wastes problem.[2] The U.S. seafood industry generates a large quantity of wastes. Thus, the disposal of the wastes posed a major problem for the industry and for preserving the cleanliness of the natural environment.

In the past, animal scientists have used seafood byproducts in feed rations to enhance body weight gain of farm livestock. Recently, Mudge[3] showed that fish solubles could serve as a source of nutrients for certain species of insects. Crab wastes have been composted and dehydrated for disposal and have been used as a fertilizer.[4] In Louisiana, crawfish waste has been shown to be an effective source of calcium for neutralizing soil acidity in the growth of Bermuda grass.[5] Fertilization of corn grown for silage use in Idaho with partially dried Rainbow Trout (*Salmo gairdneri*) fish manure wastes indicated increased yield.[6] Interest in the utilization of seafood wastes for crop production is also gaining interest outside the U.S. Thus, Christensen[7] reported the use of fish pond sediments for cropping of maize and mungbean in Asia. Since the generation of wastes is associated with the existence and activities of *Homo sapiens*, it is not surprising that the problem of seafood wastes is not delimited by national boundaries but is global in scope. In this paper, pertinent past and recent information concerned with the utilization and action of seafood wastes and byproducts on plant growth are presented and discussed.

Approach

The realization of the complex components present in seafood wastes dictated that our initial approach to the problem should be relatively manageable and straight forward. As a first step in dissecting the problem, it was decided to determine simply whether or not agricultural crop plants could be grown using the processed seafood wastes under controlled defined conditions. In many experiments conducted, a sand culture technique[8] using purified or sea sand was used for determining the action of seafood wastes on crop growth. Measurements of plant growth responses and the determination of mineral composition of useful parts of crop plants were made to assess the effectiveness or ineffectiveness of the seafood wastes. In some recent experiments, the chemical changes in the crop growing medium were also determined. After several years of investigations, the studies were expanded to experiments under field environments involving scientists from different states. The results of these efforts were summarized in a Virginia Experiment Station Research publication.[9] In these studies, similar basal rates of the processed seafood wastes were followed to allow comparison between different locations.

Concentrated liquid fish fertilizer was used for plant fertilization. The manufacture, sources, and chemical composition of the seafood products are detailed in a previous report.[9] To give an idea of the fertilizer value of the seafood wastes based upon a macronutrient, 1 ml of concentrated liquid fish when dissolved in 1.0 liter of water contains an equivalent of 60 mg of nitrogen. The nitrogen is mainly in the organic form. Crop plants were fertilized with various rates of the diluted fish solutions applied to the growing medium at intervals. Crab meal was purchased from a commercial source and used as a pulverized dehydrated material. It was incorporated and mixed thoroughly with sand at the start of the experiments. Each g of pulverized crab meal contained 6.5 m.e. calcium in addition to other organic and inorganic substances.[4] At different growth intervals, leachates were collected for pH and nitrogen determinations. Inorganic nitrogen in the filtered (Whatman No. 1 paper) leachates was determined colorimetrically following extraction with 2N KCl.[10] The calcium and other mineral contents were determined by atomic absorption spectrophotometry.[11] In all cases, crop growth and yields, and in some cases, chemical composition were used to gauge the influences of the seafood materials as nutrients on crop performance. Overall, the approach in these investigations of the past decade was to objectively ascertain the general efficacy and usefulness of seafood wastes and byproducts as a nutrient source for crop production and to gain an understanding of how the seafood materials alter plant behavior.

Observations and Results

The impression gained from both controlled greenhouse and field experiments involving a wide selection of food and nonfood crops investigated was that seafood and its byproducts have beneficial effects on plant growth. Depending upon the kinds of crops and the purposes for which they were grown, the effectiveness of the seafood nutrients varies. But by being attentive to a proper selection of crop plant and fertilization with dilute moderate concentrations of the seafood materials, most tested crop plants have shown beneficial responses. Plants grown in pots benefited more from seafood nutrients that field-grown crops. Generally, the fertilized plants showed a darker green coloration, thicker and smaller foliage, and a sturdy growth form (Fig. 1A). In flowering and fruiting plants, the seafood materials delayed these processes and the life span of the crops was extended (Fig. 1B).

Plants can grow to fruition (from seed to seed) by being provided only with diluted liquid fish solution. However, if calcium is inadequate in the growing medium, particularly for crops requiring a relatively high supply of the element, growth will be hindered and deficiency symptoms will develop. For examples, when crops like lettuce or tomato were grown in a sand culture medium containing less than 0.01% calcium and fertilized with liquid fish solutions, the seedlings grew poorly (Fig. 2B) and developed characteristic marginal tip burn of the leaves and died within a short period of time (Fig. 2D, 2F). In media which contained adequate calcium or were augmented with varying rates of crab meal to provide calcium, the seedlings grew normally and exhibited a healthy dark-green foliage (Fig. 2A, 2C, 2E). The most vigorous plant growth was seen when a moderate concentration of liquid fish fertilization was supplemented with moderate to high rates of crab meal in the growing medium.

Fertilization of plants with a combination of liquid fish and crab meal was superior to either product used by itself alone. When only fish product was used, the pHs of the sand medium leachates were between 3.5–4.7 varying with the concentrations of the liquid fish used for fertilization. Thus, unless the growing media were buffered or provided with adequate calcium, plant growth responses will not be favorable. However, when crab meal ranging between 0.2–0.6% (by weight) was incorporated into the sand growing medium, the pHs of the medium

Fig. 1. Plant growth responses to liquid fish fertilization. A: *from left to right*—Hoagland nutrient solution, casein hydrolysate, low, medium, and high concentrations of liquid fish. Note the vigor and darker foliage of the corn plants fertilized with the fish wastes; B: *from left to right*—tap water, low and high rates of liquid fish, and Hoagland nutrient solution. Note the sturdy growth form, darker foliage, and delay in senescence of the pea plants fertilized with the fish wastes.

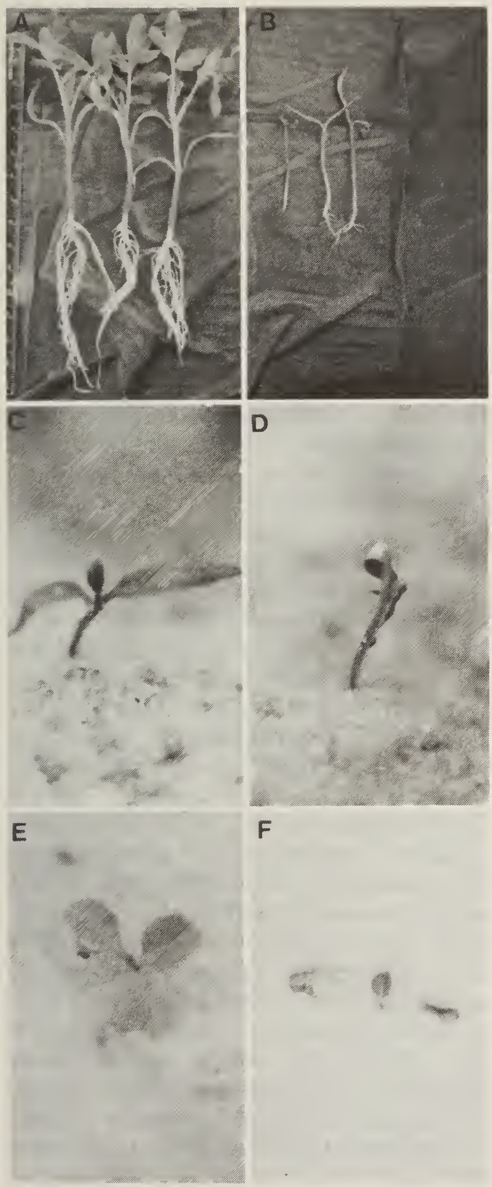

Fig. 2. Plant growth responses to seafood wastes. A = Healthy vigorous tomato plants fertilized with liquid fish and crab meal; B = Stunted and poorly developed tomato plants fertilized with liquid fish alone in a calcium-deficient medium; C = Normal healthy tomato seedling grown with liquid fish in a sand medium containing crab meal as a calcium source; D = Necrotic and shrinking tomato seedling grown in a medium lacking calcium; E = Healthy lettuce seedling fertilized with liquid fish and crab meal; and F = Necrotic and poorly developed lettuce seedling grown with liquid fish in a medium lacking calcium.

were increased to above 6.5. These pHs are conducive to plant growth. Therefore, it is important to bear in mind when contemplating the use of seafood wastes and byproducts for commercial applications to ascertain the pH and calcium status of the growing media for a selected crop in order to obtain the desired results. Disregard of such factors will surely reap disappointments and unprofitable results.

When crab meal was incorporated into a sand medium and kept moist with distilled water and then sampled for calcium at 3–14 days intervals over a period of 4 months, it was found that over 200–400 parts per million of calcium were detected in the samples. The release of calcium from the crab meal followed a fluctuating up and down wavelike pattern over the sampling period. The wavelike pattern of calcium release into the sand medium appears to be due to a differential rate of disintegration of varying particle sizes of the crab shells. Presumably, the released calcium following incubation was available for plant growth. The presumption was supported by the fact that plants fertilized with a complete nutrient solution of inorganic salts lacking calcium but with crab meal added to the growing medium grew vigorously and showed no calcium deficiency symptoms. Furthermore, the content of calcium in plant tissues was similar to the calcium content in plant tissues of plants fertilized with a complete inorganic nutrient solution. Calcium being an essential element for maintaining the growth and health of plants and animals, it is not surprising that crab meal which provided calcium should exert a decisive influence on the growth and development of crop plants.

The chemical composition of seafood and its byproducts varies and thus some adjustment must be made in order to obtain the desired results with a crop. It seems best to use seafood materials as a supplementary source of nutrients. While seafood materials contain all the inorganic and organic substances essential for plant growth, they may not provide a *bal-*

anced source of nutrients for all crop plant species. Some degree of tailoring must be made. It is desirable to maintain a pH of 5.5–6.5 for most crops and adequate calcium in the growing medium of plants for best results when using seafood materials as nutrients.

Certain food crops like lettuce and tomato are predominantly grown and consumed to provide essential minerals in the human diets. Thus, particular attention was given to determining the mineral composition of these two crops grown under greenhouse and field conditions. The phosphorus and calcium contents of greenhouse-grown lettuce fertilized with seafood nutrients compared favorably with field-grown lettuce. However, the potassium and iron contents of the greenhouse-grown lettuce were only a fraction that of the field-grown lettuce. In tomato, although phosphorus content of greenhouse-grown fruits was higher than field-grown fruits, the potassium and calcium contents were lower than the field-grown fruits. In general, the mineral composition results indicated that the seafood nutrients are available for uptake and utilization by crop plants.

Discussion

The investigations carried out to ascertain the nutritional influences of seafood and its byproducts on the growth of crop plants over the past 10 years have clearly shown that the processed seafood materials have beneficial effects on plant growth. It is heartening to know that from three perspectives, namely, (a) from a biological viewpoint a plant can grow and complete its life cycle provided only with nutrients derived from seafood materials alone, (b) from an economic viewpoint the seafood wastes now appear to have a dollar value and (c) from an ecological viewpoint, judicious fractional usages of the seafood materials as a fertilizer will help to lessen the contamination of the natural environment by massive indiscriminate dumpings of the unused seafood wastes onto land and sea. The realization that such nutrient-rich seafood and its byproducts can have a healthful and growth-stimulatory action on agricultural crops should serve as an impetus to continue research studies in order to provide the essential information for the profitable commercial uses by interested individuals. It is unfortunate, however, that the prevailing N-P-K mentality for crop fertilization is given so much credence that new ventures to explore crop fertilization are readily dismissed without due examination. It seems that the animal nutritionists are far ahead of the crop nutritionists in their approach to livestock feeding. The animal nutritionists have formulated and used different kinds of feed rations for livestock. The challenge to the crop nutritionists is to think beyond N-P-K and come up with similar feed formulae tailor made for crop growth and nutrition. The new technology may be many years into the future, but the first step will need to be a readjustment of an N-P-K only mentality and approach for crop fertilization. As mentioned previously,[9] an approach for understanding how fish hydrolysates affect plant growth was to formulate mixtures of various organic and inorganic components known to be present for testing and comparing to the complete seafood materials. Such an approach may lead to discovering certain formulations which may be better suited for growing plants and for providing a basis for reformulating or refining the original material for agricultural crop fertilization and marketing. Perhaps, it may be useful to house a functional research unit to investigate marine fertilizers and bioregulators for plant and animal feeds under the established institutes like the Scripps Institute of Oceanography at La Jolla or Woods Hole Oceanographic Institute. Alternatively, a bold entrepreneur with unlimited venture capital could initiate a Biotechnological Marine-Agriculture Center which in time will yield dividends and save mankind from pollution and starvation.

The ancient practice of using seafood wastes and byproducts for agricultural crops fell into disfavor with the advent of the availability of commercial inorganic fertilizers. The N-P-K mentality is so entrenched in modern practice and teaching of crop fertilization that even considering the complex components of organic and inorganic substances present in seafood materials, the liquified seafood materials are constrained to be manufactured and marketed under labels of N-P-K. Such a view is unrealistic and impedes progress toward a better understanding of plant nutrition. Considering the gradual erosion of our crop lands and steady depletion of soil nutrients, the demands for more efficient and innovative methods of agricultural production and nutrients-rich food crops for animals and human consumption, new approaches and materials for fertilization are needed.

A primary objective when these studies were begun was to determine the general efficacy of the seafood wastes on crop growth. As it turns out, the results revealed that in addition to plant growth stimulation by the seafood nutrients, reproductive development, and plant aging were delayed. These intriguing observations are unexplained at present. The composition of seafood materials is complex,[12] and we lack the biochemical and physiological understanding of the single and combined actions of the different seafood components on metabolic processes. For these reasons, no satisfactory explanation is possible at this time concerning the action of seafood materials on plant reproductive development and aging. These observations remain areas for further investigations. Such studies can yield significant results for understanding how seafood components affect plant growth and development and agricultural productivity.

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Deciphering Environmental Records From Caribbean Corals: A Living History of Human Impact on the Tropics

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ABSTRACT

Corals may provide the best existing long term records of tropical climate changes and of human impact on the tropical environment, once we learn how to decode the information recorded in their skeletons. A program monitoring growth rates of the major Caribbean reef building coral, *Montastrea annularis*, will provide data needed to calibrate and interpret data obtainable from very old corals, and to determine the major environmental factors associated with current success or failure of coral reefs in different areas.

Corals as Environmental Recorders

Corals, the natural world's greatest architects, are unique among marine organisms in their slow, continuous growth, steadily building wave resistant limestone skeletons beneath a very thin layer of flesh. X-Ray examination of the skeleton of some species reveals a pattern of dense annual bands, whose thickness varies from year to year, just like tree rings. For example, the coral (Figure 1), *Montastrea annularis,* collected by the author and Dr. Peter Goreau near a river mouth in Western Jamaica in 1986 and X-Rayed by Dr. Richard Dodge, shows a large decline in growth over the past few years. This is probably the result of intensified erosion following recent slash and burn agriculture in previously unfarmed swampland (Goreau, et al., in preparation).

Corals are animals with specialized stinging cells on their tentacles for catching minute planktonic animals but they also depend heavily on symbiotic algae living within their cells.[1] These algae leak a large proportion of their photosynthetic production to their animal hosts, whose metabolic wastes, in turn, provide the algae with much of their "food". Coral reefs have extremely high metabolism,[2,3] as much per unit area as a tropical rain forest, though produced by far less living biomass. Corals are unable to store food

Fig. 1. X-Radiograph of coral growing near river mouth in Jamaica, 1986. Growth rates have slowed markedly in recent years. Photograph by R. E. Dodge.

for very long, so growth rates are sensitive to short term variations in climate and factors affecting availability of food and light.

Montastrea annularis skeletons are known to contain high resolution information as variations in skeletal density,[4,5,6,7,8,9] fluorescence[10] (Goreau et al., in prep.), naturally occuring stable isotopes of carbon and oxygen,[11,12,13] the ratios of trace metals such as magnesium, strontium, lead, zinc, and copper to calcium,[11,14] and natural and artificially produced radioactive elements.[15] While these variations can be measured they cannot now be interpreted in terms of environmental variations as few corals have been studied in areas where suitable environmental data[16] were available. Corals clearly have a unique and detailed story to tell, but it's recounting awaits a "Rosetta Stone" permitting translation of the encoded message. Simultaneous monitoring of growth rates of the major Caribbean reef-building coral, *Montastrea annularis,* across its range, will provide a calibration of this record.

Because some corals may grow for thousands of years, they possess valuable long term climate records from the tropical oceans. Such information is important because global atmospheric and oceanic heat transport largely depends on how warm the tropical surface ocean gets, so the winds and currents which affect temperatures and rainfall in temperate regions are very sensitive to variations in tropical ocean temperatures.[17] The deep sea sedimentary record cannot provide climate information on the required time scale because feeding of mud ingesting deep sea clams and worms alters it severely.[18] Long-term marine climate records from the tropics are largely patchily located, away from reefs, and less than 20 years old.[17] If they can be correctly interpreted, corals could significantly improve weather forecast reliability based on tropical sea surface temperatures recorded by satellites.

Corals are very sensitive to excessive runoff and siltation from clearance of coastal forests or drainage of swamps. Coastal development in the form of dredging, beach alteration, fishing, boat traffic, tar balls, sewage, all have negative impacts on coral reefs. Many tropical beach resorts located near lush coral growth now front dead reefs, whose skeletons are covered with waving mats of filamentous or fleshy algae, housing a greatly reduced diversity of organisms. These reefs have often been pushed over the brink by increased freshwater and sediment flows to the sea, by eutrophication caused by nutrients from raw sewage and cesspit runoff, by overharvesting of major algae eating fish and invertebrates, or by natural events like hurricanes, epidemics, etc.[19]

Research Plan

The study will focus on *Montastrea annularis,* a species with one of the widest environmental ranges of any Caribbean coral species. The most important Atlantic reef building coral, it grows from the surface to nearly 200 feet, dominating reef framework construction except in the shallowest and deepest waters or where there has been intense recent disturbance.[20] They often grow in large hemispherical masses in shallower water and form a clear annual dense skeletal band in October–November in Jamaica. This time lies between water temperature extremes but appears to coincide with annual release of coral larvae (N. I. Goreau & J. Battey, pers. comm.), which is apparently cued by some more subtle feature of the environment than temperature extremes. Controversy has existed about time and cause of dense band formation, largely because corals have generally not been studied in the field year round. One purpose of this project is to resolve this controversy by determining if the dense band forms at the same time across the Caribbean, or if it is timed to take advantage of local conditions favorable to survivorship of larvae (such as nutrients or food supplied by breaking internal wave amplification as suggested by Giese.[21] Coral larvae contain symbiotic algae, but their survival appears to depend on early catching of food prey after settling.[22]

We will monitor growth rates on a year-round basis using non-destructive techniques. Two inch long, non-corrosive stainless steel nails, scored at regular intervals, will be used as growth monitors. These are nailed into the coral just like a nail is driven into the side of a tree. As the coral grows up and around the nail the height of its surface is read off at intervals, allowing the extnesion rate versus time to be determined. Following an initial evaluation currently underway at the Discovery Bay Marine Laboratory, Jamaica, growth monitors will be deployed across the Caribbean at sites regularly visited by cooperating researchers from Caribbean Marine Laboratories or by members of local dive clubs.

After one to two years of replicate growth measurements have been obtained at each site, some corals will be sampled using a small hand-held underwater pneumatic drill, which will take a core about one inch long and three fourths of an inch across. The extracted core will be replaced by a concrete plug of the same dimensions to ensure that boring organisms do not settle in the cavity and undermine or damage the coral.[6] Cores will be sliced into sections, X-rayed, examined for ultraviolet fluorescence, and cut into segments corresponding to around one month's growth, which will be analysed for stable isotopes and trace metals.

At selected sites coral tissue samples will be taken periodically, fixed and stained with histochemical dyes to reveal the state of tissue reproductive development to determine in more detail relationships between coral reproduction[23,24] and formation of the dense skeletal band.

Cooperation and Conservation in the Caribbean

This project is collaborative, not individual, and its success will rely on marine scientists and divers across the Caribbean who will donate their time to take growth readings and to obtain and mail coral cores. The project will provide the required equipment (calibrated stainless steel nails, chemical tissue fixatives, underwater pneumatic corers, mailing costs) but has no support for travel, salaries, or overhead.

Among the many individuals who have already agreed to participate in the program, or who have previously indicated interest in such a project, are: Dr. Carlos Goenaga, Universidad de Puerto Rico who will be in charge of histochemical studies; Dr. Richard Dodge, Nova University, Florida, who will handle X-Ray measurements; Dr. Peter Goreau, Middlebury College, Vermont, who will work on ultraviolet fluorescence; Dr. Brian Lapointe, Harbor Branch Foundation, active in research in the Florida Keys and the Belize Barrier Reef; Dr. Jeremy Woodley, Discovery Bay Marine Laboratory, Jamaica; Dr. Tom Sleeter, Bermuda Biological Station; Dr. Francisco Giraldes, Museo Nacional de Santo Domingo, Republica Dominicana; Dr. Dennis Hubbard, West Indies Laboratory, St. Croix; Dr. Jeremy Jackson, Smithsonian Tropical Institution, Panama; Dr. Allan Smith, Eastern Caribbean Natural Area Management Program, St. Lucia; Dr. Wayne Hunte, Bellairs Marine Laboratory, Barbados; Dr. Richard Laydoo, Institute of Marine Affairs, Trinidad and Tobago; Dr. Raymond Hayes, Howard University, Washington D.C., active in the Cayman Islands; and the Sub Aqua Clubs in Jamaica and St. Lucia. We will actively seek participation from all other diving individuals willing to adopt a coral and monitor its growth. The result will be a picture of the health of this species across its range.

This project wil be conducted concurrently with some independent but relevant research programs:

1) Dr. Peter Goreau will document changes in coral reefs over the past 35 years in Jamaica, by rephotographing sites photographed by the late Thomas F. Goreau from 1950 till 1970.

2) Fishermen often degrade the entire ecosystem by overharvesting fish or killing corals to grace tourist's coffee tables. Relief from unsustainable overharvesting can only come when intensive mariculture techniques provide satisfactory economic returns from small areas. Recent work in Jamaica with Dr. Brian Lapointe, Cy Macfarlane, Stefan Goreau, and others (in prep.) has verified that back-reef communities around underground springs in Jamaica are ideal sites for intensive mariculture of economically valuable seaweeds and fish.[25] If fishermen find it in their interest to become sea farmers, rather than hunters, the reef can continue sheltering the most productive, diverse, and beautiful of marine ecosystems, protecting coasts from storm waves, and providing a living monitor of the health of tropical coastal ecosystems and of forces driving global weather patterns and climate change.

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Restoring Balance Between the Endangered Black-Footed Ferret (*Mustela nigripes*) and Human Use of the Great Plains and Intermountain West

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ABSTRACT

The ferret is our most endangered mammal. Conservation work has focused on restoring the species to healthy numbers in many secure populations. Ferrets were directly and indirectly reduced from a 100 million acre range in about 1910 to less than 7,000 acres by 1981 (99.9+% reduction) by habitat loss and possibly other factors. Recent work (1981–1986) near Meeteetse, Wyoming, the site of the only known wild population, and searches elsewhere for more ferrets are described. The small Meeteetse population (peak number 129 in 1984) suffered a catastrophic die-off in 1985 from disease. The last 18 ferrets were taken into captivity for breeding. In 1987, two litters were born. Several sites to return ferrets to the wild are being prepared. There is every reason to believe ferrets will eventually be recovered, thus restoring the balance between this species and human uses of the Great Plains and the intermountain West.

Introduction

Discovery of the small black-footed ferret (*Mustela nigripes*) (Figure 1) population near Meeteetse, Wyoming, in late September, 1981, brought the prospect that this critically endangered mammal could be recovered and restored to healthy numbers. By late 1983, there was almost a promise of a successful conservation story, a textbook case, for a species feared extinct was rediscovered, to be followed by very careful conservation research, successful captive breeding, and finally the progeny reintroduced to the wild in several secure preserves.[1,2] First, however, captive breeding was delayed. Next, the wild Meeteetse population was decimated in 1985. In 1985, 1986, and 1987, the last 18 wild ferrets were captured and serve as the nuclear breeding population for recovery of the species. The fate of the species now depends on the few captive ferrets.[3]

Ferret History and Searches

Ferrets formerly occupied all or parts of 12 states and 2 Canadian provinces and became the unintended victim of habitat loss as prairie dogs, their chief food source, were destroyed by wholesale poisoning which began in the 1880's and continues to the present. Not only were ferrets killed directly, but fragmentation of their habitat made survivors more susceptible to random catastrophes, such as accidents, disease, and so on, that accelerated extinction. The ferret's historic range included over 100 million acres, but by the late 1940's not a single ferret could be found. Only one small population was ever studied between the time the species was first described by John Audubon and John Bachman in 1851 and discovery of the Meeteetse ferrets in 1981. In 1964, a ferret family was found in southcentral South Dakota and over the next 11 years, 10 other litters and about 90 different individuals were found. After 1974, no ferrets could be located. A captive breeding program came too late, using the last 9 ferrets seen there. The captive rearing program provided much needed information, however, on how to house and breed ferrets. It also demonstrated that ferrets are susceptible to canine distemper when several ferrets died of the disease. The South Dakota field studies and laboratory efforts provided the badly needed outline of ferret life history for the first time. With the apparent extinction of the South Dakota Ferret population, many people and agencies feared the species extinct. As a result, efforts to locate more ferrets nearby came to a standstill over the next 7 years.

Despite this, my colleagues and I never gave up hope of finding ferrets and continued looking year after year. When the first Meeteetse ferret turned up, killed by a ranch dog in a rancher's front yard, both the rancher and state officials invited me to visit. Also involved were several state and federal agencies, all charged under

Photo: Doug Brown

Fig. 1. Black-footed ferret peering out of prairie dog hole at night. This same endangered species appears on a U.S. Postal Service .22 cent stamp currently in circulation.

various laws with saving ferrets and their habitats and other endangered species—Wyoming Game and Fish Department, U.S. Fish and Wildlife Service, Bureau of Land Management, and U.S. Forest Service. Several ranchers were also involved. Besides this set of organizations, my independent studies were endorsed and supported by Wildlife Preservation Trust International, New York Zoological Society (Wildlife Conservation International), World Wildlife Fund-U.S., National Geographic Society, Charles A. Lindbergh Fund, The Nature Conservancy, National Wildlife Federation, Chicago Zoological Society, and others. My colleagues and I volunteered all of our time over the next 4.5 years while these conservation organizations covered field expenses. Our field work on ferrets was conducted year-round, through cold winter days and long summer nights, between 1981 and 1986.

Saving Ferrets: A Plan

My vision of ferret conservation and recovery in 1981 was straightforward. Because the ferret was recognized both nationally and internationally as a critically endangered species, and because so many universities, conservation organizations, state and federal agencies, and local people were interested and available, I expected that a large range of resources—financial, personnel, experience, information, and facilities—would be available to maximize chances of saving ferrets. The talent available included national and international expertise in population genetics, management of small populations, experienced field researchers; extant land and wildlife laws, policies (Endangered Species Act), and various programs; and well-tested breeding facilities, with extensive support staffs, at several major zoos and research facilities. This was all that was needed.

The first step in ferret conservation, as I saw it, was to acquire key information about the "health" of the Meeteetse ferret population and to continue searching for other ferrets near Meeteetse and in other areas and states using new survey techniques we would develop at Meeteetse. Learning about the Meeteetse ferrets would require a sensitive research program. All the methods my colleagues and I proposed were indirect and did not require handling ferrets. Ideally, the Meeteetse ferret population would show a "surplus" of young early each fall after only 2 or at most 3 years, and our study plans reflected this. The surplus ferrets could be captured each fall, used in several captive breeding programs using existing facilities, experience, and personnel, and the offspring could be reintroduced to the wild throughout their former range, thereby establishing many secure, self-sustaining wild populations. Under this scenario, ferrets could be well on the road to full recovery in 5+ years from the date they were first located. In the meantime, searches for more ferrets and for reintroduction sites would accelerate species recovery. Simultaneously, all the necessary active management protection of the wild Meeteetse ferrets (and any other ferret populations found) would be forthcoming, including disease monitoring, possible predator control, and land protection. My colleagues and I went to the field work right away, attempting to do our part for ferret conservation.

My recovery model had two major goals: conservation of the Meeteetse ferrets and their habitat and recovery of the species. My plan addressed several basic questions, first determining the health of the Meeteetse ferrets, accompanied by goals, specific objectives, timetables, and expected results. I believed all along that the Meeteetse ferrets held the key to recovery of the species. A close working relationship based on trust with ranchers of the Meeteetse region and with other interested parties was essential. In 1981 and again in 1982, I outlined a plan whereby the various organizations and research efforts could be woven into a cooperative, well-integrated program to meet this conservation task. It was designed so that ferrets as well as all the organizations, agencies, and individuals would "win."

Studying the Meeteetse Ferrets

We learned many details of ferret behavior and ecology. The ferrets were, in fact, producing a "surplus" of young each year, captive breeding facilities were available, and sites to return ferrets to the wild were located. Ever since the 1870's, ferrets had been known to associate with prairie dogs (*Cynomys* spp.); ferrets eat prairie dogs and use their burrows for shelter and sites to rear young. At Meeteetse we found ferrets on 37 white-tailed prairie dog colonies totalling about 8,000 acres in over 100 square miles. The largest colony of 3,500 acres contained two-thirds of all the ferrets. Clumped around this large colony within 3 miles were 10 other large colonies. Nearly all the ferrets were found in this dense clump of colonies about a township in size. Beyond these 37 colonies, prairie dogs were scarce for miles. It was obvious that the 37 colonies were an "island" of ferret habitat, beyond which dispersing ferrets stood little chance of survival. This meant there was little chance that ferrets would ever recolonize those prairie dog colonies 30+ miles away by themselves. Indeed, we repeatedly searched, but never found ferrets outside the 37-colony "island." The Meeteetse ferrets occurred at about 1 ferret/125 acres of prairie dogs. Snow tracking ferrets over 250 times in the first 3 winters revealed much new information. It also tested our field rigor as we worked and slept out at 43 degrees below zero. We found that individuals remain within certain areas and may be active every night or inactive up to 6 days. The "average" ferret may investigate about 65 prairie dog holes in 1 mile of travel each night. In the breeding season in February and March, ferrets may travel over 5 miles per night "checking things out" and making many characteristic marks and scrapes in the snow. Within the 37 colonies, 15 ferrets were observed to travel between individual colonies. These 37 colonies were equally owned by private ranchers, the state of Wyoming, and the U.S. government (Bureau of Land Management).

In all, we saw at least 275 different ferrets. Between 1982 and 1985, we found 68 litters averaging 3.3 young. The population was comprised of about 67% juveniles and 33% adults each August. Sex ratios showed 1 male:1 female for juveniles and 0.4 male:1 female in adults. Ferret numbers varied dramatically, with the seasons and years. Our best data was from the single large colony; it showed 37 ferrets in summer 1982, 46 in 1983, 65 in 1984, and 16 in 1985, all early August counts. Data from the total ferret area (keeping in mind that the 1982 count was incomplete) showed 61 ferrets in 1982, 88 in 1983, 129 in 1984, and 58 in 1985, again early August counts. In September and October of 1984 and 1985, a mark/recapture estimate of population size was made cooperatively by us, U.S. Fish and Wildlife Service, and Wyoming Game and Fish Department. It showed 128 ± 25 ferrets in 1984 and 31 ± 8 in 1985. A "back" estimate to 1983 showed 113 ± 60 ferrets present, more than our spotlighting count of 88. Ferrets seem to disappear in large numbers from the fall of one year to spring breeding of the next year. We estimated annual losses of 67+% of the total population. Juvenile losses were highest, around 85%, whereas adult losses were estimated to be about 50%. Predation from owls, hawks, eagles, coyotes, and badgers, and losses from accidents and dispersal seemed to account for the huge annual ferret mortality. This meant to us and some of our associates in the U.S. Fish and Wildlife Service that a "surplus" of Meeteetse ferrets existed to begin captive breeding. A few of the ferrets that were lost from natural causes each fall and winter could be removed for captive rearing programs. In fact, in December, 1983, we outlined a captive breeding program, described its components, and encouraged governmental implementation of the plan.[4] Several captive breeding facilities were available and waiting for ferrets. Captive breeding was not undertaken, however.

A tragic picture of the wild ferret population emerged in 1985. By early July, 1985, our initial counts showed the ferret population was much lower than in previous years, especially given its large size of 129 the previous fall. Intensive spotlight surveys were immediately undertaken to find ferrets. At this time a volunteer for the U.S. Fish and Wildlife Service discovered sylvatic plague in the ferrets' prey—prairie dogs. Plague has been known to destroy 95+% of prairie dog populations in days or weeks. Our concern for the ferrets and the prairie dogs on which they depend sharply increased. Intensive surveys conducted largely by us and the U.S. Fish and Wildlife Service showed 58 ferrets (13 litters) in 1985 as compared to 129 ferrets (25 litters) at the same time in 1984. Many of these ferrets were seen only once, unlike our observations in past years when ferrets, once located, could be repeatedly located night after night. Mark/recapture population estimates showed only 31 ± 8 ferrets on September 10, 16 ± 5 on October 9, and 6 ± 4 on November 1, 1985. Thus, we can document the loss of about 150 ferrets between Fall, 1984 and Fall, 1985. During July to September, ferrets were dying at about one every 2–3 days. The probable cause was later diagnosed as canine distemper, always present in nature, and probably brought in by skunks, racoons, foxes, coyotes, or badgers in June, 1985 or before.

Between September 12 and October 11, 1985, 6 ferrets were live-captured from Meeteetse and placed in a Wyoming Game and Fish Department facility. On October 22, canine distemper was diagnosed when one of the captive ferrets died and another showed symptoms. All 6 ferrets were housed in the same room, and because distemper can be spread through the air, all 6 ferrets eventually died. Housing rare animals like this is contrary to standard quarantine procedures. Between October 25 and November 2, another 6 ferrets out of the dozen estimated to remain in the wild were caught, taken to Laramie, housed individually, and survive to the present. Five of these may be very closely related (first and second generation). No young were produced in captivity in 1986.

The 1986 Meeteetse summer surveys showed that 4 adults survived. Fortunately, two were females with litters (5 young each). Twelve of these were relocated and captured between August, 1986 and February, 1987. Thus, the captive population was expanded to 18. In 1987, 2 litters were born in captivity, 1 with 6 young and the other with 2 (1 of which later died). As of early summer 1987, the fate of this rare species will turn on the success of the captive population. Searches for more wild ferrets continue, and sites to reintroduce ferrets back to the wild have been located and are being prepared. Despite the setbacks and complexity of the ferret recovery effort, there is every reason to believe that it will ultimately be a success.

Much Meeteetse data has been published in various scientific journals, government bulletins, monographs, and other outlets.[5,6,7,8] In all, about 40 papers detail ferret ecology, behavior, and conservation options. Other reports have been submitted for publication and should appear in print this year.

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Utilizing Laser Spectroscopy to Determine Radioactivity Levels in Nuclear Waste

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ABSTRACT

The recently developed technique of fast beam laser spectroscopy is being applied to the detection of trace amounts of long-lived radioactive elements in nuclear waste and eventually in the environment. As nuclear energy generation is proliferated and nuclear tests continue, the task to reduce the risks of radiation pollution must be accomplished by isotope selective evaluation of radioactive test samples. This will help to achieve a better balance between the nuclear industries and the preservation of our environment.

Introduction

The detection of radioactive elements in the environment and in nuclear waste requires sensitive detection methods to determine the amount and spatial distribution of the radioactive pollution. This need and also the development of even more refined measurement techniques for safeguarding nuclear materials have for several years been recognized by the U.S. Department of Energy and the International Atomic Energy Agency. While high standards of nuclear safeguarding have so far been achieved, reliable monitoring of the long-lived radioactive isotopes of, for instance, plutonium, uranium, yttrium, and promethium remains inadequate. This is due to the difficult detection of the minute amounts of these isotopes present in nuclear waste and in the environment. By comparison, the short-lived isotopes are easy to observe due to their high radioactivity. With nuclear fission being an important power source and with the growth of nuclear industries, radioactive pollution may be caused by weapons tests, nuclear accidents, and leakage from nuclear power plants and nuclear industries. Table I lists the main fission products with half-lives longer than days. To these isotopes the long-lived isotopes of uranium, ^{235}U, with a half-life of 7×10^8 years, and of plutonium, ^{239}Pu, with a half-life of 2×10^4 years, should be added, since these elements are the major nuclear fuels and therefore the starting points in the fission cycle.

It should be pointed out that significant progress is being made in the field of radioactive waste management, in particular in developing safe systems for the disposal of high-level, long-lived nuclear

Table I. Compilation of major fission products. Only isotopes with half-lives longer than days (d) and years (a) are listed.

Element	Isotope	Half-Life	Fission yield [%]
krypton	85 Kr	10 a	1.5
rubidium	87 Rb	6×10^{10} a	3
strontium	89 Sr	51 d	5
strontium	90 Sr	28 d	6
yttrium	91 Y	59 d	6
zirconium	95 Zr	63 d	6
ruthenium	103 Ru	40 d	3
ruthenium	106 Ru	1 a	0.5
iodine	129 I	1×10^7 a	1
iodine	131 I	8 d	3
cesium	135 Cs	3×10^6 a	6
cesium	136 Cs	13 d	6
cesium	137 Cs	27 a	6
barium	140 Ba	13 d	6
cerium	144 Ce	33 d	6
cerium	144 Ce	290 d	6
promethium	147 Pm	2.6 a	2.6

wastes in deep geological formations and under the seabed. Here again levels of long-lived radioactive isotopes must be monitored with emphasis being placed also on the migration properties of these isotopes. It is important that a good detection method be both element and isotope specific and therefore free from isobaric interferences. In this way the measured isotopic composition of the detected radioactive isotope will give information about its origin. Taking plutonium as an example, the present detection methods[1] are still inadequate and are based on α-spectroscopy (detection limit $\simeq 4 \times 10^8$ atoms), neutron activation analysis (detection limit $\simeq 4 \times 10^{11}$ atoms), and mass spectrometry (detection limit 1×10^6 atoms). The most commonly used method is α-spectroscopy where presently long counting times must be used and where isotopic selectivity is far from being complete. Neutron activation is not isotope selective and is comparatively insensitive. Mass spectroscopy techniques are only mass number specific but not element specific.

In contrast the various shortcomings listed are not present at all or only occur to a lower degree when laser methods, such as resonance ionization spectroscopy[2] or collinear fast beam laser spectroscopy,[3,4] are employed.

Principle of the Detection Method

During the past year we have constructed an apparatus at Texas A&M Uni-

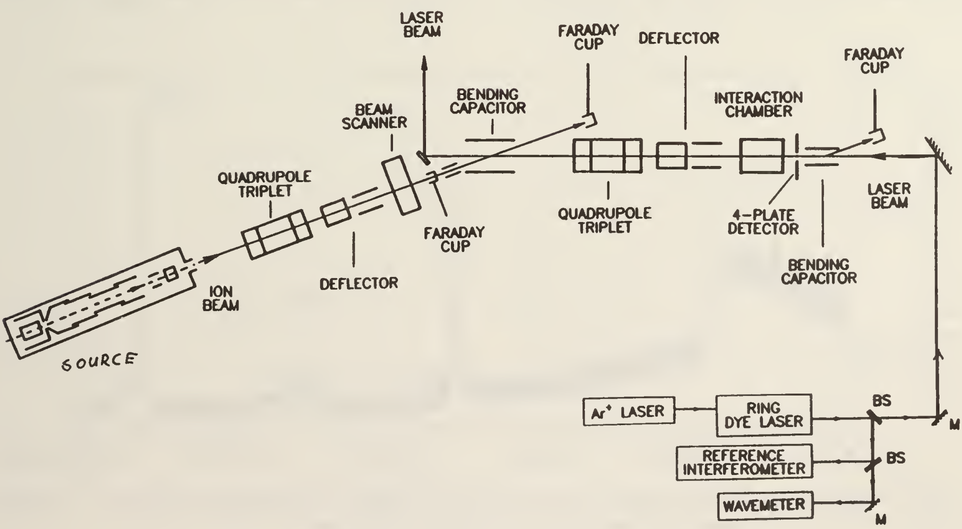

Fig. 1. Collinear fast beam laser spectroscopy apparatus.

versity (TAMU) which is based on collinear fast beam laser spectroscopy and which is dedicated to the detection of the long-lived radioactive isotopes with half-lives longer than one hour. Most of the elements in Table I, and possibly also plutonium and uranium, can be detected isotope specifically with this apparatus. The arrangement is similar to an apparatus which we have set up at Brookhaven National Laboratory on-line to the High Flux Beam Reactor and the TRISTAN mass separator. There we study short-lived isotopes with half-lives from seconds to hours. The main difference is that the TAMU apparatus has a set of disposable ion sources which can be quickly loaded with radioactive samples through a lock without breaking the vacuum. In addition, one of the ion sources is of novel design and is based on ion storage[5] principles. The minute radioactive sample is first loaded onto a rhenium filament, then evaporated, ionized and stored. Once enough ions have been accumulated in the stored ion source, they are extracted with high efficiency to form an ion beam which can be studied.

A description of the principle of the methods follows. Fig. 1 depicts the apparatus. A tunable single mode dye laser and an ion beam are merged collinearly and the fluorescent light is detected at resonance. The spectra obtained are Doppler-free since longitudinal cooling of the ion beam is effected by velocity bunching. A sensitivity of about 10^6 ions/sec. in the beam has been obtained. Fig. 2 demonstrates this in a registration curve obtained with our apparatus at Brookhaven for radioactive barium ions at subpico ampere beam currents. It took only a few minutes to produce the signals. The unique feature of laser spectroscopy yielding unambiguously the amounts of the various isotopes present in the sample is evident from the height of the various peaks belonging to different isotopes. With this information is is possible to determine the origin of the sample under investigation, whether it was produced, for instance, as fallout from nuclear weapons tests, by leakage from nuclear power plants or from naturally occurring radioactivity.

Future Developments

Each element listed in Table 1, and also plutonium and uranium require the development of a specific laser excitation and detection scheme. Our first candidates after barium are krypton and uranium. We are also planning to add a

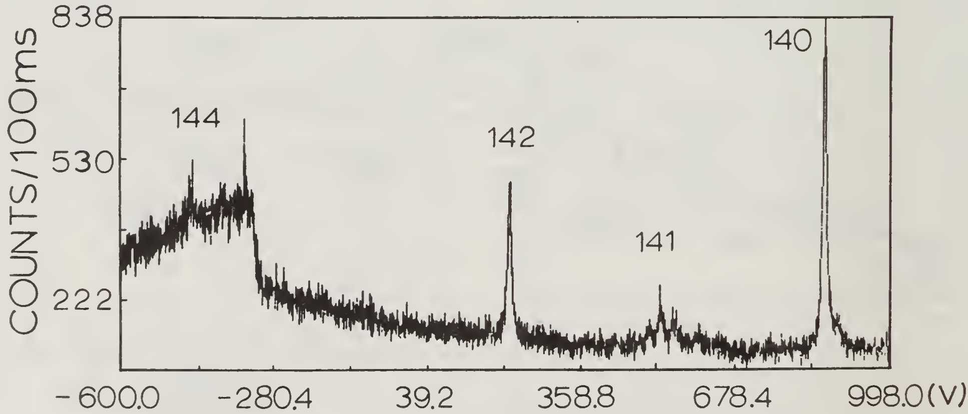

Fig. 2. Fluorescence signals versus the post acceleration voltage. The different isotopes $^{140-144}$Ba were Doppler shifted into resonance at a fixed laser wavelength of 614.3 nm.

charge exchange chamber to the apparatus to convert the fast ion beam into a fast atom beam. This will be effected by using a heat pipe type oven region containing an alkali vapor and will enhance the versatility of our system since not only ions but also atoms, which have their spectra in a different optical region, can be investigated. Other important tasks remaining to be done are:

- preparation of test samples for standardization and to compare collinear fast beam laser spectroscopy with other methods
- safe handling of plutonium contaminations

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The Panare Indians and Their Forest: Survival of a Venezuelan Culture

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ABSTRACT

Results are presented for an ethnobotanical study of the Panare Indians, an indigenous Carib-speaking group of the Guayana Highland region in southern Venezuela. A total of 373 species of angiosperms are accounted for based on nearly five months of intensive collecting and interviewing in the Panare village of Corozal. Of this total, 110 species (30%) are recorded as being utilized by the Panare. These species were grouped into utilization categories, revealing that the Panare had indicated 63 species as sources of food, 35 species used in construction and crafts, 18 species as medicinals, and 12 species used commercially; some species occurred in more than one category. The role of these useful plants in the Panare culture is discussed. This documentation of the heavy dependance that the Panare have on the plants of their environment provides solid arguments for the conservation of tropical forests and further emphasizes the need for additional ethnobotanical work to better understand the balance between indigenous peoples and plants in the tropics.

Introduction

Indigenous peoples have a prodigious knowledge of the environment. The study of this knowledge is an important way to search for new foods, drugs, and other products of potential value for Western society. By categorizing this knowledge we gain insights as to how indigenous groups have harmoniously interacted with their surroundings for millennia. Such studies produce strong arguments, based on ethnoscientific data, for tropical forest conservation.

There is an urgent need for studies on indigenous peoples in the tropics due to ever increasing threats to the cultural integrity of these groups from development, mining, and agricultural concerns. The precarious situation of the Panare, a Carib-speaking group in southern Venezuela, and the prospects for the loss of much of the Panare's knowledge about plants in the near future, provided the impetus for the present study. The Panare had not previously been the subjects of an ethnobotanical study, but anthropological contributions have been made recently.[1,2,3] These works provide information on the history and current status of the Panare.

Setting and Methods

Fieldwork was conducted in Corozal, Venezuela (6° 55′N, 66° 30′W). The terrain ranges from the Orinoco floodplains to the west at about 90 m elevation to the mountains to the east at about 500 m elevation. Granitic outcrops are abundant throughout. The average annual rainfall in the region is about 2400 mm. There is a dry season from about Dec–May.

General plant collections were made and these shown to informants to determine names and possible uses. Two forest inventories were also conducted in order to quantify Panare plant use; this aspect is discussed elsewhere.[4] Here, useful plants are considered in the context of the following categories: food, construction and crafts, medicinal, and commercial.

Results and Discussion

During the course of the project, 373 species of plants were collected. Of these, 110 species (30% of the total) were indicated by informants as being useful. In order to discuss these species here, I have grouped them into the above mentioned categories. The Panare indicated 63 species that provide food, 35 in the construction and crafts area, 18 used as medicinals, and 12 used in commerce.

Food Plants

Of the 63 species of food plants, 15 of these are cultivated. Three of these are trees and are grown in dooryard gardens: cashew, *Anacardium occidentale,* mango, *Mangifera indica* (Anacardiaceae), and papaya, *Carica papaya* (Caricaceae). In the agricultural fields, usually located several km from the village, most of the food crops are grown. There are six species of tuber crops; of these manioc, *Manihot esculenta* (Euphorbiaceae) is the most important. The other tuber crops are sweet potato, *Ipomoea batatus* (Convolvulaceae), yams, *Dioscorea alata* and *D. trifida* (Dioscoreaceae), and yautia, *Xanthosoma sagittifolium* and *X. violaceum* (Araceae). The only grain cultivated, maize, *Zea mays* (Poaceae) is nearly as important to the Panare as is manioc. Sweet eating bananas, *Musa* x *paradisiaca* (Musaceae) are commonly cultivated. Two species of cucurbits are grown: melon, *Cucumis melo* and *Cucurbita moschata* (Cucurbitaceae), but neither is especially important. Other minor food crops include peanut, *Arachis hypogaea* (Leguminosae) and pepper, *Capsicum frutescens* (Solanaceae).

Although 48 of the total of 63 species of food plants are collected from the forest, they actually comprise only a small fraction of the caloric intake of the Panare. In most cases, the foods collected from the forest are done on an opportunistic basis. Several are important enough to warrent specific mention. These species, which produce large and/or abundant fruits, include *Astrocaryum aculeatum, Mauritia flexuosa, Maximiliana maripa, Syagrus orinocensis* (Arecaceae), several species of *Inga* (Leguminosae), *Spondias mombin* (Anacardiaceae), two unidentified species of Sapotaceae, *Genipa americana* (Rubiaceae), *Parahancornia oblongata* (Apocynaceae), and *Parinari excelsa* (Chrysobalanaceae).

Construction & Crafts Plants

In this category, 35 species are included. Several species of trees are useful in constructing dwelling frameworks due to their hard, durable wood: *Tapirira velutinifolia* (Anacardiaceae), *Casearia ulmifolia* (Flacourtiaceae), *Hymenolobium flavum* and *Machaerium* sp. (Leguminosae), *Luehea candida* (Tiliaceae), *Amaioua corymbosa* (Rubiaceae), and an unidentified species of Myrtaceae. The roof of dweelings is thatched almost exclusively with the leaves of *Mauritia flexuosa* (Arecaceae). The dwelling is lashed together with any of a number of lianas (woody climbers): *Anemopaegma karstenii, Arrabidaea inaequalis, Cydista aequinoctialis, Melloa quadrivalis,* and *Paragonia pyramidata* (Bignoniaceae), and *Serjania rhombea* (Sapindaceae).

Traditionally, the Panare only made undecorated, utilitarian burden baskets woven from the leaves of *Maximiliana maripa* (Arecaceae). Strips of thin, fibrous bark are used to form the tumpline (head strap) for these baskets; the barks come from *Lecythis corrugata* subsp. *rosea* (Lecythidaceae), and *Cochlospermum orinocense* and *C. vitifolium* (Bixaceae).

The practice of weaving decorative baskets was introduced to the Panare some years ago by a missionary. The missionary, who had learned the technique himself from the Ye'kuana Indians, a group living to the southeast of Panare territory, sought to provide the Panare with a way to earn cash. The western Panare have taken up commercial basketry in a major way and their work surpasses that of the Yu'kuana in its design complexity. Baskets are woven exclusively of the split stems of a large mountain herb, *Ischnosiphon arouma* (Marantaceae). These pieces are soaked in water until soft and then either used directly or dyed red or black. The red coloring comes from the stem exudates of at least two common trees: *Swartzia laevicarpa* (Leguminosae) and *Byrsonima crassifolia* (Malpighiaceae). The black coloring comes from the bark of *Casearia silvestris* (Flacourtiaceae), a common tree in gallery forests on the savanna. Handles are made of a piece of fibrous bark from *Rollinia exsucca* (Annonaceae) or *Cochlospermum* spp. (Bixaceae).

The Panare grow cotton, *Gossypium barbadense* (Malvaceae) from which they produce cloth for clothing and hammocks. Red, black, and purple dyes are used for coloring cloth and/or decorating bodies. Red is certainly the Panare's favorite color. Loincloths and hammocks are dyed red and their bodies are frequently decorated with red. The source of this red is the seed coat of achiote, *Bixa orellana* (Bixaceae), a widely cultivated shrub of cultural significance for many indigenous groups. A black color for making geometric designs on the skin is obtained from fruits of the widespread tree *Genipa americana* (Rubiaceae). A purple dye, for coloring skin, cloth, or sometimes decorative baskets, is obtained from the leaves of *Picramnia spruceana* (Simaroubaceae). Another purplish dye is obtained from the mature fruits of an herb, *Renealmia aromatica* (Zingiberaceae); this is used for dyeing cloth.

Two species were recorded as providing poisons for hunting or fishing. *Strychnos toxifera* (Loganiaceae), a woody vine of mountain forests, is the source of curare. The bark of this vine is scraped off, and boiled in water until a black, dried cake is remaining. This is pulverized and stored until needed in hunting; blowgun darts are tipped with the curare. A small herb, *Piper piscatorum* (Piperaceae), is the source of a fish poison; the method of using it was not specified.

Three species are used in making necklaces. *Abrus precatorius* and *Pachyrrhizus* sp. (Leguminosae) and *Coix lacryma-jobi* (Poaceae) provide seeds that are strung together. Two other miscellaneous uses in the "Construction & Crafts" category are the small shrub, *Turnera* sp. (Turneraceae), the leafy branches of which are tied together to make a crude broom, and *Crotalaria pilosa* (Leguminosae), the dried fruits of which are used as rattles.

Medicinal Plants

Little specific information was obtained about medicinal plants. Only 18 species were indicated as such, and then only with vague explanations of methods of treatment, dosage, etc. One explanation for the paucity of information obtained lies in the fact that, traditionally, a shaman would be responsible for knowing about medical and magic plants; apparently, the average Panare did not have specific knowledge about such things. There are very few Panare shamen still living and there are not any in Corozal. Thus, the few species I did record as being medicinals are probably among the more common and generally known among the Panare pharmacopoeia. This listing must be regarded as only a beginning in this area; a separate ethnomedicinal study should be conducted with a shaman in the near future.

Several species were indicated as being of some medicinal value, but no information beyond that was obtained: *Tabebuia rosea* (Bignoniaceae), *Sclerolobium* sp., *Senna silvestris* (Leguminosae), *Chaunochiton angustifolium* (Olacaceae), and two unidentified species of Melastomataceae. Decoctions of leaves from two species are used as medicinal bath: *Clidemia novemnervia* (Melastomataceae) and *Siparuna guianensis* (Monimiaceae).

A poultice for aching muscles is made from *Phthirusa retroflexa* (Loranthaceae) or *Piper marginatum* (Piperaceae). *Tabebuia serratifolia* (Bignoniaceae) is used to cure stomachaches. *Roupala montana* (Proteaceae) is used to treat head ailments. A decoction of *Psychotria colorata* (Rubiaceae) is drunk as a remedy for coughing. Leaves of *Piper piscatorum* (Piperaceae) are chewed (perhaps as a stimulant?). *Borreria capitata* (Rubiaceae) is used to treat cuts and wounds. Likewise, resinous exudates of *Copaifera* sp. and *Swartzia laevicarpa* (Leguminosae) are applied to cuts in the skin. Finally, *Simarouba amara* is used to treat snakebites.

Commercial Plants

Several of the species discussed in the "Construction & Crafts" section are also among the 12 used in commerce. Necklaces strung with seeds of *Coix lacryma-jobi, Abrus precatorius,* and *Pachyrrhizus* sp. are sold to tourists and traders. Baskets woven from *Ischnosiphon arouma* stems, with handles of *Rollinia exsucca* and *Cochlospermum vitifolium* barks, and painted with red, black, and purple dyes from *Swartzia laevicarpa, Byrsonima crassifolia, Casearia sylvestris,* and *Picramnia spruceana,* are sold. Another important commercial activity is the collection of seeds of a mountain forest tree, *Dipteryx punctata* (Leguminosae); seeds are sold for extraction of coumarin, a fragrant compound used in the manufacture of perfume, soap, etc. A minor source of cash comes from the sale of native plants, such as *Chrysothemis dichroa* (Gesneriaceae), for use as ornamentals.

Summary

I have shown that the Corozal Panare use at least 30% of the plants in their environment. This number would no doubt increase if more time were spent collecting in the area, especially in the company of a shaman; this is particularly true with respect to medicinal plants. Scarcely any useful plants are gathered from the savanna habitat; traditional Panare culture depends on the mountain forest for plant resources. As acculturation increases, the knowledge of plants among the Panare will decrease and will eventually be lost forever. The need for more ethnobotanical studies of indigenous groups in the neotropics is obvious if we are to catalogue these peoples' knowledge of the plant world and understand their perceptions of balance between the needs of man and the "needs" of the natural environment.

Acknowledgments

Appreciation is extended to the Charles A. Lindbergh Fund and the Harry Frank Guggenheim Foundation for a generous grant that financed this research. Collaboration in Venezuela from the Herbario

Nacional, the Herbario Ovalles, and the Herbario Universitario is gratefully acknowledged. The field help of Margot Grillo and Sondra Wentzel, and the expertise of linguist Marie-Claude Muller is much appreciated. This paper is dedicated to the Panare.

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Development of a Direct Solar Stirling Engine: Mechanical Energy for Developing Countries

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ABSTRACT

Solar energy is a source of energy which works in total harmony with the natural environment. The energy form most needed by the human community for carrying out everyday tasks is mechanical. Therefore the problem of converting solar energy to mechanical energy is an important one to consider. Approaches to this problem, heretofore, have been largely based upon high power focusing and tracking systems. Such systems tend to be too expensive for small-scale use in developing countries where the need for mechanical power is great and where preserving the balance of nature is essential. This paper provides an overview of a project supported by The Charles A. Lindbergh Fund to investigate the potential of operating a Stirling engine from direct unfocused or moderately concentrated solar energy. A small Ringbom Stirling engine was designed and constructed to test solar operation and collect operating data. Scaling equations were derived for use in the analytic design of the engine. It is hoped that the data and experience obtained from this project will serve as a useful first step toward the development of larger practical size engines in the near future.

Introduction

The Stirling engine is a closed cycle engine which can be activated by any external heat source. With an environmentally clean heat source, the Stirling has the potential to provide useful mechanical power without sacrificing environmental quality. The optimal heat source with respect to preserving natural balances is the sun. A Stirling operating on solar energy would operate on the cleanest and most renewable of "fuels" in genuine harmony with nature. Moreover, the need for small power plants is particularly acute in arid developing countries where sunshine is abundant, combustible fuels are scarce, and environmental balances are delicate. Therefore scientific studies aimed at eventually realizing practical low cost small solar power plants for domestic and agricultural uses are well worthwhile.

The idea of running Stirling engines on solar energy is neither new nor unexplored. Indeed it dates back to 1872 with the pioneering work of John Ericsson[3] and work continues to the present.[11] However all of the Solar/Stirling concepts prior to this Lindbergh project utilized

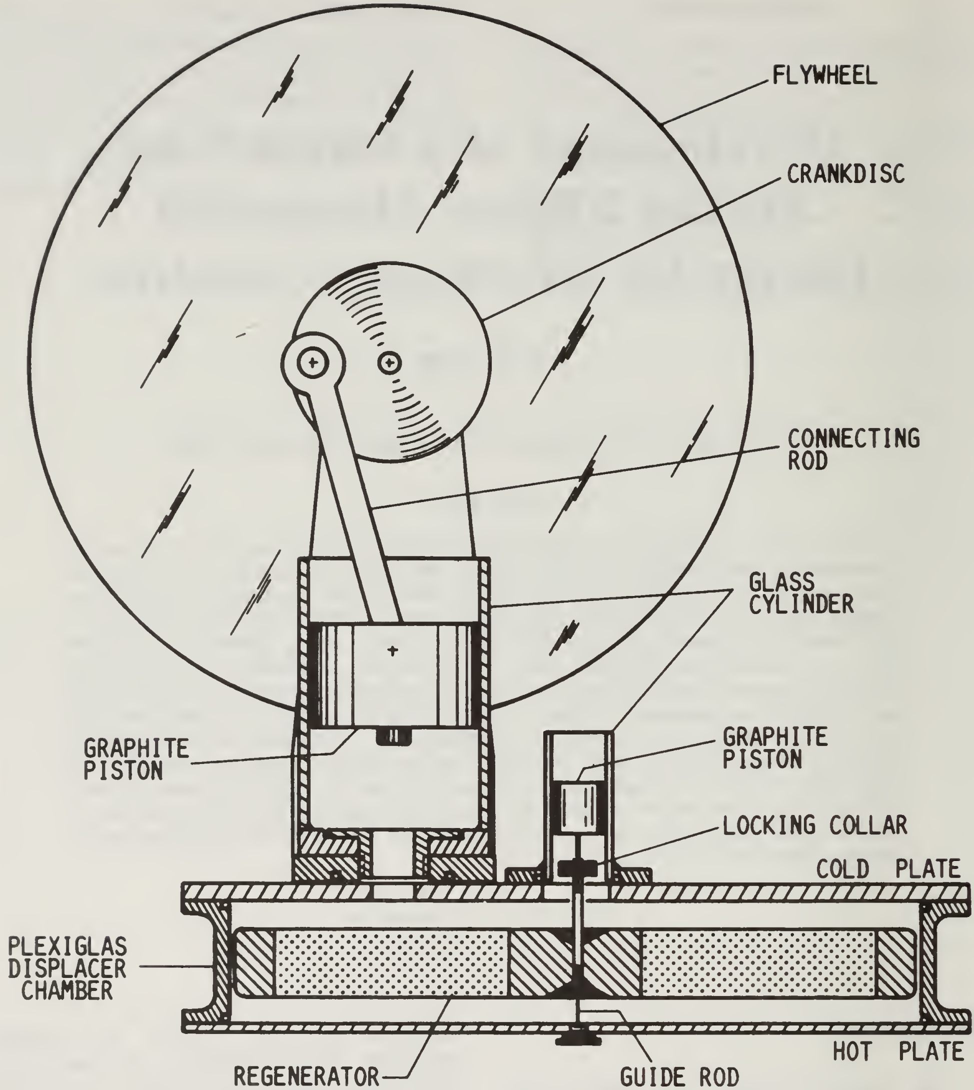

Fig. 1. Sectional view of the project engine.

high power focusing devices paired with high temperature engines. These focusing systems typically require high precision in fabrication, permanent installation, and continuous tracking of the sun as it moves through the day. These requirements make such units suitable only for large scale use in industrialized countries.

Prior work by Kolin[1,2] and Senft[6] showed that it is possible to operate Stirling engines from relatively low temperature heat sources. This opened-up for the first time the possibility of using such engines with unfocused or moderately concentrated solar energy. This would eliminate the need for high precision collectors, continuous tracking devices, and high temperature tolerant engine materials. This in turn could make the solar-to-mechanical conversion process practical with inexpensive small scale units.

From a scientific point of view, what was most needed at that point was data on the temperatures and power output that could be achieved by a Stirling engine operating on direct or mildly concentrated sunlight. A small testbed engine was designed and constructed to collect this data and evaluate various collector and engine concepts. Although itself too small and rudimentary for practical use, this first engine would provide the data and initial experience necessary to assess its practical potential and map out future research and development directions. This paper summarizes the project and its results in a general way. More detailed information on the topics covered here can be found in references 8–10.

Engine Design

A Ringbom engine is a Stirling engine with a conventional crank operated piston and a gas-driven free displacer. The Ringbom type of Stirling engine was chosen for this project because it offers a number of advantages for low temperature solar operation. A sectional view of the project engine is shown in Figure 1.

Engine design began with the choice of overall size. This was an important decision since it would affect construction cost and time, testability, and adaptability to changing experimental requirements. Scaling equations were developed from earlier theoretical work.[4,5,7] It was found that two Ringboms having the same ratios of rod area, swept volume, dead space and temperature, and having the same mean pressure, have stable speed limits in the ratio

$$\frac{\overline{\omega}_1}{\overline{\omega}_2} = \sqrt{\frac{A_1 M_{D2} L_2}{A_2 M_{D1} L_1}}$$

where

$\overline{\omega}$ = overdriven speed limit

A = displacer area

M_d = displacer mass

L = half displacer stroke.

This equation was extremely useful in rapidly calculating basic engine component geometry for several overall size ranges and selecting the most suitable size for the project engine. The specifications chosen for the engine were

A = displacer area = 132 cm^2

A_p = piston area = 8.31 cm^2

A_R = displacer rod area = 0.713 cm^2

L = half displacer stroke = 1.50 cm

L_p = half piston stroke = .523 cm

V_D = dead volume = 14.5 cm^3

M_D = displacer mass = 6.0 g.

Because the peak operating temperature of the engine would be below 100 C, the engine was fabricated largely from aluminum and plastics. Standard ready-made parts were used for the pistons and cylinders, bearings, seals, and fasteners.

Solar Tests

The hot end of the engine incorporates a flat plate collector. The hot plate of the engine is the solar absorber. It was given a layer of Thurmalox solar-absorptive coating and a cover window of 3mm thick plexiglas was fitted over the blackened plate with an air space of 6mm and sealed around the periphery.

Mounted on a tilting stand, the engine was operated outdoors and temperatures of the engine hot and cold plates and speeds of the engine shaft were measured and recorded under various loads. These temperatures and speeds were the central "unknowns" that motivated this project.

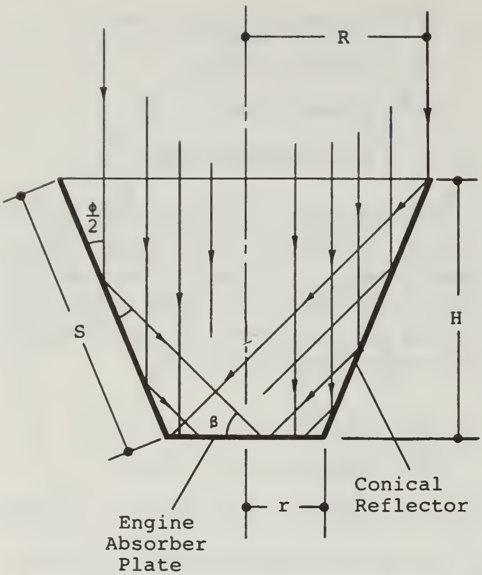

Fig. 2. Conical reflector geometry.

The engine functioned very well with this simple flat plate collector as an interesting demonstrator of solar-to-mechanical energy conversion. However, engine power was limited by the low temperature differentials obtained across the engine plates. The measured ΔT across the plates was typically 20°C. To produce practical amounts of power at this temperature differential the engine would have to be of enormous proportions. Therefore, modifications were carried out to increase the ΔT across the engine.

A deep finned cooler plate was fitted on the cold side of the engine to decrease its operating temperature. To increase the temperature of the hot plate of the engine, a conical reflector was fitted. Figure 2 shows the principle of the conical reflector. The engine absorber plate receives solar energy directly through the central portion of the cone plus an additional amount is intercepted and reflected onto the plate by the surface of the cone. Since the conical reflector in this application does not focus to a point or to a line, it does not require a continuous tracking device; manual repositioning of the reflector every hour or two would suffice to keep the engine operating near full capacity. For the same reasons, the conical reflector does not require a high degree of precision in its manufacture. Furthermore, it can be inexpensively roll-formed from sheet material. Thus the conical reflector is ideal for inexpensive small scale engine units.

Figure 3 shows the project engine with a conical reflector fitted. The cone pictured is a full once-reflecting cone with an apex angle of 60 degrees. It was made very inexpensively from cardboard tag stock covered with 3M brand ECP-244 solar reflecting film. This film has an advertised reflectivity of 86%. After cutting the required sector from the sheet material, it was rolled into shape and the seam glued. Two stiffening rings cut from thick poster board were glued to the outside surface of the cone to maintain circularity. The stiffening rings are visible in Figure 3 and the lower one serves as a clamping flange to secure the cone to the engine with spring clips.

The ideal concentration factor for a 60 degree full cone is 4. The following equation can be used to obtain an estimate of its actual performance on the engine:

$$E = I\pi r^2(a + 4\, b \cos \phi(1 + \cos \phi))$$

where

E = power absorbed by engine plate

I = solar flux intensity

r = radius of engine plate

ϕ = cone apex angle

and where a and b are factors between 0 and 1 to account for losses in transmission through the collector window, in energy absorption by the plate, and in reflection from the surface of the cone. This equation with conservative estimates for a and b showed that the 60 degree cone should

Fig. 3. The engine fitted with a 60 degree conical reflector and finned cooler plate.

have an actual energy concentration factor of 3 over the flat plate collector alone, which would represent a considerable improvement in engine performance. Now this calculation is based upon the axis of the cone pointing directly at the sun. My colleague Dr. D. Leake calculated the concentration factor as a function of ray entry angle. The results show that performance does not rapidly decrease with aiming error. For the 60 degree cone, the unit can perform above 85% of peak for one hour, and above 70% of peak for two hours. Thus the cone appears to be quite practical for applications without requiring a continuous tracking device.

The 60 degree cone worked very well in the test program. The details of these tests can be found in references 8 and 10. The net result of the conical reflector and the finned cooler plate was to increase engine power by a factor of about seven.

Power Measurements

Engine power measurements were made in the laboratory. The strategy adopted was to duplicate in the lab the engine temperatures and speeds measured outdoors. Since these conditions could be held constant in the lab, measuring engine power was more reliable and convenient than in the ever changing conditions outdoors.

Figure 4 shows the setup used to measure engine power. The engine is in the center mounted on a stand. Heating the engine from below is an electric heater. Power to the heater is controlled by the variable transformer partially visible on the far left of the photo. To the immediate left of the engine is a dual probe thermocouple thermometer used to monitor the temperatures of the hot and cold plates of the engine. A small fan not

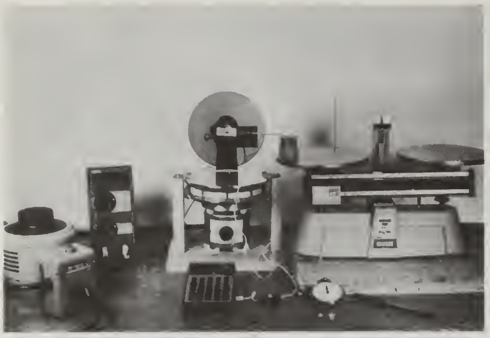

Fig. 4. The laboratory setup for measuring engine power.

shown was used to control the temperature of the engine cold plate.

Speed of the engine was measured by counting revolutions electronically over a time period of 30 seconds measured by a hand held stopwatch. To count the revolutions, a magnet was secured to the engine flywheel positioned to close a reed switch once per revolution. This switch was wired into a T1-30 calculator in place of its "SUM" key. In practice, the calculator memory is cleared and a "1" is entered into the working register. At the same instant that the stopwatch is started, the reed switch circuit is connected to the calculator by depressing a manual switch seen on the bench alongside the calculator. Each time the flywheel magnet swings past and closes the reed switch, one unit is added to the calculator memory. At the end of 30 seconds, the counting circuit switch is opened. The calculator memory is recalled and multiplied by 2 to show the engine speed in revolutions per minute. This proved to be a very convenient and accurate way to measure engine speed.

Engine torque was measured by an arm on the shaft acting on the pan of a balance seen on the right in Figure 4. The grip of the torque arm on the engine shaft is adjustable over a wide range. The arm of course was in a level position when balance readings were taken, and the balance was "zeroed" to compensate for the leveling block on the left pan. This torque measuring method turned out to be very stable.

Figure 5 shows a typical power/speed curve measured from the engine. Peak power was 0.252 Watt at 270 rpm. The temperatures corresponded to those typically recorded in bright sunlight with the conical reflector and finned cooler plate in place on the engine.

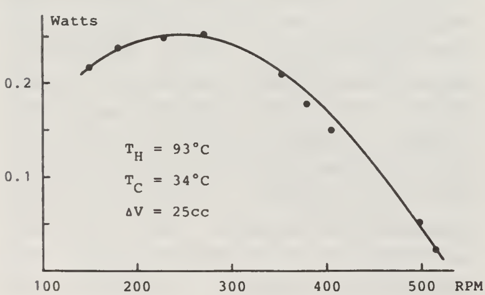

Fig. 5. Power vs. speed curve for the engine.

Conclusion

The project demonstrated that a Stirling engine can be designed to operate from direct unfocused solar energy and provided initial experience and data taken under actual operating conditions. The data collected is perhaps the most important direct result of the project since measurements of engine power, speed and temperatures are essential to guide further development. Indeed, the data clearly show that further work on the engine to increase specific power by a factor of four to eight is necessary in order to realize reasonably small engines capable of doing useful work. Ways to accomplish this include the following: improving the performance of the collector plate, reducing conduction losses through the engine, using a conical reflector having a greater concentration factor, adding internal heat exchangers to increase engine speed, and pressurizing to increase cyclic work. It is felt that a judicious combination of these ideas could ultimately lead to low-cost solar engines having a power output of two or three hundred Watts. Such engines could be of great benefit for household use in remote undeveloped locations.

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A Study on the Use of Cyanobacterin as an Herbicide for Crops

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ABSTRACT

Cyanobacterin an antibiotic secreted by the cyanobacterium, *Scytonema hofmanni* has been studied as a potential herbicide for terrestrial plants. Since the compound is natural, it is assumed at this point that it is biodegradable, certainly a positive aspect of the compound. If it becomes possible to utilize cyanobacterin as a herbicide on earth without damage to existing ecology, its impact will be to provide a balance between technological progress in controlling undesirable plant growth and the preservation of our natural environment.

Excretion of organic substances by algae suggest that these compounds are abundant and of ecological significance.[1,2] Most of these substances are produced by marine flora, principally the red and brown algae.[3] Some antibiotic substances have been reported in freshwater chlorophytes and may also occur in the cyanobacteria.[4] It has been suggested that some of these may have allelopathic effects and thus play a role in the species succession noted in freshwater[5,6] and marine[7] ecosystems. Except for the mammalian neurotoxin, anatoxin A from *Anabaena flos-aquae,*[8] antibiotic substances from freshwater cyanobacteria have not been isolated or characterized. In 1982, I[9] reported on the occurrence of an antibiotic in the freshwater cyanobacterium *Scytonema hofmanni.* Prior to this publication during the summers of 1978, 1979, 1980, and 1981, I worked full-time at the Freshwater Biological Institute in Navarre, Minnesota. This prestigious laboratory of the University of Minnesota hired me to work on the toxins secreted by blue-green algae. Occasionally these algae bloom in Minnesota lakes and cause the death of dogs, ducks, geese, horses and cows, to name a few examples. Early in my discussion with University scientists, I realized that the algae were probably not secreting a chemical to harm vertebrates but that these compounds were being released to influence the growth of organisms around them.

I set up some petri dishes with algae combinations growing in them. One alga was streaked across the dish and another was streaked across the alga at right angles to it. The close association of the algae indicated how compatible they were. Most algae grew together but when *Scytonema hofmanni* was used it prevented the growth of other algae. I had discovered an alga that secretes a toxin or antibiotic. The antiobiotic, named cyanobacterin, has a molecular weight of 430, an empirical formula of $C_{23}H_{23}O_6C1$ and contains a 4-lactone and a chlorinated aromatic nucleus.

Using my Lindbergh grant I wanted to test the antibiotic, cyanobacterin on higher plants to see what the effects would be.

Recent studies on *Euglena* indicate that the antibiotic acts on photosynthetic membranes. This means that the antibiotic may be a potential herbicide. If the compound does act as a herbicide, it will be one of the few natural compounds that does. Natural compounds are usually biodegradable, decomposing in the environment without harmful effects on other organisms. Before this new natural antibiotic can be applied to the environment in any way, its effect on seed plants must be determined.

Cultures of *Lemna* (3 species) corn, curled dock, wild buckwheat, wild oats, and green foxtail plants were treated with cyanobacterin.[10] In *Lemna* an aquatic species cyanobacterin was added to the culture medium and growth measured by counting plants. Cyanobacterin was sprayed on the seedlings of the land plants. Dry weights of plants were obtained 15 days after treatment. The results show that cyanobacterin does inhibit plant growth. In *Lemna* concentration of 1.0 μg per ml is toxic. Cyanobacterin added to the soil had no effect but in green foxtail and wild oats 50% of plants affected, curled dock, 65%; wild buckwheat, 75%; corn and pea 100% were killed. Variations were probably due to the slightly different doses received.

The antibiotic from *Scytonema hofmanni* kills some plants but not all. In other words the chemical will probably be specific for certain plant species, killing some but not affecting others. Exact conclusions are difficult to predict at this point, but the concentration of the antibiotic tested would seem to be very important because most plant species respond to specific concentrations of chemicals. Low concentrations may not affect a plant but an optimum or high concentration is needed. One of the major goals of this research is to determine the optimum concentration of antibiotic needed to kill a certain plant.

Seeds of straight neck summer squash, zucinni, butternut squash, wheat, bean, sunflower, rye, corn, and cucumber were soaked for 15 minutes in 5 μM cyanobacterin. Preliminary results showed that presoaking the seeds in cyanobacterin speeded up the germination rate of the seeds compared to controls. This is not surprising since some herbicides such as 2,4D also act as growth promotors.

It has already been mentioned that cyanobacterin effects the thyllacoid membranes of *Euglena*. The mode of action of the antibiotic is to interfer with electron transport[11] in photosynthesis. This is similar to herbicides such as 3-(3,4-dichloropheny) 1, 1 dimethyl urea (DCMU). Cyanobacterin appears to inhibit electron transport in photosystem II at a site different from that of DCMU.[12]

The total synthesis and x-ray structure of cyanobacterin has been determined.[13] At the present time analogs of cyanobacterin are being synthesized and studied by comparing their mode of action to cyanobacterin.

On the original chromatogram from which cyanobacterin was isolated there are several other active antibiotics which have not been studied to any great extent. The occurrences of these other antibiotics demonstrates that organisms such as *Scytonema hofmanni* do not rely on one antibiotic chemical for their survival but may possess a whole range of antibiotic chemicals to reduce competition from neighboring and competing organisms.

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Incorporation of Tree Corridors for Wildlife Movement in Timber Areas: Balancing Wood Production with Wildlife Habitat Management

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ABSTRACT

Tree corridors, approximately 80 m in width, in a fragmented forest/clearcut landscape in northern Maine were evaluated relative to their use by small mammals and ungulates. Responses of wildlife to the landscape mosaic were species specific. Corridors were not perceived any differently than the unbroken forest by small mammals; ungulates, however, used corridors more often than the forest or clearcuts. It is concluded that the incorporation of tree corridors for wildlife use in timber areas offers a means of balancing wood production with wildlife habitat management.

Introduction

The future undoubtedly will bring an increased demand for forest products. One direct result of this demand will be intensified timber harvesting combined with wildlife habitat modifications. As the urgency to maximize natural resource outputs intensifies, creative approaches to managing wildlife in harmony with other resources will need to be developed.[1]

Landscapes on which timber management is practiced typically consist of a mosaic of remnant forest patches surrounded by a matrix of earlier successional communities. Animal species diversity often decreases in these forest "islands" due to hindered movement across the mosaic coupled with greater rates of extinction over immigration.[2] Preston[3] suggested that decreased species diversity might be prevented by leaving interconnecting corridors of undisturbed forest habitat between forest patches. In addition to travel routes, corridors may provide food resources and protection as well as permanent habitat for some species.

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Despite these promising expectations, the implementation and analysis of large scale forest corridors for wildlife use in areas managed primarily for timber are conspicuously lacking. It was the purpose of this research to evaluate the role that tree corridors play in a fragmented forest landscape relative to their use by selected wildlife species.

Methods

Study Site

The study was conducted in a mature spruce-fir (*Picea rubens* and *Abies balsemea*) forest in northern Maine on International Paper Company land near Clayton Lake (T11 R12) between 8 June and 11 August 1986. The landcape mosaic consisted of three major habitat components: clearcuts, forest, and tree corridors (Fig. 1). Five grouped clearcuts ranging in size from 60 to 200 ha ($\bar{x}$ = 115 ha) and in age from two to six years constituted the central body of the area. Clearcuts were surrounded by more or less continuous forest heavily damaged by spruce budworm (*Choristoneura fumiferana*). Interspersed among the clearcuts and linked with the forest was a series of tree corridors averaging approximately 80 m in width. Shrub and herb density and diversity varied considerably between and within the major habitat groups owing to differing ages and degree of spruce budworm damage.

Animal Sampling

Small mammals were live trapped for 33 days, for blocks of eight or nine days, by means of 450 5.1 × 6.4 × 16.5 cm collapsible Sherman live traps. Traps were positioned across all habitats in the SE section of the study site (Figs. 1 & 2). Fifteen 5 × 6 trap grids were established with traps set at 10 m spacing (Fig. 1). Three grids were positioned in the corridor and also in the forest, with 50 m spacing between grids within the same habitat. An additional six grids were located in the clearcuts on either side of the corridor grids and continuous with them. The three remaining grids were set in the clearcut adjacent to, and continuous with, the forest grids. This trap layout resulted in a total of 270, 90 and 90 traps set in clearcuts, the forest and corridor, respectively.

Significant bear damage to traps occurred during the study resulting in the reduction of available traps as the study progressed. Traps were repaired and replaced when possible. The resulting total number of trap nights for the clearcuts, forest and corridor were 7234, 2294 and 2338, respectively.

Traps were baited with either peanut butter or vegetable shortening and supplied with cotton for insulation and nesting material. Traps were monitored once daily when in use and closed during periods of non-use. Captured mice and voles were ear tagged; shrews, however, were not tagged because of anticipated high trap mortality.

Moose (*Alces alces*) and whitetail deer (*Odocoileus virginianus*) presence was monitored with 86 3.7 × 22.1 m fecal plots (29 in clearcuts, 30 in corridors, 27 in the forest) randomly dispersed in the three major habitats across the entire study site. Fecal plots were surveyed in May and June 1986, and number of encountered fecal piles and the defecating species were recorded.

Statistical Analysis

In the preliminary analyses presented here, all data were grouped by habitat, and mammal habitat use evaluated by chi-square analysis. To analyze for differences in ungulate fecal piles per habitat, moose and deer data were combined into

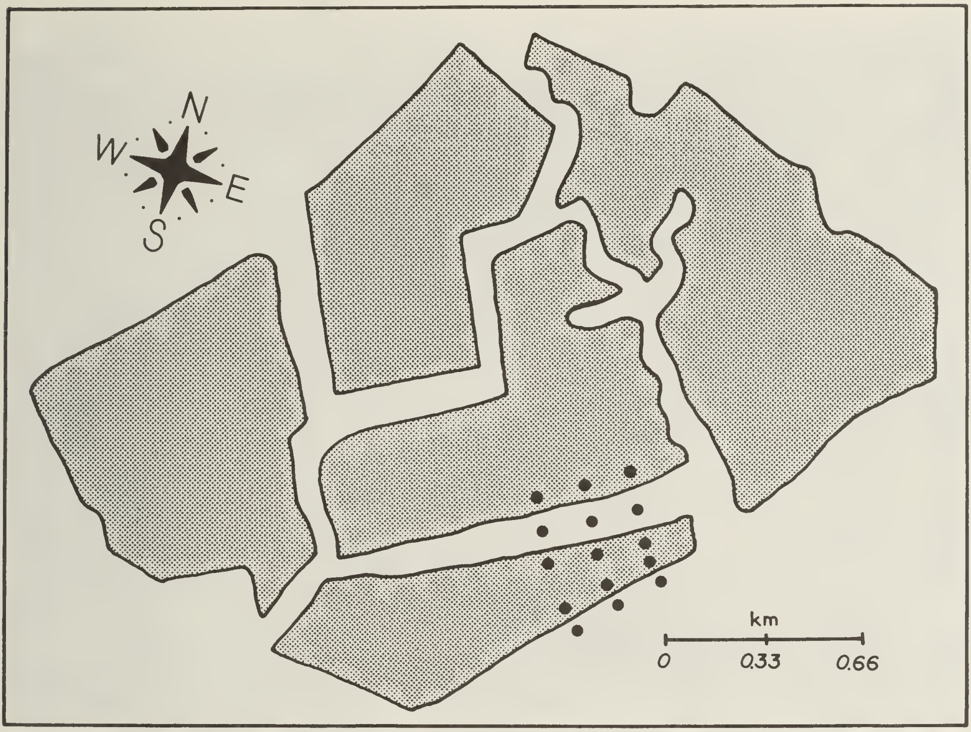

Fig. 1. Diagrammatic representation of the clearcut/corridor/forest mosaic study site near Clayton Lake (T11 R12), Maine. Clearcuts are denoted by stippled areas, and forests and corridors by non-stippled areas. The approximate locations of 15 5 × 6 Sherman trap grids for small mammal censusing are indicated by darkened circles.

one group due to small sample sizes for separate species.

Results

Small Mammals

Three species of small mammals were captured in sufficient abundance to allow for habitat use analysis. The boreal red-back vole (*Clethrionomys gapperi*) was the most abundant small mammal, with 132 total captures. Voles were not distributed evenly across the landscape ($p < 0.001$), with captures occurring most frequently in forested habitats and least frequently in clearcuts (Fig. 3). Capture success in the forest was similar to capture success in the corridor ($p = 0.55$).

The masked shrew (*Sorex cinereus*), with 111 captures, was the second most frequently captured small mammal. Shrews were found in approximately the same proportion ($p = 0.37$) in each of the three habitats (Fig. 3).

The deer mouse (*Peromyscus maniculatus*) was captured 100 trap nights and was concentrated in clearcuts ($p < 0.001$). Occupation of the corridor and forest was extremely low for this species (Fig. 3).

Ungulates

Ungulate fecal pile deposition was not uniform among the three habitats ($p = 0.03$). Defecation occurred more frequently in corridors than in either clear-

Fig. 2. Aerial perspective of the SE section of the study site with a view to the NE. Small mammal trapping effort was restricted to this area. Refer to Fig. 1 for location of traps.

cuts or the forest. The forest was the least used habitat in the landscape mosaic.

Discussion

Responses of animals to a landscape mosaic, and to tree corridors in particular, are species specific. The predominant boreal redback vole presence in the corridor and forest suggest a dependency of this species on features of the forested environment. Redback voles rely heavily on ectomycorrhizal fungi, symbiotes of trees, as a nutritional source,[4] but this food source is largely lacking in clearcuts.[5] In addition, redback voles have a high water turnover rate[6] and may require the moist soil and litter conditions of forested areas to maintain an adequate water balance.[7]

The masked shrew was distributed evenly throughout the landscape, suggesting that its major environmental requirements were available in each of the three habitats. Iverson *et al.*[8] described this shrew as a "nonselective" species because of its tolerance for a broad variety of habitat types. In addition, it does not appear to be influenced by vegetation type, amount of cover or availability of food.[9] Within this landscape unit, therefore, masked shrews are relatively ubiquitous insectivores.

Deer mice, conversely, were almost entirely restricted to clearcuts. Although some consider the deer mouse a ubiquitous species, Getz[7] determined that large clearcuts provide favorable conditions for deer mice, possibly due to increased food supplies. The deer mouse is also an opportunist, and it is possible that deer mice concentrated in the clearcut areas because of reduced competition from other species there. There is good indication that the deer mouse is a relatively non-ag-

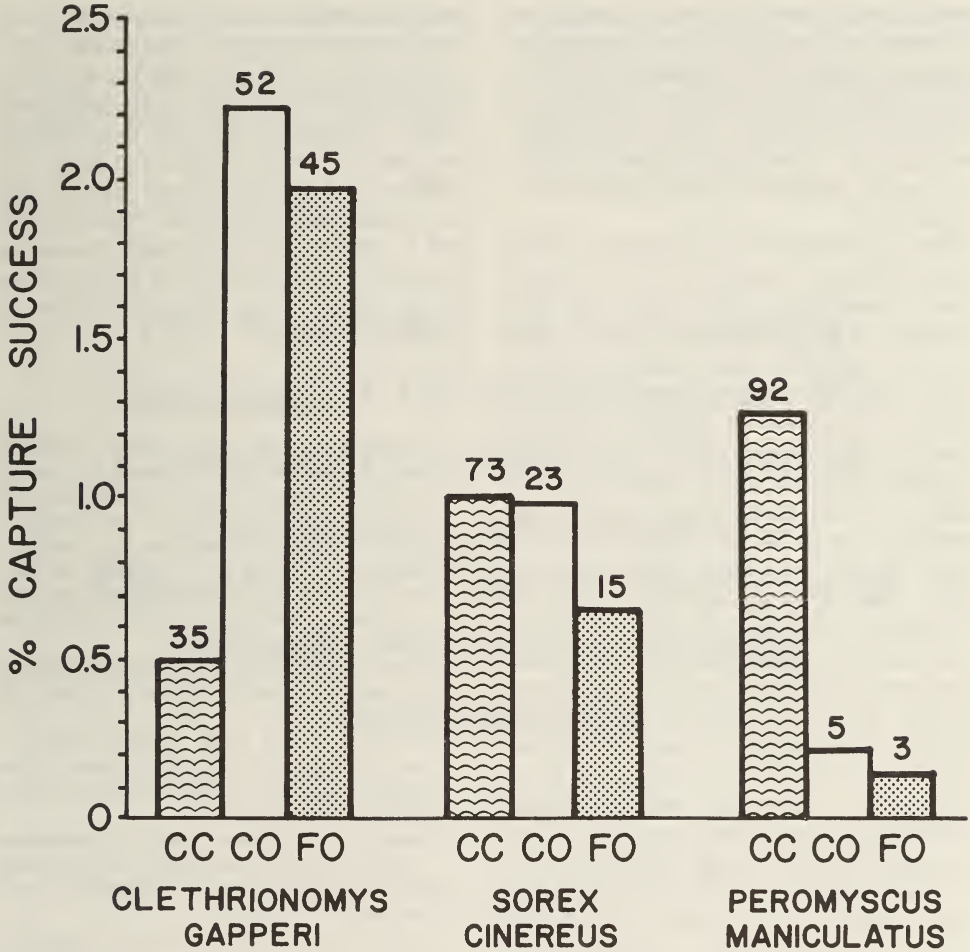

Fig. 3. Percent capture success of the three most frequently captured small mammal species. Clearcut, corridor and forest habitats are denotd by CC, CO and FO, respectively. Numbers above bars represent actual number of captures. Total trap nights per habitat were not uniform; refer to text for details.

gressive species,[10] and thus may be a poor competitor against more aggressive species, such as voles. It is hypothesized that high vole activity moderated deer mouse levels in the forested areas.

Although all three small mammal species showed a pronounced species specific response to the landscape mosaic, corridors appeared to be treated as an extension of the forest and not as a separate landscape entity. This response is likely due to the small home ranges of these animals relative to corridor size. Thus, an interspersion of tree corridors in forest management areas can help maintain species diversity by facilitating dispersion of small mammals.

Ungulate response to tree corridors differed from that of small mammals. If one assumes that the rate of ungulate fecal deposition is constant over time and between habitat types, then moose and deer spent maximum time in corridors and minimum time in forests. It is commonly recognized that patch clearcutting increases edge habitat, which is preferred by deer due to proximity of forage (clearcuts) and cover (forests).[11] Timber removal also enhances habitat for ungulates by reverting the area to an earlier seral vegetation stage, with resulting better forage.[12] There is a limitation, however, to the distance deer will venture into a clearcut. Hanley[13] found the greatest deer habitat use in clearcuts directly adjacent to the forest.

Since corridors were used more often than clearcuts, corridors may provide more advantages to deer and moose than clearcuts. It is hypothesized that corridors not only provide cover and food proximity, but also maximal edge; corridors may be perceived as habitat composed completely of edge. Thus food is easily available from all points within the corridor, not just along the clearcut/forest interface, as in forests, while cover remains readily attainable. Corridors appear, then, to be superior ungulate habitat in timber harvest areas.

In summary, animals do not necessarily perceive a landscape mosaic in the same manner that it is perceived by man, the primary determinant of the habitat patterns. To evaluate the impact of landscapes on numerous species, then, environmental patchiness must be viewed on various levels of scale. Wiens[14] defines the patch structure of an environment as "that which is recognized by or relevant to the organism under consideration." Thus patchiness is "organism-defined." It would seem, then, that a mixture of patch sizes, composition, and arrangements are necessary for maintenance of a diverse fauna in managed forest landscapes. It is hoped that in the future, the wildlife component of the forest resource will not be overlooked in efforts to maximize wood production and minimize harvesting costs, and that efforts will be made to incorporate wildlife habitat management with timber management practices.

Acknowledgments

Diane Borden, Doug Maguire and Jay Matteson are sincerely thanked for their numerous hours in the field under very wet, hot and "buggy" conditions. International Paper Co., through the efforts of Tom Eubanks and Mike Macedo, provided accommodations at the research site and all forms of logistical help. The Charles A. Lindbergh Fund was the major source of financing for this project, and I gratefully acknowledge those associated with the Fund for their unwavering support and hopeful belief in "corridors."

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The Feasibility of Incinerating Chlorinated Hydrocarbons in the Catalytically Stabilized Thermal Combustor: An Attractive Alternative to Current Methods of Organic Hazardous Wastes Incineration

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ABSTRACT

The catalytically stabilized thermal (CST) combustor has many properties that make it a promising means of coping with the problems associated with the incineration of chlorinated hydrocarbons (CHC). The lean stability limits of various mixtures of Methyl Chloride/Ethane wee studied under a variety of operating conditions in a platinum coated honeycombed ceramic monolith. Pre-heating the inlet air and the addition of hydrogen were both found to decrease the minimum operating temperature of the burner needed to maintain stable combustion. At all steady state operating conditions, no CO was found above the detectable limit of 100 ppm and no hydrocarbons or CHC were found above the detectable limit of 0.1 ppm. This corresponds to a total fuel destruction efficiency of at least 99.9998%. The results of this study are promising and justify further work to develop the CST combustor as an attractive alternative to current methods of organic hazardous wastes incineration.

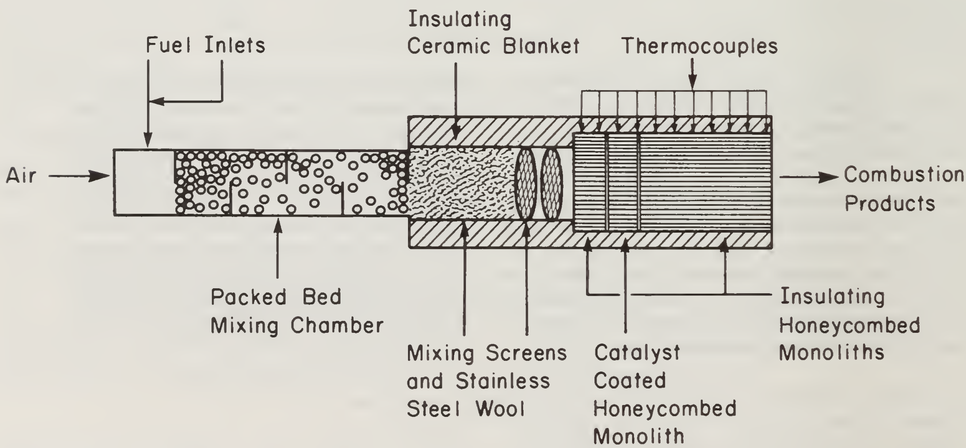
The safe disposal of chlorinated hydrocarbons (CHC) and other toxic organic chemicals is one of the greatest challenges facing the chemical industry. Current incinerators offer relatively complete destruction, but require large volumes to achieve an acceptable conversion. An attractive alternative is the use of the catalytically stabilized thermal (CST) combustor. The size of an efficient CST burner can be much smaller (and even mobile), enabling economic (and more complete) on-site destruction of toxic wastes.

The CST combustor has many features that make it a promising burner design for the incineration of CHC and other organic wastes: (1) It utilizes heterogeneous catalytic reactions to help initiate and stabilize gas phase reactions. (2) It has the ability to burn very lean fuel mixtures and reduce the amounts of CO, NOx and other combustion by-products emitted. (3) It can operate as a near "plug-flow" reactor requiring a relatively small volume to achieve high conversion rates. A more complete description on the CST combustor can be found elsewhere.[3]

CHC fuels are much harder to burn and have a higher tendency to soot than their hydrocarbon counterparts.[1] This is becaue the Cl radicals "scavenge" the reaction mixture for H radicals, reducing the amount of H available for important combustion propagation reactions. The presence of chlorine in the mixture extends the flame front, causing the heat release from the flame to be extended and making the flame much more difficult to stabilize. Also, the extended reaction front increases the probability that partial combustion products will be emitted.

An important advantage of the CST burner is its ability to operate as a near "plug flow" reactor. This is very different from typical incinerators that use back-mixing to help stabilize the combustion process and to achieve high heat release rates. Back-mixing, however, inherently results in a wide residence time distribution (Figure 1, 1A). Because such incinerators produce a wide residence time distribution, a large volume reaction chamber is required to insure that the residence time is adequate for the required conversion.

The volume of the incinerator can be reduced without compromising efficiency by operating the combustor as a plug flow reactor. Because the catalyst in the CST combustor can help stabilize the flame, backmixing is not required and a tubular flow pattern may be used. Ideally, all fluid elements entering a plug flow tubular type reactor will move down the tube in an undistrubed "plug" and there is no



SCHEMATIC DIAGRAM OF EXPERIMENTAL APPARATUS

Fig. 1.

"distribution" of residence times (Figure 1B). In real tubular reactors, however, there will be some degree of dispersion (Figure 1C). It should be noted that even if a "plug" flow is not approximated in the tubular reactor, the tubular geometry will still make the minimum residence time easier to control and reduces the volume of the burner.

We have no knowledge of any previous work done to evaluate the CST combustor for the destruction of CHC fuels, although the catalytic oxidation of CHC fuels have been reported at temperatures below 500 C.[2,4,5] These oxidation reactors, however, do not utilize gas phase reactions to achieve high conversion rates. The purpose of this preliminary study is to determine the lean stability limits for CHC combustion in a CST burner. Also, the completeness of the combustion reactions must be found to

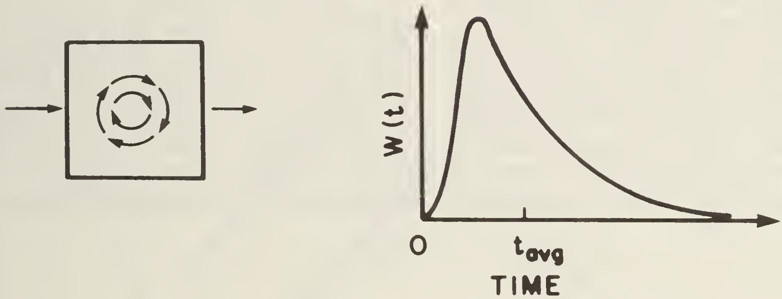


FIGURE 1A: WELL-STIRRED (MIXED) REACTOR RESIDENCE TIME

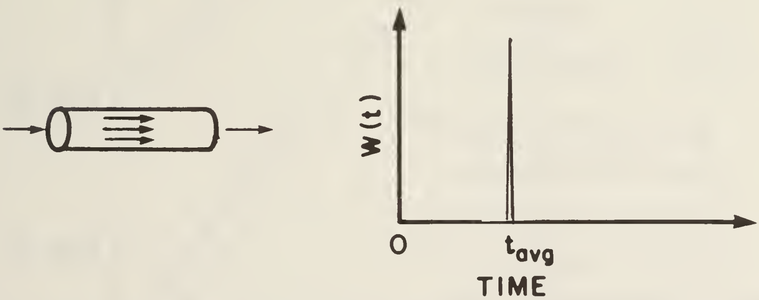


FIGURE 1B: IDEAL PLUG FLOW TUBULAR REACTOR RESIDENCE TIME

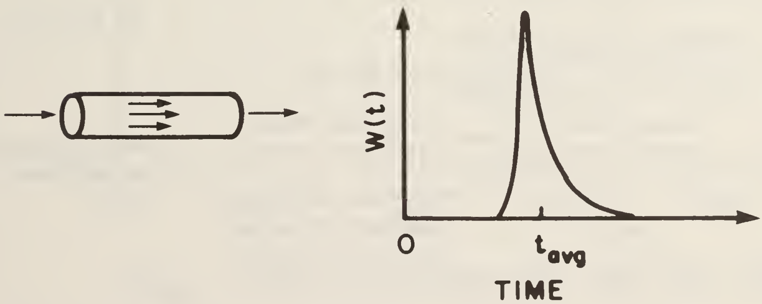


FIGURE 1C: REAL TUBULAR REACTOR RESIDENCE TIME determine if the CST combustor is indeed a practical advancement for CHC incineration.

Methodology and Results

Methyl chloride was used as the test CHC with ethane used as an auxiliary fuel. A schematic diagram of the experimental apparatus is shown in Figure 2. Air and fuel(s) are thoroughly mixed in a packed bed chamber before passing into the catalytic bed. Both the upstream and downstream ends of the catalytic bed are radiation shielded and insulated using ceramic monoliths. The 10.2 cm long downstream insulating monolith also increases the residence time of the combustion gases in the high temperature environment.

The combustor wall temperature is monitored using thermocouples placed every 1.2 cm in the axial direction. Combustion exhaust samples are taken using a water cooled sampling probe and are analyzed using a gas chromatograph equipped with flame ionization and thermal conductivity detectors.

The catalyst bed was made using ceramic cordierite ($2MgO$, $2Al_2O_3$, $5SiO_2$) monoliths coated with alumina followed by a platinum loading of 5.0 kg/m^3. The monoliths have small square open channels with the cross-section in a square honeycombed configuration (cell density = 31 cells/cm^2). The primary advantage of this geometry is that the parallel channels allow the gases to pass through the combustion zone in an approximate plug flow

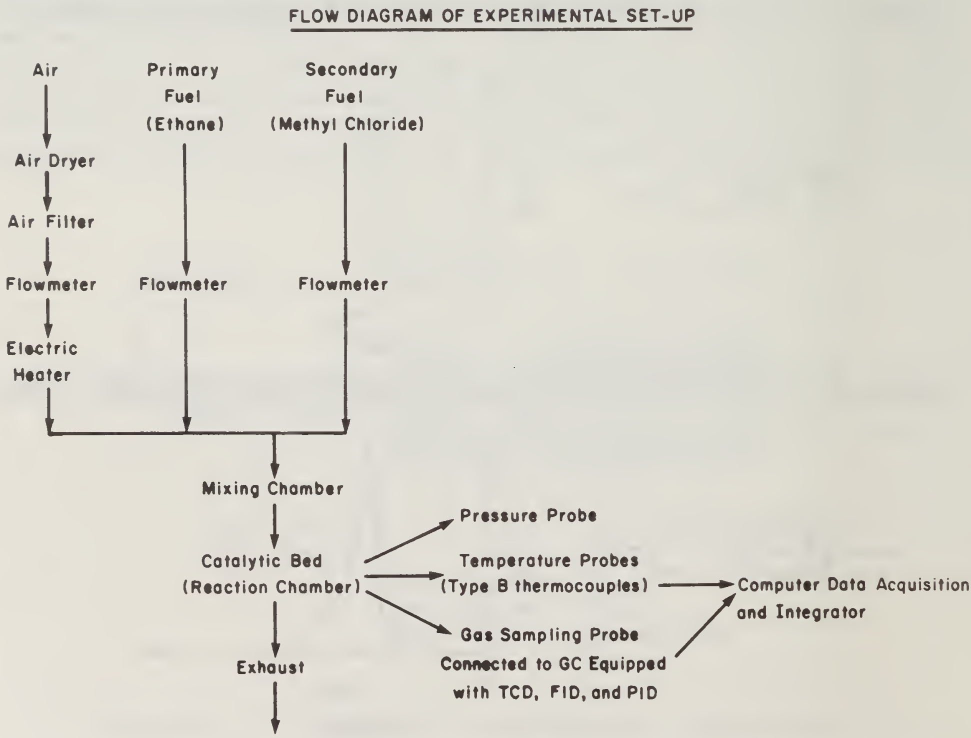


Fig. 2.

fashion. The catalytic bed length was 2.5 cm.

The total flowrate is characterized using the reference inlet velocity. This is the calculated average velocity of the unreacted inlet gases through the catalytic bed and was maintained at 97 cm/sec. The total fuel to air ratio is specified using the equivalence ratio, defined to be the ratio of the fuel actually used to the stoichiometric amount of fuel needed for complete combustion. The equivalence ratio

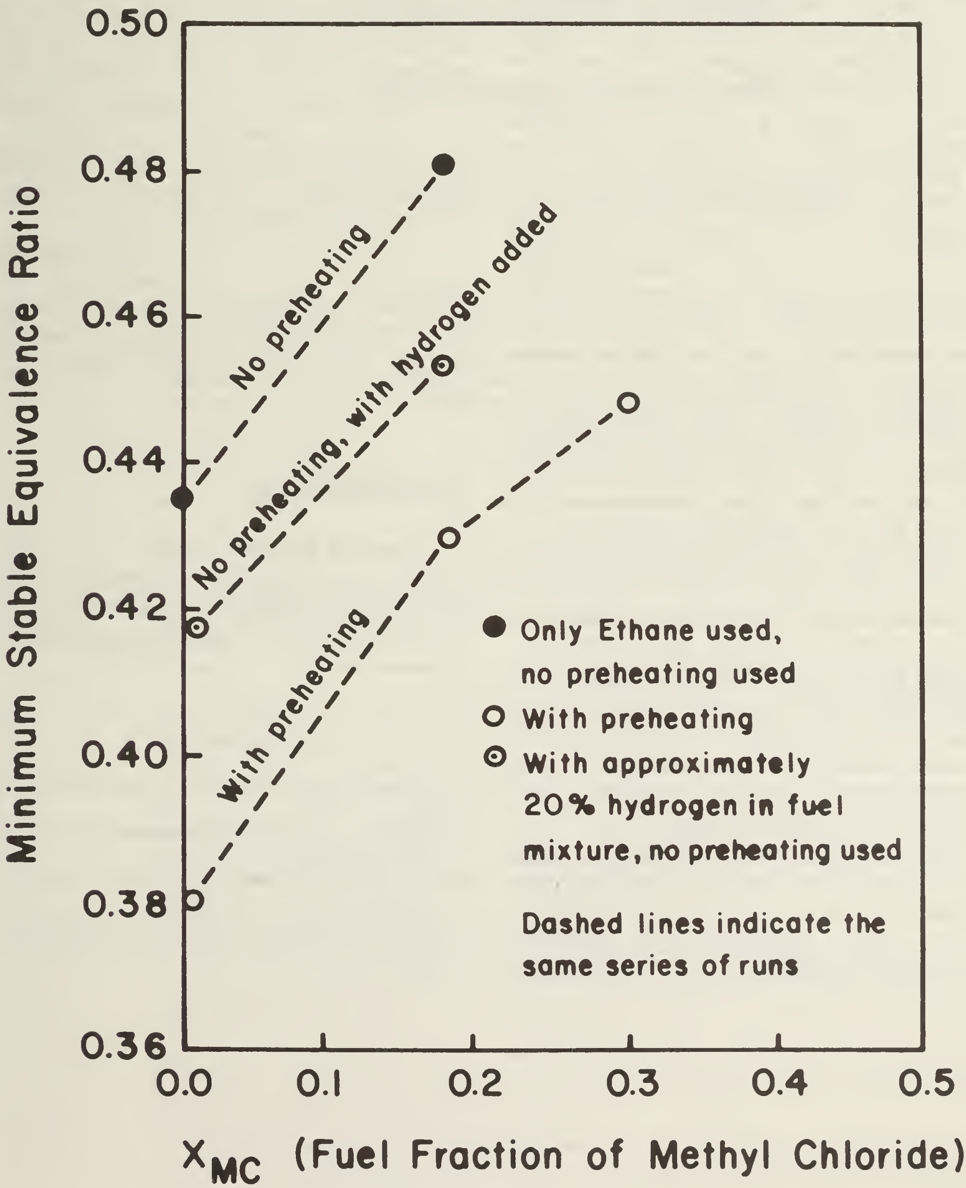


Fig. 3.

of chlorinated feeds is calculated by assuming that all the Cl and H will form HCl if both are present. Any "extra" Cl and H will form Cl_2 and HCl, respectively. Although this is not based on the thermodynamically favorable products, it is useful as an heuristic aid.

The results so far have been very promising. CO, a good indicator of incomplete combustion, was below our detectable limit of 100 ppm in all steady state runs. Total hydrocarbons (and CHC) were below our detectable limits of about 0.1 ppm corresponding to a total fuel destruction efficiency (DE) of at least 99.9998% and a DE of CHC of at least 99.998%.

The first set of runs found the lean stability limit of the burner using unpreheated air and a small amount of CH_3Cl ($X = 0.177$) added to a predominately ethane fuel mixture. Cl hindered the combustion enough to require a higher equivalence ratio (higher temperature) to maintain stability. The temperature required even at the minimum total equivalence ratio (0.42) was high (above 1550 K) and near the upper temperature limit of the catalyst and catalyst support.

The inlet air was preheated by 100 K in the second series of runs reducing the minimum equivalence ratio needed from 0.42 to 0.38. Preheating allowed the minimum stable operating temperature to be decreased by reducing the total fuel needed to maintain stability. A Ch_3Cl fuel fraction of 0.30 was stabilized at a temperature of 1510 K at an overall equivalence ratio of approximately 0.45.

The last series of runs tested the effect of adding a fixed amount of hydrogen (approx. 10%) to the fuel mixture. This decreased the minimum stable operating temperature 60–100 K (and the minimum stable total equivalence ratio from 0.42 to 0.39) (See Figure 3).

Summary

Some of the more significant observations are; (1) CO and total hydrocarbons (and CHC) were below detectable limits. This is a remarkable achievement for an unoptimized initial combustor. (2) The presence of Cl did not deactivate the catalyst. (3) Preheating improves combustor stability, allowing it to operate at a lower temperature and a higher fraction of CHC be used. (4) Hydrogen can extend the extinction limits of the burner.

Future work will focus on optimizing burner performance by preheating and operation with higher temperature catalysts. The effect of the H/Cl ratio will be studied by using different chlorinated fuels.

Acknowledgements

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Marine Natural Products As Ecologically Sound Agrochemicals and Cancer Drugs

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ABSTRACT

Charles Lindbergh's warning regarding the need to balance technological innovation with the preservation of, and respect for, wildness most often makes us think of the potential dangers of high technology: nuclear war, the escape of biologically engineered organisms, and other such modern day problems. However, nothing in man's history has more dramatically affected wildness and the global environment than farming. The advent of agriculture resulted in huge tracts of diverse forest communities being converted into largely monospecific stands of a few crops (primarily grains such as corn, wheat, and rice). As these crops increased in abundance, they became increasingly susceptible to insect pests since these pests could more easily find and consume the crop species when it was not surrounded by the more complex forest vegetation. Controlling these crop pests is one of the major problems of today's agriculture and the wide-spread use of synthetic pesticides has created significant problems for man's health and for the world's environment. With support from the Lindbergh Fund, we are investigating the possibility of using marine natural products as ecologically sound agrochemicals and as potential anticancer agents.

The impact of insect pests on agriculture is staggering. In most cases the primary means of combating this threat has been the large-scale application of synthetic insecticides. Unfortunately many of these compounds are generalized toxins and are highly resistant to degradation, resulting in environmental accumulation of chemicals that are dangerous to both man and numerous beneficial organisms. What is needed are pesticides that are biodegradable and that target the specific pest without affecting other unrelated organisms. Natural products from marine algae show promise in both respects. Many are small organic molecules that are presumably more easily degraded than larger synthetic ones like DDT. Additionally, our recent work in the Caribbean has discovered several seaweed compounds that deter feeding by small arthropods (amphipod crustaceans) that are closely related to terrestrial insects. However, these compounds have no affect on feeding by vertebrates (fishes). Such compounds have potential as insect-specific pesticides.

Our laboratory uses a combination of field and laboratory feeding tests coupled with various chemical analyses to identify those seaweeds most likely to possess unique chemicals with herbivore-specific antifeedant properties. These natural products are then purified and structurally elucidated by collaborating natural products chemists at Scripps Institution of Oceanography. These purified compounds are retested against various marine herbivores, against terrestrial insects, and against human cancer cells. The terrestrial insect tests and the anticancer tests are conducted by collaborators at the University of Arizona and the National Cancer Institute.

Although we are in the very early stages of this work, it has already produced several valuable leads that we hope will eventually further The Lindbergh Fund's goal of balancing technological advancement with the preservation of environmental quality.

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A Genetic Study of Insect Pest Control: A Basis for Development of Safer Insecticides

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ABSTRACT

Since the introduction of DDT in the mid-1940's, synthetic organic insecticides have played a major role in the control of insect pests of medical and agricultural importance. Continued use of pesticides, however, has resulted in the appearance of resistant strains whose control requires the introduction of increased levels of insecticides into the environment. An understanding of the genetic events involved in insecticide resistance would contribute to 1) the more effective use of available insecticides, 2) the development of new, safer insecticides with reduced environmental toxicity, and 3) the exploitation of genetic methods for eradication or reduction of insect populations.

The ability to control insect pests using various chemical agents has led to major advances in agricultural productivity and in the control of insect-borne diseases of man and domesticated animals. On the order of a dozen major classes of chemical insecticides, including arsenicals, cyanide, chlorinated hydrocarbons, organophosphates, carbamates, and pyrethroids have been, or presently are in use for control of pest insects.

The earliest control agents were simple inorganic chemicals such as arsenic derivatives, cyanide, and lime sulfur, which were in use primarily during the mid to late 19th century. Resistance to these types of insecticides was first described for the San Jose scale insect in 1908, and over the next 38 years, eleven additional species were shown to have developed resistance to one or more of these simple chemical control agents.[1]

The introduction of the synthetic organic insecticide, DDT (dichlorodiphenyltrichloroethane), in the mid 1940's marked the beginning of "modern" insect control. Initially, chemicals such as DDT and other chlorinated hydrocarbons appeared to represent a major technological advance in insect control. For example, in the 1950's, extensive use of DDT reduced active transmission of malaria by about 5-fold and by 1966, an all time low of 40,000 cases was reported in India.[2]

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Success in the control of insect-borne disease, however, was short-lived, due to the relatively rapid appearance of insecticide-resistant strains of mosquitoes. By 1978, the annual number of cases of malaria in India had risen to 5.8 million.[2]

The rapid appearance of insecticide-resistant strains in response to DDT was largely unanticipated. Similarly, the long-term impact of pesticide residues on the environment did not become apparent until several years after the use of organic pesticides became widespread. These developments, together with the increasing cost of producing new, more toxic compounds for control of resistant species, have prompted a new emphasis on alternatives to chemical control of insect pests, including the exploitation of insect parasites or predators, and control by microorganisms including bacteria, protozoa, fungi and viruses, as well as the use of insect growth regulators to disrupt normal developmental and reproductive processes. Although these approaches have shown considerable promise, they are generally not as effective as chemical insecticides, and are unlikely to meet the needs of the agricultural industry in the immediate future. In spite of their environmental impact, chemical insecticides will remain prominent in insect control in the foreseeable future.

Continued application of insecticides has resulted in the appearance of over 447 resistant species of insects and mites. Insect populations with full susceptibility to control agents are rare today, and resistance constitutes a serious obstacle to the efforts of many countries to increase agricultural productivity and control vector-borne diseases.[3] Two major resistance mechanisms have been identified in insects: 1) decreased sensitivity of the insecticide target site and 2) increased capacity for detoxication of the insecticide. Both mechanisms have the same net effect: more chemical must be applied to achieve satisfactory levels of control.

The appearance of insecticide-resistant strains appears to involve normal genetic and physiological processes, which evolved independently of the introduction of pesticides into the environment. A major challenge today lies in identifying the molecular bases for these adaptive processes, so that more effective control strategies can be developed. Modest goals of such research include developing the ability to detect genetic changes leading to resistance early, before resistance becomes established at the population level. Early detection would facilitate effective use of existing control agents as well as minimize the environmental effects of inappropriately applied chemicals.

Recently, scientists have begun to identify genetic changes that contribute to insecticide resistance. Target site alterations, for example, have been defined for the enzyme acetylcholinesterase, a key element in nerve transmission whose activity is inhibited by organophosphorous and carbamate insecticides. Individual insects in which a genetic event results in the production of altered enzyme have a selective advantage for survival and reproduction in the presence of these particular insecticides.

Increased levels of detoxifying enzymes, including esterases, oridases, glutathione transferases, and dehydrochlorinases, has been shown to be an important resistance mechanism in several different species including mosquitoes.[4] An important genetic mechanism that can result in overproduction of detoxifying enzymes is gene amplification, in which extra copies of the genetic information coding for the detoxifying enzyme accumulate in the genetic material, and are passed on to future generations.

We have been interested in developing a cell culture model system for investigating gene amplification in the mosquito, *Aedes albopictus*. Cultured cells were selected for resistance to the antifolate agent methotrexate,[5] and resistant cells were shown to produce excess amounts of the target enzyme, dihydrofolate reductase. These cells were then used as starting material for purification of dihydrofolate reductase.[6] The N-terminal amino acids of the purified enzyme were microsequenced, and from the amino acid sequence, the corresponding DNA sequence was deduced. The DNA sequence has been synthesized chemically, and used to identify DNA sequences containing the dihydrofolate reductase gene from a library of mosquito genetic information.

This approach has enabled us to begin to analyze at a molecular level the detailed structure of an amplified insect gene. We hope to use the information that can result from these studies to analyze the early events accompanying the development of resistance, and the stability of resistance in the absence of selective pressure. We anticipate that these studies will lead to a more balanced approach to the use of synthetic organic chemicals for insect control.

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Development of a Rare Halophyte Grain: Prospects For Reclamation of Salt-Ruined Lands

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ABSTRACT

It has been a dream of humankind to find a crop to grow on the billions of acres of salt-ruined lands. Meanwhile, the destruction of coastal salt-tolerant plant species threatens to turn this dream into a nightmare. The development of salt-loving crops (*Distichlis* spp.) from a nearly extinct variety demonstrates the urgency of protecting virgin saline habitats. These salt-loving plants have the potential for land reclamation, forage, lawns, and for allowing many Third World and arid nations to feed themselves.

Food and extinction of species are the foci of two problems of global imbalance: 1) the destruction of agricultural lands which is out of balance with the human need for food, and 2) the extinction of the earth's flora which is out of balance with the human need of that flora.

This project deals specifically with destruction of coastal floras. It is difficult to estimate world wide how much has been lost or will be lost as humankind continues to wreak havoc along the world's irreplacable narrow strip of coastal vegetation where many habitats contain unique varieties.

There is a perceived need and obligation of scientists to inform the leaders of our societies about the long-term economic value of these wild plants to humankind. This project provides an example of a wild plant, recently thought extinct due to humans, that may have an unprecedented benefit for humans. Through this "extinct" plant, the project considers how the salting of the world's agricultural lands (Figure 1) can be brought into balance with the World's need for food.

It has been suggested that humankind's irrigation projects have salinized the earth's surface so that there are no longer virgin areas left.[1] Worldwide there are nearly 4 billion acres[2] that are too saline for conventional crops. By comparison,

Fig. 1. Salinization of a wheat field.

only 2 billion acres are irrigated, and as much as one third[3] may have significantly reduced productivity due to salt.

The technology that created the grain glut has allowed the Developed Countries to get by with far fewer acres . . . and crops . . . human sustenance hangs in balance by a mere three crops (wheat, rice, and corn).

Most of the salt problems, however, occur in the arid Third World countries, which cannot feed themselves. Still, the United States is not immune to salt problems; witness the San Jouaquin Valley and many of the western states. Further, some meterorologists believe the Midwest will become much drier and saltier to the extent that the United States may become an importer of grain. While it is being debated as to whether this will happen, the United States continues to lose 200,000–300,000 acres per year due to salt.[4]

The current global state of affairs lead Bronowski to state, "I guess the single most important biological contribution to world peace will be to produce plants which grow effectively in quite salty water."

It is becoming better known that some wild plants do grow effectively in quite salty water.[5,6,7] True halophytes or salt-loving plants begin to optimize productivity at a salt level where conventional crops are no longer effective.

Given the existence of salt-loving plants, where in the world does one go to find a halophyte crop and how is it developed? Through two grants from the Rockefeller Foundation to the University of Arizona's Environmental Research Lab we searched the globe. What to look for? Because the principle human sustenance crops are all grains, it might behoove us to look for a grain halophyte.

We learned that the Indians may have had a halophyte grain . . . a variety of the genus *Distichlis*. Due to human intervention, however, it was thought extinct.[8,9] We also learned that the Indians used reed rafts similar to those of Egypt and Bolivia to collect the grain which was then stored in thatched granary baskets and that the grain was highly esteemed by the Indians. The legends and history of this grain have many aspects in common with wild rice.

Aerial reconnaissance flights along with continued ground exploration succeeded in locating a few extant patches. The yields observed, however, were quite low, about 10 pounds/acre. And, when the University's test plot only yielded the equivalent of about 1 pound/acre, work on the grain was abondoned with due cause.

The project, however, continued in our backyard and we returned to the field. With the aid of the Tinker Foundation we continued exploring for additional germplasm.

Meanwhile, growth studies at various salt levels were able to definitively demonstrate for the first time that this grain plant is a true halophyte.[10] When the salinity was increased to that of sea water however, the substantially reduced growth, typical of other halophytes, verified the inappropriateness of destroying the worlds coasts for sea water-irrigated farms.

Many valuable wild halophytes occur where the advent of sea water agriculture might destroy them. There are only 20,000 miles of desert coastline, much of which is rocky and not suitable for agriculture and many areas are encroached upon by marinas and other coastal developments. Inland, however, there are 6,000,000 square miles of salty land. It would be indeed sad to see coastal halophyte crops developed only to have them replace what remains of our wild and rich library of halophyte species. Fortunately, virtually all of the potential halophyte crop species studied to date grow better at the lower salt levels such as those found in salty agricultural areas. Conveniently, agricultural areas already have irrigation systems, equipment, and people in place. Thus the more favorable economics of growing halophyte crops in salty farm land is more likely to protect the wild salt marshes and swamps than human ideals.

With 4 billion acres of salt-ruined land to work with, we found no difficulty in steering away from coastal fields and with the help of local farmers prepared test plots in salinized agricultural areas. We learned to direct seed into salty soil. After a number of trials, we gained sufficient rudimentary knowledge to grow the halophyte grain on salt-ruined soil. Two years were required to establish the first fields and obtain a harvest of grain.

Selected varieties of the grain resemble wheat much as wild rice resembles rice. So, following the nomenclature of the Minnesotans, the term "WildWheat" was coined and trademarked.

Remarkably, WildWheat grain grown even in full-strength sea water is not salty. The total ash content is less than wheat or barley.[10] The plant excretes the salt via salt glands, keeping the grain and tissues low in salt-content. Thus, even the foilage can be grazed by cattle without ill effects.[11]

Nutritionally, WildWheat grain is excellent and unique. For instance, ordinary wheat and other cereals have phytates which bind to the essential minerals rendering them unavailable as nutrients. WildWheat grain has relatively low amounts of this anti-nutritional factor.[12] It is, however, high in bran and fiber. The relative amount of bran is high, exceeding 40% by weight.[13] The fiber is also very high, nearly three times that of wheat.[14]

The grain protein has a good balance of the essential amino acids, twice the adult recommended daily allowance (RDA) in most cases. Interestingly, it is possible to make muffins even though there seems to be an absence of gluten. While this may be a boon to those allergic to this wheat protein, the bottom line is, "How does it taste?"

A single-blind sensory evaluation study (taste panel) compared whole wheat honey muffins with muffins made using 25%, 50%, 75% and 100% WildWheat flour. In flavor, little significant difference was found. There was a tendency, however, for "white-bread eaters" to prefer whole wheat and for "dark-bread eaters" to prefer WildWheat grain muffins. The overall acceptability results were similar, but with a tendency to prefer a mixture (Figure 2). The potential acceptability problems associated with eating habits and customs is abrogated by these studies.

An integral aspect of the WildWheat grain introduction strategy is to introduce the nutritious food as a gourmet item. The economic success of WildWheat grain as a gourmet food could have an important benefit. It may facilitate a quicker acceptance by other peoples and nations if the food is recognized to be of gourmet quality. It should be noted that considerable genetic variation occurs suggesting that it may be possible to breed for culturally adjusted flavors, textures, colors and/or protein quality.

With the aid of the Mexican government, the University of Sonora and the University of Arizona, in depth studies are being conducted on the nutritional characteristics of different varieties with regard to protein and starch properties.

By selection we have already found high-yielding varieties which have been hybridized with other varieties. And we have observed a ten-fold increase in yield or about where ordinary wheat was in the 1930s. Six plant patents are pending.

There are now numerous test plots for studying the agricultural aspects of WildWheat grain (Figure 3). For instance, it has the ability to build the top soil. As a perennial, a field may never need to be plowed or planted again. Fertilizer and chemical amendments may not be necessary. A number of investigators

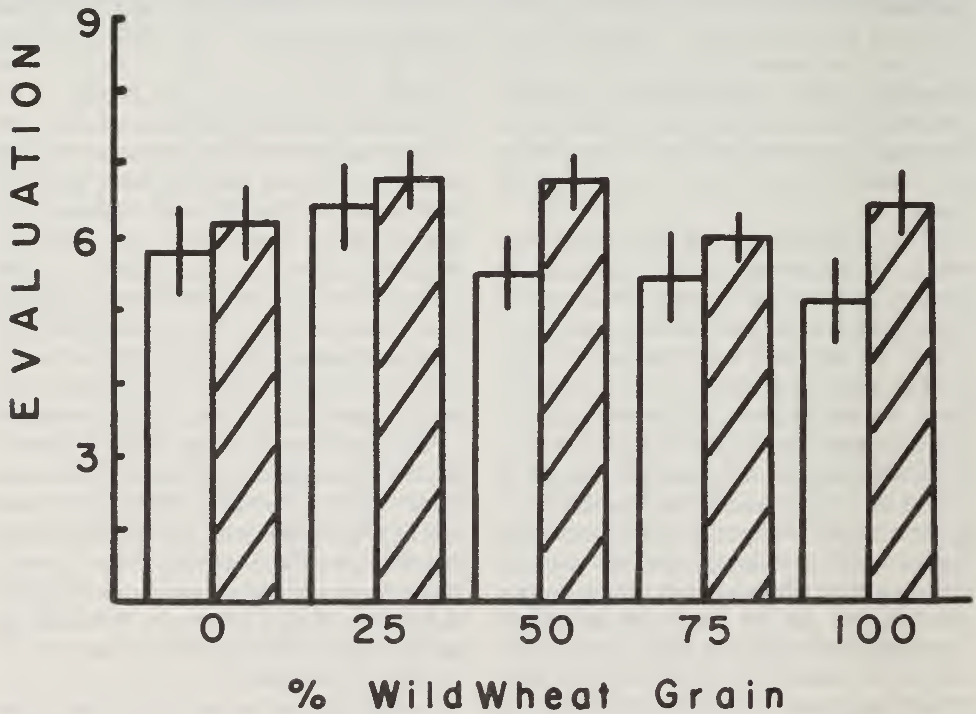

Fig. 2. Overall acceptability evaluation (taste panel) of whole wheat honey muffins and mixtures with 25%, 50%, 75%, and 100% whole WildWheat grain flour. Open columns for occasional consumers of dark breads and hashed columns for frequent consumers of dark breads.

Fig. 3. Agricultural test plots with WildWheat grain plants grown in salinity of 11,000 parts per million salt (approximately 1/3 sea water).

from other universities are also working with us on various aspects of this unusual grain.

The recent expansion of activity in this project would have been impossible without The Charles A. Lindbergh Grant. In addition, it indirectly made possible the 1986 harvest of over 1000 pounds. It occurred to us that this might be enough grain to conduct test marketing. A Tucson company, Engineering and Research Associates, is helping to coordinate this. Three Tucson restaurants* have begun to serve the grain and Nieman-Marcus has offered a very limited amount for sale.

WildWheat grain is being "born" much as wild rice was "born" 50 years ago in Charles Lindbergh's home state.[15] But the potential of WildWheat grain may go far beyond that of wild rice. WildWheat grain and forage has the potential for reclaiming vast areas of salt-ruined land, stabilizing soil from wind and water erosion, providing pasturage, and helping the Third World to feed itself. WildWheat grain's greatest potential, however, may be as a classic example of what humans stand to gain from the wild condition through a balanced use and development of technology.

*The Arizona Inn, In Cahoots Restaurant, and the Rincon Market (Tucson).

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The Economic Utilization of the Babassu Palm: A Conservation Strategy For Sustaining Tropical Forest Resources

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ABSTRACT

This paper discusses progress on research towards the improvement of the utilization of the babassu palm (*Orbignya phalerata*) since a Lindbergh Grant was provided in 1980. The palm is a wild species occurring on some 200,000 Km^2 in Brazil, where it is harvested for oil and charcoal production. The palm is especially prolific on degraded sites that have been cleared of forest and thus helps to stabilize the ecosystem. Improvement in its utilization and introduction elsewhere will provide short and long term benefits and help conserve and exploit tropical forest resources in a biologically sound way.

Introduction

The babassu palm covers a vast area of Brazil and Bolivia, but is most abundant in the Brazilian states of Maranhão, Piauí and Goiás. In Brazil alone, some 200,000 km^2 is covered by stands of Babassu palms. The palm is an important resource to the livelihood of ca. two million people who harvest its fruits for oil and charcoal production. In fact, the babassu palm oil industry is said to be the largest oilseed industry based solely on the harvest of a wild plant.

The babassu palm grows in areas that have been cleared of forest and often is found in high density stands on so-called degraded sites otherwise unsuited for conventional agriculture (Fig. 1). As a source of food and protein-rich meal (the presscake remains after oil extraction) it is a valuable resource for human and animal nutrition, in a region of the world where these commodities are often in short supply. In addition, the endocarp ("shell") that remains after extracting the kernels is converted into charcoal for use in the home and in industry. Charcoal from babassu has a higher energy content and lower sulfur than many mineral coals.

The challenge was to begin a program to better understand utilization of the babassu palm, so that it could be used more effectively in the regions where it is native, and be useful in other areas of the tropics where food and energy are in short supply. With this objective, a project was supported in 1980 by The Charles A.

Fig. 1. Stand of babassu palm in Maranhão, Brazil.

Lindbergh Fund, to work towards a more rational utilization of the babassu palm. Clearly, domesticating and distributing a tree with many valuable products which could grow in less than ideal conditions would be an effective way of helping to meet people's expanding needs while preserving and improving the environment. In the years that followed, collaborative efforts beteween U.S. and Brazilian, Colombian, Mexican, Bolivian, and Honduran scientists have led to the development of a network of researchers investigating the babassu palm resource. These studies have focused on many different facets of the palm and its environment, primarily along two different lines: domesticating the palm for use in plantations either within or outside of the native range and developing techniques for managing native stands of palms to improve yields.

Subsequent support was received from a number of sources, including the U.S. Agency for International Development, U.S.D.A. Forest Service, Consortium for the Study of Man's Relationship with the Global Environment, National Science Foundation, Inter-American Foundation, Scott Paper Company, Joyce Mertz-Gilmore Foundation, Pittsburgh Foundation and Brazil's Conselho Nacional de Desenvolvimento Cientifico e Tecnológico (CNPq). In addition, responsibility for the cost of the germplasm bank and national research program on babassu in Brazil was borne by the Centro Nacional de Recursos Genéticos/Empresa Brasileira de Pesquisa Agropecuária (CENARGEN/EMBRAPA) in Brasilia. Working as a multinational consortium, a great deal of knowledge about the babassu resource has been obtained. Studies of this kind, by definition, take decades to complete and thanks to the support of many individuals and foundations, this effort will be continuing into the future.

It is the intent of this paper to summarize research on babassu that has occurred since 1980, when the new initiative

Fig. 2. Germplasm collecting sites from eight expeditions during 1981–1987.

began. Research lines are presented below as individual sections, with a brief explanation of the activities.

I. Fieldwork/Germplasm Collection

Expeditions to study the babassu and related palms in their native habitat and to collect germplasm were carried out in a number of locations, as indicated in Figure 2. Germplasm expeditions were as follows:

1981: Brazil (Pará, Goiás, Piauí, Maranhão) November–December.
1982: Bolivia (Bení, Santa Cruz) July–August.
1983: Mexico (Nayarit, Quintana Roo) March.
1983: Brazil (Maranhão, Goiás) August–September
1984: Colombia (Buenaventura, Tumaco Region) July.
1984: Brazil (Goiás, Minas Gerais) October.
1986: Brazil (Bahia, Piauí, Goiás, Minas Gerais) January–February.
1987: Honduras (Atlantida, Comayagua, Colón); Belize (Cayo) July.

Genetic material that was collected has been distributed to a number of locations.

Chief among these is the CENARGEN germplasm banks in Piauí and Maranhão, Brazil. Herbarium specimens have been sent to a number of institutions for study by specialists. CENARGEN has produced a computer inventory of all material collected or received as a result of these expeditions.

II. Nursery Trials

Because babassu is a wild species, little was known about its germination and requirements in the nursery. Time required for germination was up to one year, and this had to be reduced to shorten the amount of time the plants spent in the nursery. Research by Claudio U. B. Pinheiro and José Mário F. Frazão successfully resulted in obtaining germination of babassu in a matter of days. The technique involves removing kernels from the fruits, scratching the surface of the seed with a razor near the embryo (scarification), dipping the seed in fungicide and planting it in moist vermiculite. In this way, seeds are able to be transplanted to plastic bags filled with soil within a few months, and grow in the nursery for 6–12 months before being set out in the field. The overall strategy for germplasm banking and characterization is outlined in Fig. 3, kindly provided by Drs. Lidio Coradin and Eduardo Lleras of CENARGEN.

Tissue culture is another way to propagate plants, and a project at CENARGEN, led by Isabel Coría Cabral was undertaken with this objective. Results obtained from this work indicate that plantlets will form from excised babassu embryos cultures *in vitro*. Ongoing work

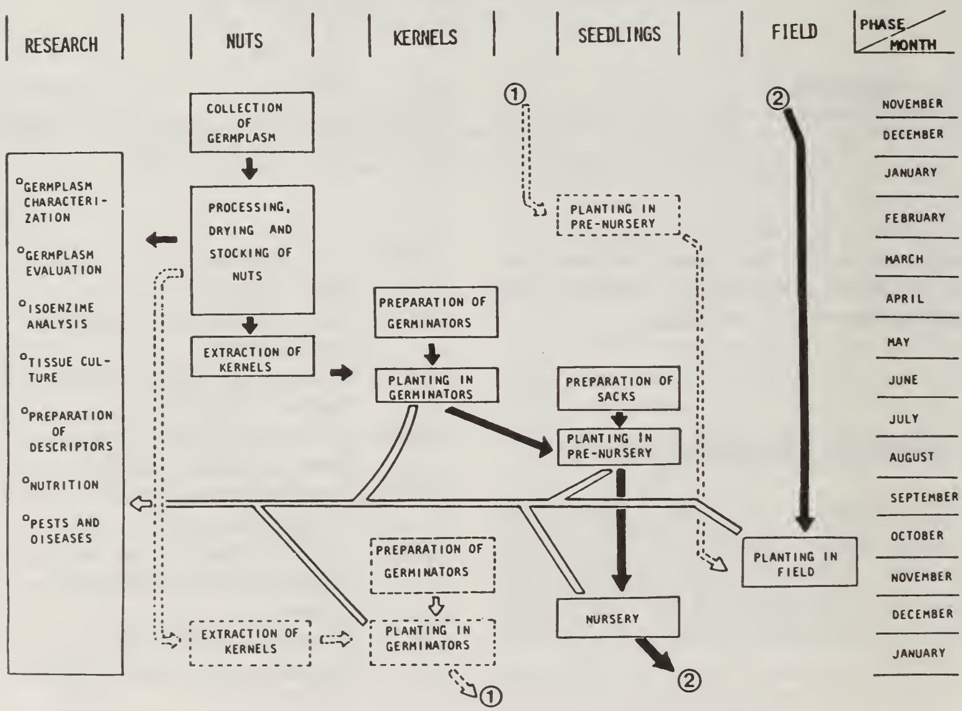

Fig. 3. Flow diagram of activities involved in the conservation of babassu germplasm. *Black:* flow of material; *open:* flow of research data; *dotted:* alternate flow of material.

Fig. 4. The type tree of x*Attabignya minarum*. Reproduced from *Brittonia* 39(1)28. 1987.

with this species and other Neotropical palms at Twyford Laboratories, Glastonbury, England, is seeking to develop cryogenic storage techniques. The results of this work will provide alternative means for germplasm preservation and transport of the babassu palm.

III. Taxonomic Studies

At the initiation of this study, at least ten scientific names in the genus *Orbignya* were associated with babassu. An essential precursor to improvement of a plant is a knowledge of its identity and relationships with closely-linked species. The true identify for the babassu palm has been determined to be *Orbignya phalerata* Mart. Three hybrid complexes were discovered to exist, involving the closely related *Maximiliana* and *Attalea*. A new hybrid genus x*Attabignya* Balick, Anderson and Medeiros-Costa was discovered and described from the Municipality of Santa Fe, Minas Gerais, Brazil (Fig. 4). The palm, x*Attabignya minarum* Balick, Anderson and Medeiros-Costa, is the result of the hybridization of the rare *Orbignya oleifera* Burret with *Attalea compta* Mart. Other hybrid complexes involve a cross between *Orbignya phalerata* and *O. eichleri* Drude,[1] as well as a cross between *Maximiliana maripa* (Correa da Serra) Drude and *Orbignya phalerata.* This latter palm is known as *Markleya dahlgreniana* Bondar.

The discovery that natural hybridization occurs at a prolific rate in the babassu complex is most significant, for it opens up many avenues for the improvement of the palm. The natural hybrids exhibit many characteristics advantageous to utilization, such as increased fruit yield, lower stature, and hybrid vigor. Furthermore, studies of the populations of one of the hybrid complexes by Medeiros-

Table 1.—Subsistence uses of babassu fruits, leaves and stems*

Subsistence uses of babassu fruits.	
Kernels	
Snack nut	
Milk	stewing meat and fish
	beverage
Liquid endosperm	treatment of sties and bleeding
	beverage
Oil	cooking
	soapmaking
	burning in lamps
Residues	animal feed
	substitute or filler for coffee
	shrimp bait
Larvae	food for people
	fish bait
Husks	
Charcoal	primary source of fuel for cooking
Smoke	insect repellant
	smoking rubber
Anesthetic	condensed gases and tar from burning used to alleviate toothache
Handicrafts	pencil holders, keychains, figurines
Mesocarp	
Animal feed	
Flour	substitute for manioc flour and former staple among Indian tribes
	chocolate-like beverage
	medicine for gastrointestinal complaints
Hunting	attractant for rodents

Table 1.—(Cont'd.)

Subsistence uses of babassu leaves.	
Fibers	
Baskets	storage and transport
Mats	doors, windows, rugs, grain-drying
Fans	ventilating fires
Sieves	sifting manioc flour and rice
Others	twine, torches, whisks, bird cages, hunting blinds, animal traps
Construction materials	
Thatch	roofing and walls
Laths	support for clay-packed walls
	frames for windows
Rails	fencing to protect agricultural plots from animals and delimit hunting zones
Agricultural uses	
Leaves burned in shifting cultivation plots to promote nutrient recycling and pest control	
Rachis used for crop stakes and building raised planters	
Living leaves in pastures provide shade for livestock and feed during dry periods	
Medicine	
Liquid expressed from rachis used as antiseptic and styptic	

Subsistence uses of babassu stems.
Construction
Bridges
Foundations
Benches
Palm heart
Food for people
Feed for animals
Ripening agent for banana
Sap (collected from stump of felled palms)
Fermented drink
Attraction of beetle larvae that are eaten or used as fish bait
Mulch/planting medium (obtained from decayed stems)
Salt (made from ash of burned stems)

*From: May *et al.*, 1985

Costa *et al.*[2] have identified morphotypes within the hybrid swarm. The taxonomy of the babassu complex is summarized in a forthcoming paper by Anderson and Balick.[3]

IV. Ecology

A major study of the ecology of the babassu palm was carried out by Anthony B. Anderson, currently of the Museu Paraense Emilio Goeldi in Belém, Brazil as his doctoral dissertation research.[4] While it is impossible to describe all the results of his research in this section, the topics covered include taxonomy and phytogeography, reproductive biology, establishment growth and productivity, population structure and dynamics, implications for management, and five appendices on various relevant subjects.

V. Economics

To get a better idea of the economics of the babassu industry, the Institute of Economic Botany of The New York Botanical Garden commissioned a field study by a group of business consultants. The objective was to identify possible ways in which wild babassu stands, and existing farming systems that incorporate babassu as an element can increase economic viability. Four sectors of the babassu industry were identified: peasants, merchants, landowners and oilseed pressers. Together, the estimated gross annual "value-added" by the industry in Brazil is US $150,000,000. Total industrial production in 1984 was estimated at 120,000 MT of oil and 90,000 MT of presscake. Production of charcoal for industrial use in 1983 was estimated at 15,000 MT; the bulk of the product is used for domestic fuel use.[5]

VI. Socioeconomics

The socioeconomic aspect of this resource has been addressed by Peter H. May, presently at the Ford Foundation in Brazil, who carried out fieldwork in Northeastern Brazil during 1983–1984. His doctoral thesis, entitled "A Modern Tragedy of the Non-Commons: Agro-Industrial Change and Equity in Brazil's Babassu Palm Zone," was recently published by Cornell University.[6] Chapter headings include: Babassu: subsidy from nature and problem resource; property rights and the tragedy of the non-commons; the babassu zone; history and character; structural change in babassu zone agriculture; babassu in peasant farming systems of Maranhão; landowners' decisions and the non-commons tragedy; the rise and decline of the babassu oil industry; technical innovation in babassu fruit processing; alternative development paths for the babassu industry; and conclusions and policy recommendations. There are many social factors that must be considered if progress is to be made on the utilization of babassu.

VII. Agroforestry

Because of the multiple uses of babassu (Table 1) this palm has great potential for expanded use in agroforestry systems. May *et al.*[7] discussed the current use of the palm in agroforestry systems in Northeastern Brazil, where the palm provides cash income, fuel, fiber, edible oil, and food to a large number of tenant farm households. Based on studies of rural families in four municipalities in Maranhão, he found that use of palms for thatch was practiced in 86% of all households, for basketry in 85% of all households, for charcoal in 83% of all households; for "milk" (a beverage from babassu) in 69% of all households, for oil in 71% of all households and palm heart (palmito) in 22% of all households. The two agroforestry systems documented in this study were palm-pasture and palm-shifting cultivation. The second system utilized crops such as rice, maize, cassava and a number of bean species. Other vegetable crops also were found to be grown. This agroforestry system was judged to be sustainable, especially in the less fertile areas where farmers have few alternatives for cultivation.

Prospects for the Future

Work on the improved utilization of babassu palms continues. Funding from a variety of agencies mentioned at the beginning of this paper has allowed a number of projects to be undertaken. Interest will continue to be relatively high in the search for alternative plant species for use in less fertile or degraded environments. Activities such as the workshop on babassu held in March, 1986 in Teresina, Brazil has helped to stimulate international interest in this palm. The weaknesses in this informal research "network" are a lack of long-term reliable funding and institutional instability insofar as priorities and programs are concerned. Nevertheless, this long-term project to improve babassu has demonstrated that multinational scientific efforts to identify and utilize plant species to strike a better balance between technology and the environment can result in many benefits, both immediate and in the future. As tropical ecosystems are increasingly degraded, species such as the babassu palm can provide a stabilizing factor to help conserve and exploit tropical forest resources in a biologically sound way.

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The Evolution of Water Supplies on the Remote Islands of Truk State: Preserving Tradition and the Environment

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ABSTRACT

Truk State is located in the tropical western Pacific area known as Micronesia. In the more remote islands of the State, traditions are stronger and the environment is more pristine. Prior to 1980, water supplies were poor in both quantity and quality. Recent improvements revolve around the concept of using rainwater for consumptive purposes and groundwater for non-consumptive purposes. Low cost wells and rainwater storage tanks, both made of ferrocement, have been developed. The use of solar power to operate pumps has greatly increased the convenience of using groundwater. In general, the application of appropriate technology has resulted in both an increase in standard of living and an improvement in hygiene. This has been accomplished with no loss of valuable traditions or adverse environmental impacts.

Truk State is one of four states in the Federated States of Micronesia (FSM). The FSM was formerly part of the U.S. Trust Territory of the Pacific Islands, a U.N. trust set up at the end of WWII. It is now an independent nation freely associated with the U.S. The FSM is located in the Caroline Islands which, in turn, are part of the very large group of islands known as Micronesia. Truk State consists of all the islands in Truk Atoll itself (hereafter referred to as Truk), the Mortlock Islands to the south, the Hall Islands to the north, and a number of other atolls to the west. The only high volcanic islands in Truk State are located within the lagoon of Truk Atoll. All the other islands in the State are low and coralline and are generally situated on the reefs defining the various atolls.

Truk State is approximately 400 miles east to west and 700 miles north to south. Truk is located roughly in the center of the State. Its lagoon is about 40 miles in diameter with the largest high island in it being only a few miles wide. Outside of Truk, there are around a dozen other inhabited atolls in the State. These atolls are located from around 50 to 200 miles from Truk. Their lagoons vary in diameter from around 5 to 50 miles. The typical atoll island has a land mass that is only a fraction of a square mile.

Almost all governmental activity takes place on Moen Island, one of the high islands in Truk lagoon. Although Moen is by no means a metropolis, it has regular jet service, some paved roads, a reasonable variety of stores, and, in some parts, conventional utilities (water, power, and sewer). None of the other islands in Truk State have yet experienced any of this development, although the other islands within Truk lagoon have ready access to some of these amenities as small boat transportation to and from Moen is possible and, indeed, very common.

In contrast, the islands outside of Truk lagoon are quite isolated. They can be reached only by government "field trip ship" (approximately once every 2 to 3 months) or by occasional fishing boats. In many respects, life on these islands is much the same as it always has been. Cultural practices, dress, diet, etc. are all more traditional than elsewhere in the State. Also, the environment of these islands is generally the most pristine.

The typical reaction of the "outsider" when visiting one of these remote islands is that every effort should be made to keep all this intact. The residents refer to this as the "zoo theory." They are, of course, correct as it is for them alone to decide on the fate of their traditions and environment. Many residents of these remote islands are well-traveled and well-educated. They have experienced the conveniences of western society—and have seen some of its uglier aspects. The dilemma that these leaders know they must resolve is: how to choose from the various avenues of development that are open to them in such a way that valuable traditional practices and environmental resources are not destroyed. A specific area to which this dilemma applies is the development of atoll island water supplies.

There are only two sources of water on atoll islands: rainwater and groundwater. Surface water does not exist because rain percolates so rapidly into the sandy soils. Prior to around 1980, neither of these sources was developed in a manner that insured water of adequate quantity and quality. Wells were often nothing more that open pits dug to the easily-reached water table. Some rainwater was caught from the few corrugated tin roofs that were available and usually stored in open 55 gallon drums. The net result of using these water sources, coupled with questionable methods of disposing of human waste (the beach), gave rise to a situation very favorable to the development and transmission of gastrointestinal and other diseases.

Not surprisingly, in 1982, Truk State experienced a cholera epidemic. Some people have regarded this epidemic as "a blessing in disguise" as it led to major improvements in rural water supplies and sanitation. In the area of water supply, techniques were developed for the construction of a low cost ferrocement rainwater tank. The newly formed Rural Sanitation Program (RSP) conducted training programs on the village level and made efforts to supply materials for tank construction to at least one home owner in every cluster of homes. Some owners of thatched roof homes even went to the expense of building a permanent home so that they would be eligible to receive a tank! A low cost well (Figure 1) was also developed for self-help construction (1,2). This well utilized a small submersible marine bilge pump driven "at the will of the sun" by a single solar module. An important criterion in both the design of the tank and the well was that, given the construction materials, they could be constructed and maintained on the local level. It is believed that the introduction of these improved water sources contributed significantly to the end of the cholera epidemic and, more generally, to an overall decrease in gastrointestinal disease in Truk State.

An important concept embodied in the RSP water supply projects is that rain-

Fig. 1. A household solar well. The solar panel located on top of the pole drives a small submersible pump located within the well casing. The well is sealed to prevent entry of surface contaminants.

water and groundwater should be used conjunctively; a dual water system is desirable. The generally higher quality rainwater from catchment and storage systems should be reserved for consumptive activities (drinking and cooking) except during periods when tanks are full or overflowing. The use of rainwater for only consumptive activities does not deplete the storage of a properly sized tank. The generally lower quality ground water should be used for non-consumptive activities (bathing, washing clothes, and toilet flushing). Atoll groundwater tables are not lowered if water is only dipped or pumped slowly (a few gpm) from wells. At worst, during periods of low rainfall, wells become slightly brackish. This generally has no adverse affect on non-consumptive activities. The application of this concept ensures that water from the appropriate source will always be available. Using solar power to pump groundwater takes this concept one step further. When it is raining, rainwater systems function and solar systems do not. When it is sunny, solar systems function and rainwater systems do not. With the help of the environment, these complimentary systems function automatically.

Recognizing the success of the Truk RSP ferrocement tank building program and the validity of the foregoing concept, the U.S Environmental Protection Agency (EPA) recently funded a project that led to the development of a ferrocement well (3). The well (Figure 2), essentially a series of interlocking cylinders, is, like the tank, simple to construct, cheap, and labor intensive. It is suitable for hand dipping of water or for use with a low-yield hand or electric (including solar) pump. This construction technique has already been adopted by the United Nations Development Program for use in its Integrated Atoll Development Project

Fig. 2. A ferrocement well. Water may be dipped from this type of well or a hand or small electric (including solar) pump can be used.

on Maloelap Atoll in the Marshall Islands. Like the RSP tank construction technique, it is expected to have wide application throughout Micronesia.

The Charles A. Lindbergh Fund provided support for a project to put all this together (4). This project called for the installation of improved water and power supply systems in a remote tropical island home (Figure 3). The object was to demonstrate that a more comfortable and healthy lifestyle is possible and that it can be achieved in a manner that has no negative on-site environmental impact. The project utilized solar power and included a water supply system with the following features:

1. two sources (groundwater and rainwater)
2. filtered and sterilized drinking water
3. pressurized water at the kitchen tap.
4. water piped to an outhouse for flushing
5. water piped to a bathing and clothes washing area
6. a back-up well equipped with a hand pump

On the balance, the project was successful; it certainly was a valuable learning tool. The local family living in the home enjoys what is probably the best water supply system in all of Micronesia. Also, the setting of the home is idyllic. However, there have been problems with the system (corrosion of wire connections, pump failures), many of which were beyond the ability of the homeowner to repair. Only because the principal investigator is now a resident of Truk are the demonstration systems still functioning. Most important, however, is that the project has led to further refinements in

Fig. 3. The Lindbergh project demonstration house. In the foreground is the enclosure for washing clothes and bathing. It is followed by the water sealed toilet and two tanks, one for rainwater and one for groundwater.

the answer to the dilemma facing remote island leaders in so far as the development of appropriate water supplies is concerned.

The most recent effort in the evolution of water supplies in the remote island of Truk State has still not been completely evaluated, but holds promise of being a major step forward (5). Funded by the U.S. Department of Energy, this project again built on previous ones. It involved the pumping of groundwater to centrally located tanks (built of ferrocement) and distribution of the water by gravity to faucets conveniently located throughout a village. Solar power was again used to operate the pumps, automatically complimenting the household rainwater catchment and storage systems installed by the RSP. The pump that was used is a positive displacement unit of the type tested on the previous Lindbergh project; the well casings are the ferrocement cylinders developed in the previous EPA project. It is evident that a system is evolving that is, indeed, utilizing the most successful aspects of previous water supply schemes in Truk State.

This particular project took place on Onary Island in Namonwito Atoll located around 100 miles northwest of Truk. Access to fresh groundwater is particularly difficult as the (only) village (population approximately 125) is located on a very narrow part of the island. Consequently, existing wells are located up to 1/2 mile away in order to get to a wider area where the fresh water lens is thicker. A common sight is women pushing wheelbarrows full of clothing to a distant well for washing. The new wells were located roughly in the same area as the existing ones. Needless to say, the women had a right to dance when the first test brought water from 1/2 mile away to the heart of the village! Onary may be the only island in Truk State (except the site of the Lindbergh project) that has a 24-hour water supply.

What will be the final outcome of this evolutionary process? Like any engineering design, it will go on and on. What I think can be said at this point, however, is that we have achieved something that works, a Spirit of St. Louis; it is not yet a Boeing 747. People are living healthier and happier lives because of improved water supply systems in Truk State. No valuable traditions have been sacrificed and the environment remains intact.

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Educating the Slash-and-Burn Farmer on the Conservation of the Rain Forest: A Challenge in Intercultural Communication

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ABSTRACT

The rapid depletion of the rain forests of the world has been attributed primarily to the indiscriminate use of this resource and to the lack of awareness of the forests' potential as a renewable resource and as new sources of products. In view of this problem, we have produced 16 educational modules designed to introduce forest conservation concepts to school children and forest farmers in the Philippines. Our objective is to have these modules printed and used throughout the public and private school systems during a special week designated as "National Conservation Week." The module for forest farmers will be distributed through the local *barangay* governments.

Introduction

Today, in the tropical countries of the world, there are an estimated 200 million slash-and-burn farmers (or forest farmers) who clear some 160,000 square kilometers of tropical forest per year, an area roughly one and one half times the size of Pennsylvania.[1] Because of their primitive methods of cutting tropical forests, burning the felled timber, and planting crops for three or four years until the nutrients have leached from the soil and they must begin the slash-and-burn cycle over again, forest farmers are considered to be the greatest threat to the world's tropical forests. Before the advent of modern medicine and the population explosion of the past several decades, primitive forest farmers lived in a balanced state with their environment. Indeed, many plants and animals that required clearings and early second growth forest for their habitat benefited by the farmers' presence. Recently, the traditional forest farmers have been joined by large numbers of subsistance farmers who, for lack of land elsewhere, move into the forest lands to farm.

Most forest farmers are unaware that they are systematically destroying one of the earth's oldest and most complex ecosystems and that their actions not only reduce the supply of renewable resources available but destabilize water cycles, leading to depletion of ground water, the erosion and eventual siltation of water courses, and the increased periodicity of floods and droughts. Living from day to day with seemingly no alternative way of survival, the idea of conservation is as foreign to the forest farmers as many of their cultural practices are to us.

If the tropical forests of the world are to survive for the benefit of all humankind, forest farming methods as they now exist must be changed. Forest farmers must be introduced to the need to conserve the tropical forests. They must be introduced to new ways of utilizing existing cleared land that will enable them to live on that land indefinitely. And they must be introduced to ways of utilizing the resources of tropical forests without destroying them.

The objective of this project was to develop a pilot educational program in the Philippines aimed at introducing forest conservation concepts to school children and to forest farmers. It seeks to educate these people so that they understand the importance of the forest as a renewable resource and as a storehouse of useful products for them to use. We hope that the Philippine Government will be able to accommodate the implementation of this project through the private and public schools and through the local *barangay* governments during an officially recognized *National Conservation Week*. We envision that the successful implementation of this project will change people's perspectives toward the rain forest, help improve their standard of living, will reduce the rate of deforestation, increase the utilization of forest products, and ensure the continued existence of most of the plants and animals of the Philippines.

Methods

From 17 July to 7 August, 1986, Kennedy, visited the Philippines to coordinate the program with the Haribon Foundation for the Conservation of Natural Resources, a non-profit conservation society dedicated to the wise use of the natural resources of the Philippines. Dr. Celso Roque, President of Haribon, agreed to be Co-Director of the project. Haribon's Acting Director, Ariel Almendral (later replaced by Julian Tongson, the new Director of Haribon), became the overall coordinating officer in the Philippines.

Three Filipino professionals, George V. Banez, Annabelle E. Plantilla, and Maria Beatriz A. Reyes (George Banez left the project after two months to accept a scholarship to attend school in Japan; he was replaced by Anna Joy Conlu, one of the top original applicants), were hired by Haribon to produce lesson plans for teachers and educational materials for students for five one-hour intensive lessons or modules at different levels of understanding for the following groups:

Group I	School children, Grades 1 to 3
Group II	School children, Grades 4 to 6
Group III	High school students

A single module was produced for forest farmers that will introduce them to new technologies for farming and alternative methods of earning a living from the land, as well as to the general theme of rain forest conservation outlined in the school modules.

The entire program consists of three phases, two for development of the materials and the third for implementing the program. Phase I, presented here, was sponsored by the Charles A. Lindbergh

Fund. The three phases are outlined below:

Phase I

1. Orientation of staff
2. Research on the subject by staff
3. Production of an outline of the modules and lesson plans
4. Production of first draft of the modules
5. Production of second draft and printing of second draft
6. Field testing and evaluation of modules in appropriate schools
7. Production of final modules

Phase II

1. Obtain financial support for completing project
2. Develop the network for distribution of the materials
3. Select a printer
4. Translate modules into several major dialects
5. Select appropriate week for *National Conservation Week* and have government through President Aquino so designate the week as an annual event

Phase III

1. Printing of modules
2. Distribution of modules
3. Implementation of the program during *National Conservation Week*

Results and Discussion

Development of the Modules

In all, 16 modules were produced. Although they differ in the manner presented, they are based on similar topics for each grade and year level. A conceptual outline of the modules with their corresponding objectives is presented in Table 1. (Selected pages from the modules for Grades 1 to 3, 4 to 6, high school and for slash-and-burn farmers are found in Figures 1, 2, 3, and 4.*)

Prior to his trip to the Philippines, Kennedy contacted education departments or specialists from the National Wildlife Federation, World Wildlife Fund-U.S. and California State University-San Bernardino all of whom provided educational materials on nature that aided in the preparation of the modules.

As part of the orientation period, Kennedy either alone or in the company of Banez, Plantilla and Reyes visited the following educational and governmental agencies where he/they met key people and obtained literature and valuable suggestions:

Asian Development Bank—Dr. Colin Rees, Environmental Officer
Bureau of Forest Development—Cirilo B. Serna, Director
College of Forestry, University of the Philippines at Los Banos—Dr. Celso B. Lantican, Dean
Department of Social Forestry, University of the Philippines at Los Banos—Dr. Senesio Mariano, Professor
Forest Research Institute—Dr. Filiberto S. Pollisco, Director, Dr. Mario Eusebio, Assistant Director
Institute for Science and Mathematics Education Development—Dr. Dolores Hernandez, Director, and Dr. Leticia P. Cortes, Science Education Specialist
Institute of Biological Sciences, University of the Philippines Main Campus in Diliman Quezon City
Institute of Forest Conservation—Prof. Jose Olivar, Director, Dr. Felix Es-

*A complete set of the educational modules may be obtained from the senior author for $20.00, postage included.

Table 1.—Outline: Conservation Education Project

Overall Theme: The Forest is for Everybody, Today and Tomorrow
Guiding Concept: The forest is a renewable resource and will provide people their needs on a sustained basis through generations only if they will realize that
1. it is exhaustible
2. they are dependent on it for survival
3. everybody should cooperate to ensure its proper usage

Module 1: Interdependence of Components
Topics to be discussed:
a. Definition of a forest
b. Description of the role of each component to the survival of each unit
c. Concept of renewability/exhaustibility

Grades 1–3:
Title of Module : What Do We see in the Forest?
Objective : To label the things found in the forest.

Grades 4–6:
Title of Module : Let's Go to the Forest
Objectives : To describe what the components of a forest are.
To define the role of each component.

High School:
Title of Module : A Closer Look Into the Forest
Objectives : To define and describe the components of a forest.
To explain the interdependence of each component.

Module 2: Dependence of People on the Forest
Topics to be discussed:
a. Benefits/Uses of the forest
a.1 economic—production of lumber and other forest products
—one of our country's dollar earners
a.2 social—aesthetic/recreational values
a.3 ecological—production of oxygen
—promotes rainfall
—acts as windbreakers/shelterbelts
—stores water

Grades 1—3:
Title of Module 2 : What Do We Get from the Forest?
Objective : To identify the benefits derived from the forest.

Grades 4–6:
Title of Module 2 : The Forest and Us
Objectives : To name the benefits derived from the forest.
To relate these uses to their daily needs.

High School:
Title of Module 2 : We Need the Forest
Objectives : To discuss the uses of the forest.
To relate the said uses to their daily needs.
To generalize the concept of people's dependence on the forest.

Module 3: Forest Dependence on People
Topics to be discussed:
a. Forest destruction
a.1 atmospheric reasons
a.2 biological reasons—pests/diseases
a.3 people's activities—illegal logging
—destructive logging practices
—kaingin making
—overpopulation

Table 1.—(Cont'd.)

b. Effects of forest destruction—erosion
—floods/droughts
siltation

Grades 1–3:
Title of Module 3 : Why Do We See Less Forest Now?
Objective : To name the causes of forest destruction.

Grades 4–6:
Title of Module 3 : The Enemies of the Forest
Objectives : To identify the causes of forest destruction.
To point out the effects of forest destruction to people.

High School:
Title of Module 3 : Effects of Forest Destruction
Objectives : To identify the causes of forest destruction.
To pinpoint the causes of forest destruction in their area.
To relate these causes to the national context.

Module 4: Forest Conservation
Topics to be discussed:
a. Definition of forest conservation
b. Activities undertaken by government and private sectors to conserve the forest

Grades 1–3:
Title of Module 4 : How Do We Care for the Forest?
Objective : To list down forest conservation measures.

Grades 4–6:
Title of Module 4 : Let's Save the Forest
Objective : To summarize ways to conserve the forest.

High School:
Title of Module 4 : Saving Our Natural Resources
Objectives : To explain the idea that the survival of people and forest is interdependent.
To discuss conservation measures.
To suggest conservation measures to their locality.

Module 5: What You Can Do
Topics to be discussed:
a. Social Forestry
a.1 mention specific projects undertaken in upland areas

Grades 1–3:
Title of Module 5 : What We Know About the Forest
Objective : To participate in the activity chosen by the teacher.

Grades 4–6:
Title of Module 5 : The Ever-Important Forest
Objective : To integrate all information learned through the modules presented.

High School:
Title of Module 5 : Our Forests and their Future
Objectives : To write to the government and private agencies about existing conditions and to ask for assistance in possibly instituting changes.
To initiate public campaigns against forest destruction.
To practice conservation measures.

KAINGINERO/FOREST FARMER MODULE:
Title of Module : The Forest and the Upland Farmer
Objectives : To disseminate information about the government's social forestry projects to forest farmers.
To write to their respective district foresters for possible consultations.
To practice forest conservation measures.

lava, OIC and Prof. Valerio T. Rabanal

Ministry of Natural Resources—Minister Ernesto Maceda

Philippine National Museum—Dr. Florante Henson, Acting Director and Pedro C. Gonzales, Curator of Zoology

Wildlife Biology Laboratory, University of the Philippines at Los Banos—Dr. Roberto Rubio, Professor Pablo Alfonso

These contacts provided valuable sources of information to the project and helped insure that the materials produced were as up-to-date and effective as they can be. Everyone supported the effort completely and all volunteered to assist in some way.

The research for the modules mainly took place at the University of the Philippines at Los Banos, where the Forest Research Institute hosted the educational team. They utilized the library facilities of the university and freely consulted with researchers and professors studying forest management and conservation, and social forestry.

Once the modules were completed in second draft, they were field tested in 8 public schools in Metro Manila and in the provinces of Bulucan and Laguna. Teacher training took place during the third week of February 1987, while the actual testing took place during the first week of March 1987. A list of the schools that participated in the testing can be found in Table 2.

The module for forest farmers was tested in Jala Jala, Rizal Province, with assistance from two social foresters from the Department of Social Forestry, University of the Philippines at Los Banos.

Table 2.—Schools selected for field testing the education modules.

I. ELEMENTARY LEVEL
- A) *National Capital Region*
  1. Pinaglabanan Elementary School
San Juan, Metro Manila
  2. Quirino Elementary School
Project 2, Quezon City
- B) *Bulacan Province—Region 3*
  1. Panjolo Elementary School
Obando, Bulacan
- C) *Laguna Province—Region 4*
  1. Talangan Elementary School
Nagcarlan, Laguna

II. HIGH SCHOOL LEVEL
- A) *National Capital Region*
  1. Ramon Magsaysay High School
Cubao, Quezon City
  2. San Juan Municipal High School
San Juan, Metro Manila
- B) *Bulacan Province—Region 3*
  1. Taliptip Barangay High School
Bulacan, Bulacan
- C) *Laguna Province—Region 4*
  1. Talangan Barangay High School
Nagcarlan, Laguna

Evaluation of the Modules

Most of the teachers found the modules interesting and easy to follow. They commented that the print size was satisfactory and that most of the drawings were clear and helped the students to understand what was presented. Some teachers offered comments on how to make the drawings more attractive and thought-provoking.

Several teachers commented that some of the modules could easily be discussed during a one-hour class, especially if the students were asigned the lessons beforehand. Others indicated it would take longer. The module on agro-forestry in particular took longer than an hour because the concept was totally new to most students, particularly those living in urban areas. Generally, students in rural areas were able to relate more easily to the modules.

Additional teacher comments include the following: 1) They thought certain topics were too advanced and needed to be covered in higher grade levels; 2) some suggested more examples to give a clearer definition of concepts; 3) some suggested that colorful pictures or posters be provided so that the students could visualize what is being discussed; and 4) some suggested that field trips into the forest would be a good learning experience for the students.

Teachers were interested in the modules during briefing and they prepared their lessons with visual and other teaching aids. However, only a few of them did any further reading on the subject.

Student reactions varied. Some were enthusiastic and eagerly participated in the class discussion, while others, especially those in urban areas, feared the forest and believed it to be a dangerous place. Urban students were interested in the lessons dealing with agriculture such as the Integrated Social Forestry Program and kaingin (slash-and-burn farming).

In class the relationship between the teacher and the students was relaxed, with little tension. After each page, the teacher would ask the class questions to determine if they understood what they had just read. When the modules were completed, the students appreciated the benefits of the forest and were less afraid of the forest.

The module for forest farmers was more difficult to evaluate because their level of education was very low and many could not read the module. Nevertheless, most of them agreed that the module was effective in disseminating information and that it encouraged them to participate in the government's social forestry projects.

These and many additional comments were considered during the preparation of the final draft.

Where Do We Go from Here

In preparation for Phases II and III of the overall project, the Haribon Foundation has prepared a preliminary grant proposal and is actively searching for funding.

The plan is to gain the support of both the Secretary of Natural Resources and Secretary of Education, who will be actively involved in obtaining the funding from within the government and from international organizations and governments.

If implemented nationally, about 13.2 million students and 300,000 forest farmers will be educated during this week at a cost of about U.S. $5.3 million. At first glance, this cost may seem large, but it actually only costs about U.S. $.40 for each student to receive 15 modules for his/her own use and U.S. $.08 for each forest farmer to receive his/her module.

The breadth and eventual success of this program during National Conservation Week will depend largely on the commitment of the Philippine government to solving one of its most serious environmental problems. All participants (both foreign and especially Filipino) in this project agree that the attitudes of the people must be changed if the forests of the Philippines are to become a renewable resource. This program is a beginning—an exploratory first step—that if successful in the Philippines can be modified and expanded and used throughout the tropical countries of the world. It is not a novel approach, but it is an attempt to produce conservation materials by an interdisciplinary team from within their own country. In addition, it is not the only answer to the tropical forest problems. Scientists and business persons all over the world should be seeking *profitable, non-destructive ways to use the resources of the rain forest.* For without education and without new ways to use the resources, the current rate of deforestation of the earth's rain forests will likely continue.

Acknowledgments

We are deeply indebted to those individuals and organizations that contributed toward the development of this project. We regret that space does not permit us to acknowledge everyone here although we have tried to do this in the modules themselves. Special thanks are due The Charles A. Lindbergh Fund for providing the financial support necessary and The Haribon Foundation for accept-ing the task of developing and furthering this project. Finally, we would like to express our appreciation to Celso Roque, co-director of this project, and to Ariel Almendral and Julian Tongson, who coordinated the project, for their assistance and cooperation throughout.

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A Study of the Short and Long-Term Capacity of Lakes to Naturally Neutralize Acid Rain: An Optimum, Cost-Effective Strategy for the Reduction of Sulfur and Nitrogen Oxide Emissions into the Environment

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ABSTRACT

Lakes and streams in North America and Europe have suffered chemical and biological damage resulting from industrial emissions of sulfur and nitrogen oxides to the atmosphere which form acid rain. Lakes are capable of neutralizing acid at some limited, but unknown, rate by natural chemical and biological processes. This project contributed toward evaluating the rate at which acid-sensitive lakes can tolerate and neutralize acid precipitation without suffering significant ecological damage. This is an essential component of designing an optimum, cost-effective strategy for the reduction of sulfur and nitrogen oxide emissions which will provide the needed protection for aquatic ecosystems at a minimum liability to industries, utilities, etc.

Chemical components of acid neutralization appear to become exhausted after only a short period of acidification (months to years), and only the biogenic components of acid neutralization are maintained for longer periods of time. A much greater reduction in acid deposition will therefore be required to restore acidified lakes and to protect unacidified lakes than would be the case if both the chemical and biological components of acid neturalization were maintained indefinitely.

Introduction

The importance of acid buffering by natural biogeochemical processes occurring within lake sediments has only recently been appreciated. Several studies

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have now shown that acid neutralization occurs in lakes by biological cycling of nitrogen and sulfur as well as by inorganic cation exchange and mineral weathering reactions. The long term capacity for acid neutralization by these processes must be evaluated in order to establish adequate, but not excessive, emission reduction levels that will protect lakes and streams from further acidification and permit the recovery of acidified freshwater systems.

In 1982 we conducted a study using enclosed ecosystems to identify and quantify the rate of natural chemical and biological acid neutralizing processes in the sediments of two unacidified lakes at the Experimental Lakes Area in northwestern Ontario[1]. This study showed that during the first year of acidification while the water columns of the enclosures were maintained at pH $\simeq$ 5.0, natural biological and chemical processes in the sandy littoral sediments of a typical Precambrian Shield lake (L302) could neutralize sulfuric acid at a rate comparable to the rate of H_2SO_4 deposition by acid precipitation in the northeastern United States (e.g., 100 cm/yr of pH 4 precipitation). The question that arose was whether this initial rate of acid neutralization continued indefinitely or if it became exhausted within a relatively short time. To answer this question, we repeated the 1982 experiment in another ELA lake (L223) that had been experimentally acidified since 1976[2]. The pH of the lake had been held at 5.0 during 1981–1983. It was maintained at 5.4 in 1984 during our experiment. If the natural acid neutralization capacity of lake sediments becomes exhausted quickly, then the initial rate of acid neutralization in L223 should have been much smaller than the rate observed in L302.

Methods

Experiments were carried out in vertically oriented flexible tubes constructed of nylon-reinforced polyethylene known as limnocorrals. A limnocorral was installed in L223 on 15 July, 1984. Sulfuric acid was added to the limnocorral to maintain a pH between 5.0 and 5.1 to compare with the rate of acid neutralization at this pH in Lake 302 (unacidified) under similar experimental conditions[1]. The pH of the limnocorral and lake surface water was monitored in the field three times per week. Sulfuric acid was added as necessary to maintain the pH of the acidified enclosure between 5.0 and 5.1. Samples were collected once per week for analysis of major cations and anions. Major cations (Na, K, Ca, Mg) were analyzed by flame atomic absorption spectroscopy. Ammonia and nitrate were measured by auto analyzer in the ELA chemistry lab on the sampling day. Sulfate and chloride were determined by ion chromatography.

Results

A pH of 5.0–5.1 was established in the limnocorral by 1 August and maintained through the experiment. Once a constant pH was reached, the rate of acid addition required to maintain that pH was exactly balanced by the rate of acid consumption within the system. The cumulative H_2SO_4 addition is shown in Figure 1A. The first 8 μeq l^{-1} of H_2SO_4 added simply lowered the pH of the water to 5.0. After 1 August, an additional 16 μeq l^{-1} of H_2SO_4 were added to maintain a constant pH of 5.0. This amount of acid must then have been neutralized within the enclosed system.

Acid additions to the enclosures of unacidified L302 in 1982 are shown in Figure 1B. The first 77 μeq l^{-1} of acid added to L302 simply titrated the water column alkalinity and lowered the pH to 5.0. No further acid additions to closed-bottom limnocorrals (i.e., enclosed water columns with no sediment contact) were required, indicating no further acid

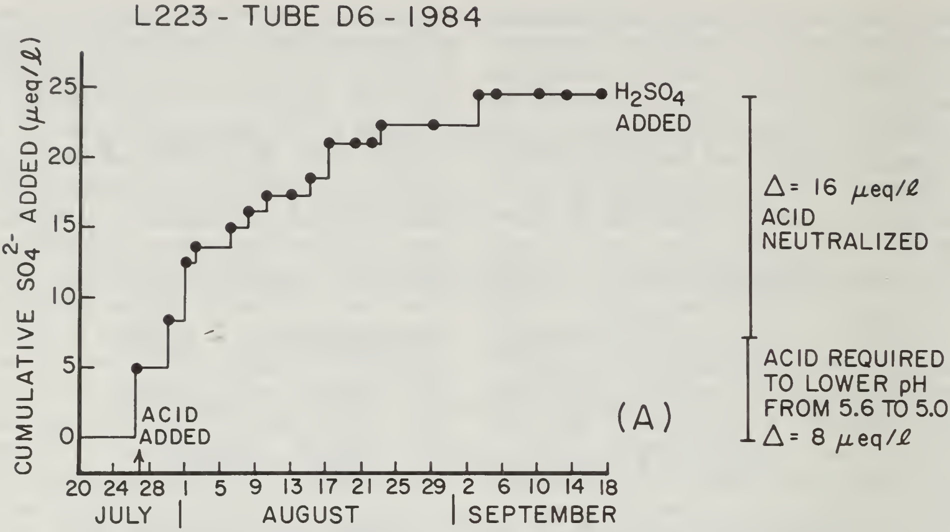

Fig. 1A. Cumulative H_2SO_4 added to the limnocorral in L223 to maintain a pH of 5.0. Once the target pH was established on about 1 August, the additional acid required to maintain the target pH was exactly balanced by acid neutralization within the enclosed system.

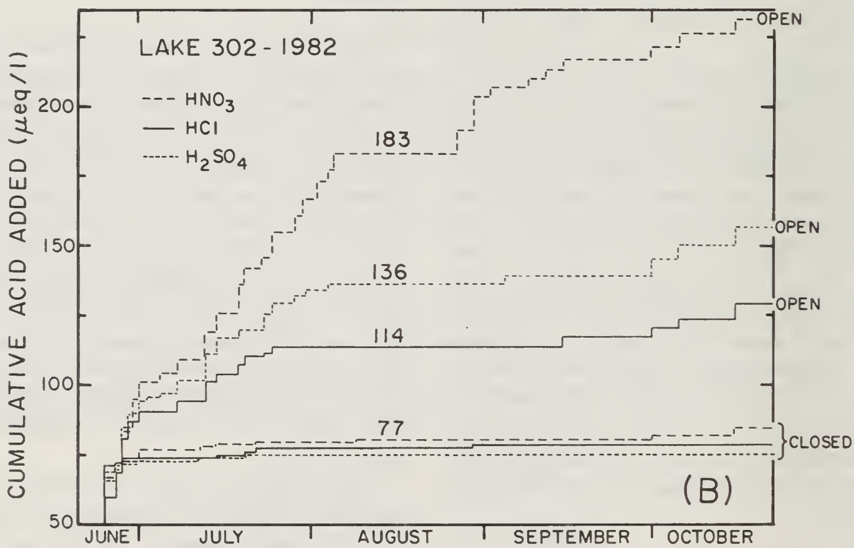

Fig. 1B. Cumulative acid added to several limnocorrals in Lake 302 (pH $\simeq$ 6.8) in 1982. The first 77 μeq l^{-1} of acid added to all enclosures simply titrated the water column alkalinity. The difference between the amount of HCl added to the open-bottom enclosure (114 μeq l^{-1}) and water column alkalinity (77 μeq l^{-1}) represents acid neutralization by exchange for base cations. The results for the open-bottom H_2SO_4 enclosure are comparable to the results for L223 in 1A. The difference between open H_2SO_4 and HCl enclosures ($136 - 114 = 22$ μeq l^{-1}) represents acid neutralization associated with sulfate consumption (see ref. 1 for details).

neutralization by biogeochemical processes in the water column. Therefore, additional acid neutralization in the open-bottom tubes must have occurred in the sediments. Note that an additional 59 μeq l^{-1} (136–77 μeq l^{-1}, see Fig. 1B) of acid were neutralized in the initial two month period in the open-bottom H_2SO_4 tube, nearly four times more than the acid neutralized over a comparable period in L223 (16 μeq l^{-1}). If the water and sediments of both lakes had similar compositions prior to experimental manipulations, then their initial acid neturalization capacities should also have been similar. L223 sediments in 1984 clearly did not have as large an initial acid neutralization capacity as the unacidified L302 sediments had under similar experimental conditions.

The response of the concentration of each of the major ions to H_2SO_4 addition showed that chemical exchange for base cations was a small (<30%) component of acid neutralization in the L223 limnocorral. Thus, acid neutralization by chemical exchange for base cations, the dominant process of acid neutralization in unacidified L302, had been almost completely exhausted in L223 by 8 years of experimental acidification. We therefore attribute the 16 μeq l^{-1} of acid neutralization in L223 primarily to sulfate consumption. Acid neutralization by sulfate consumption at a rate of 16 μeq l^{-1} in 2 months is only slightly less than the rate of 22 μeq l^{-1} in 2 months observed in L302 (Figure 1B: 136–114 = 22 μeq l^{-1} of neutralization by SO_4^{2-} consumption; see ref. 1). The differences between the two lakes (16 vs. 22 μeq l^{-1} in 2 months) may not reflect a decline in SO_4^{2-} consumption rate of L223 sediments at all, and may be within the natural spatial variability in these lakes.

Conclusions

By comparing results of similar experiments in L302 (unacidified) and L223 (acidified for 8 years) we have shown that acid neutralization by chemical exchange for base cations was almost completely exhausted after 8 years of acidification in L223. In contrast, sulfate reduction in L223 continued to neutralize acid at a rate within 30% of that measured in L302. Nearly two thirds of the H_2SO_4 neutralization in L302 occurred by exchange for base cations. Therefore, the initial rapid rate of acid neutralization measured in L302, which was nearly equivalent to the rate of acid deposition over much of eastern Canada and the U.S., cannot be used to predict the long term rate of acid deposition that can be tolerated, or neutralized, by lakes. Only the portion of the total H_2SO_4 neutralization which results from sulfate consumption is maintained for many years. Within-lake processes appear to be able to neutralize acid over long periods of time at only a small fraction of current H_2SO_4 deposition rates in parts of Europe and Eastern North America.

Acknowledgement

D.W. Schindler provided the opportunity to perform our field project at the Experimental Lakes Area and made helpful comments on an earlier draft of this paper. C. Ford and G. Gove assisted with field and laboratory work. Financial support was provided by grants from The Charles A. Lindbergh Fund and the National Science Foundation (DEB 80 17639).

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Restoration of Waters Contaminated with Persistent Organic Compounds by Stimulating Natural Microbial Populations

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ABSTRACT

An ever increasing volume of anthropogenic organic compounds is being released into the environment, causing a significant risk and incidence of the contamination of our natural water resources. Many of these chemicals persist for long periods of time in the environment, which has led to the assumption that they are resistant to degradation or detoxification by naturally occurring microbial populations.

Yet, several laboratory studies have found that some microorganisms isolated from environmental samples are capable of degrading compounds once considered completely recalcitrant to such activity. The work of enriching for and isolating microorganisms with capability of degrading these toxic chemicals has just begun. Few species of microorganisms and few compounds-of-interest have been investigated, and their interactions in the subsurface are poorly characterized.

The proposed work seeks to develop ways to stimulate the biodegradation of hazardous organic compounds by microorganisms already present in the subsurface, as well as to increase our ability to predict the fate of such contaminants in the environment, thereby restoring a better balance between technological progress and preservation of our environment.

In the last few decades, a large amount of our technological progress has involved the development and use of an ever-increasing variety of synthetic organic chemicals in industry, medicine, agriculture, and domestic products. Examples of these chemicals include those in plastics, solvents, lubricants, pharmaceuticals, fuels, preservatives, pesticides, paints and finishing products.

As a result of this rapid and extensive technological progress, a tremendous volume of synthetic organic compounds is released deliberately or accidentally into the environment, causing a significant risk and incidence of the contamination of our natural water resources. It is possible to gain an appreciation of the magnitude of this threat to our environment when it is considered that at least 17 million waste disposal facilities exist in the United States alone. These facilities contribute more than 6.5 billion cubic meters of liquid into the ground each year. Twenty-thousand landfills account for the major portion of solid wastes disposed of, which originated from municipal and industrial activities.[1]

It is inevitable that soil, groundwater and surface water are exposed to these chemicals, resulting in a degradation of environmental quality. The extent of environmental degradation of groundwater is largely unknown. Virtually all cases of groundwater contamination that have been reported resulted from the contamination of water-supply wells. In many cases in which contamination reaches a point of detection such as a water supply well, aquifiers are already extensively contaminated. There are also many other instances of contamination which have not been detected because water supply wells or some other potential points of detection such as monitor well networks are not located near the source(s) of pollution.

Although more than 5 million compounds have been listed in *Chemical Abstracts*, toxicological data exist for only approximately 1 per cent of them.[2] For this reason the potential risk to human health and the environment posed by exposure to the vast majority of man-made chemicals is largely unknown. Even for those compounds for which some toxicological data exist, the effects of long-term exposure at low concentrations are unknown.

Due to the persistent nature of many anthropogenic compounds, it is often assumed that the environment is poorly able to absorb or detoxify significant quantities of many potential and actual contaminants. Those chemicals which have been observed to persist for long periods of time in the environment are generally considered to be resistant to biodegradation by indigenous microbial populations. Many compounds are valued because of their persistence in the environment. Examples include wood preservatives, paints and finishing products. Others are valued for their biocidal properties, which give them their persistant character with respect to microbial activity.

Natural life processes produce a wide variety of organic compounds. They include everything from simple sugars, fats, proteins, nucleic acids, to relatively stable structural polymers such as lignin and chitin. Several naturally occurring organics are produced by organisms to repel, inhibit or kill other organisms. For example, many antibiotics used in medicine today were first isolated from microorganisms such as bacteria and fungi.

It is widely accepted by microbiologists and biochemists that all of these organic compounds are broken down and the by-products recycled in nature by microorganisms. This is known as the principle of microbial infallibility. The reason for this belief is that all of these compounds were produced in nature by enzymes, which are biochemical catalysts used by all living things to synthesize new cell material (anabolism) from simpler building blocks also produced by enzymatic activity (catabolism). Catabolism also provides energy for maintenance and growth. Therefore biochemicals that are enzymatically produced should also be capable of being enzymatically degraded under the proper conditions and by suitable microbes, at least when we consider the laws of thermodynamics and what is already known about the tremendous capabilities of microbial metabolism.

Many anthropogenic compounds, however, do not occur in nature and have not been produced enzymatically. Because microorganisms have not been exposed to them before, they have not developed or evolved the machinery necessary to degrade the chemicals to less harmful structures or to metabolically useful substances. Compounds such as these are known as xenobiotics. Many, if not most, of the chemicals which are of environmental concern fall into this category.

Yet many xenobiotics are similar in structure to naturally occurring organic compounds which are actively degraded by microorganisms. For example, chlorinated phenols, which do not occur to a significant extent in nature, differ from the common compound, phenol, only in possessing chlorines atached to the aromatic ring. Phenol is broken down by some species of bacteria and fungi to form carbon dioxide, methane, or metabolic intermediates. Due to the similarity in structure between phenol and its chlorinated analogues, it is reasonable to assume that microorganisms could also develop the machinery to degrade the latter. A similar statement can be made about many halogenated hydrocarbons, which include a large number of compounds of industrial and agricultural importance.

However, recent work with microorganisms obtained from natural ecosystems such as those in soil, surface and groundwater as well as from wastewater treatment systems has shown that several chemicals once considered resistant can, in fact, be biodegraded at measurable rates. Examples of such compounds include the pesticides DDT and trichlorophenoxyacetic acid.

Significant work has been done in the area of isolating microorganisms from mixed cultures which can degrade compounds of environmental importance, most particularly those 114 chemicals which have been designated by the United States Environmental Protection Agency as priority pollutants.[3] Yet it can be said that this work has just begun. Relatively few of those compounds which are potentially harmful to human health and the environment have been tested for biodegradability. Only a small number of species of microorganisms have been examined in terms of their ability to degrade xenobiotics, most of which include bacteria. Few fungi, including yeasts, which are at least as genetically diverse as bacteria, have been studied in terms of degrading pollutants. Even less is known about the abilities of algae and protozoa to effect decreases in contaminant concentrations.

Little is known about the microbial ecology of subsurface environments such as aquifiers and the unsaturated zone below the surficial soil. The nature and extent of changes which take place in microbial populations in these environments as the result of introduction of contaminants are relatively undetermined, although some educated guesses can be made based on results of laboratory work performed with mixed cultures, which are cultures of microorganisms in which several species occur. The nature of ecological and biochemical mechanisms involved in the adaptation of complex microbial communities to metabolize xenobiotics must be elucidated in order to be able to predict the fate of these compounds in the environment with some degree of confidence. Such information will include that concerning conditions of soil, biomass, nutrients and physical factors which afford the optimum degree and rate of degradation of compounds-of-interest.

This knowledge will not only allow us to more accurately predict the fate of hazardous substances in the environment, it will allow us to design and implement methods for the *in situ* remediation of groundwater contamination. Although most remediation technologies remain largely unproven in their effectiveness, *in situ* removal of contaminants from the environment, where practical, is a desirable option. *In situ* restoration of polluted groundwaters and aquifers is the most straightforward way of dealing with contamination, and it is probably at low cost relative to 'collect and treat' systems. Such treatment systems involve pumping water out of the ground, treating it above-surface in one or more ways, and returning it to the ground either by means of injection wells or infiltration through the land surface.

Treatment of groundwater, *in situ*, may take several forms. One way is to add nutrients or growth factors to the groundwater which will stimulate the growth and degradation activity of microorganisms capable of degrading contaminants. An example is the addition of oxygen, either by sparging or in the form of hydrogen peroxide, in those cases where oxygen is required but does not occur in sufficient concentrations for significant biodegradation to occur. Another potential method is to inject microorganisms which are known to degrade some of the compounds-of-interest. Such microorganisms may have been isolated previously from other environments or have been genetically engineered to perform the required biochemical reactions. It is the former method that is the focus of the proposed work.

The primary purpose of the proposed work, which is so generously supported by The Charles A. Lindbergh Fund, is to seek ways to degrade selected persistent organic compounds by stimulating *in situ* biological processes. Selected compounds including chlorinated phenols, which have been designated by the Environmental Protection Agency as priority pollutants and which have been observed as common contaminants of natural waters.

Methods

The research will involve obtaining microorganisms from soil and water samples which degrade one or more of the compounds-of-interest. Mixed cultures will be obtained by exposing environmental samples to the compounds until significant disappearance of the chemicals, relative to that in sterile controls, is observed. Pure cultures of microorganisms will be isolated from these enrichments using standard microbiological techniques.

Subsequent experiments performed with these cultures will determine rates of disappearance of the chlorinated organics under different environmental conditions, growth rates of the microorganisms, nutrient requirements for biodegradation to occur, and the effect of other organic substrates on the degradation of the compounds-of-interest. The nature and quantity of metabolic by-products released as a result of the biodegradation of the chlorinated hydrocarbons will also be examined.

Most of the experiments will be done in batch at approximately 26°C with mixing provided. Compounds of interest and other nutrients will be added to the batch culture, and compound disappearance and microbial growth will be monitored, as well as environmental parameters such as temperature and pH. Concentrations of the chlorinated aromatics and of metabolic by-products will be measured using ultraviolet-visible light spectrophotometry or a chromatographic method such as gas chromatography (GC) or High Performance Liquid Chromatography (HPLC). Population densities in cultures will be measured in several ways, including viable plate counts, optical density and cell dry-weight measurements. All data will be compared to controls, which will include both sterile and inoculated reactor vessels.

Information resulting from the above-described research will allow the development of a model for predicting the fate of the compounds-of-interest and related compounds in groundwater. This will enable workers in the field to better calculate risks to the environment and human health due to the disposal of liquid wastes containing these chemicals as well as due to inadvertent contamination, such as that resulting from spills or leading subsurface storage tanks.

Results will also allow for the design and implementation of a system for the *in situ* restoration of contaminated groundwater. The design and implementation of such a system will also be a crucial test of the validity of applying results obtained in the laboratory to the field. Such an application is the ultimate purpose and method of evaluation for the proposed work.

Conclusion

It is hoped that the implementation of results obtained in the proposed work will allow balance between technology and the natural environment to be restored in some areas, and its disruption prevented in others. Greater knowledge of the capabilities of indigenous microorganisms to detoxify harmful organic compounds, as well as the development of ways to stimulate and improve the efficiency of such activity, will allow us to more confidently implement technological progress associated with the development, production, and use of a wide variety of organic chemicals, particularly as we become better able to predict the fate of xenobiotic substances in the environment. The development of *in situ* methods for remediating contaminated aquifiers is likely to be most suitable in the long term because it provides a means for ecosystems to restore themselves or to maintain vitality even when exposed to contamination events.

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Human Care in Nursing: Is It Surviving the High Technology Setting?

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ABSTRACT

The study of caring provided by nurses in high technology health care settings is pertinent to the principles of the Lindbergh Fund. This study is concerned with the balance that is being maintained between the human environment and the technological environment. With the increased use of machines and computerized technology in the care of patients, many people are asking if it is the machines that are being tended or the patients themselves. Many are asking how the human is treated in these settings.

The study is concerned with the examination of nurses caring for patients in high technology health care settings by these same nurses and patients. The researchers will videotape nurse-patient situations and play it back to the nurses and the patients to obtain their perceptions of the caring provided by the nurse. The verbatim notes of the videotape playbacks will consist of data collection. Using content analysis and the constant comparative method, themes and categories will emerge from the data. This is a continuation of the researcher's 1985 study concerning "The Meaning of Caring in the Nursing Role." In that study, the researcher investigated the presence of caring behaviors provided by community health nurses to patients in their homes. The 1985 study revealed that caring in nursing is an interpersonal communication that occurs between nurses and patients. As a communication, it consists of content and relationship aspects. The content aspects of the communication of caring in nursing in which there was congruence between the nurses' and the patients' statements were found to be health teaching, health assessment, and physical care. The relationship aspects in which there was congruence were concern, progress and hope, listening, the personal relationship, building self-esteem, touching, and laughter and humor. Communication theory also states that the content and the relationship aspects of any communication are irreducible. This means that caring in nursing practice exists when, for example, physical care occurs simultaneously with listening, and/or concern, touching, etc. Physical care does not exist alone; it exists along with some relationship aspect. Without the two together, caring is not occuring in the nurse-patient relationship. The patient may be treated, but is not cared for.

The project will contribute toward a better balance between the growth of medicotechnology and the preservation of our human environment by identifying which interpersonal behaviors are important to patients in life threatening, high technology health care situations. The study will reveal the kinds of caring behaviors nurses use in highly mechanized treatment settings. It will clarify if the nurses behaviors are perceived as caring by patients. If they are not, it will provide information about the types of behaviors patients do perceive as caring. For it is in our relationships with one another that we become more or less human.

The investigation of caring by nurses in high technology health care settings will examine how nurses work with patients to communicate human support and concern. The personal relationships that develop between patients and nurses are vital for obtaining optimum treatment results. It has been observed that the human aspect of nursing care appears to be increasingly displaced by the specialization and the institutionalization of medical treatment. The question has been raised whether nurses care for the patient or the environment of the machines and health care systems. Health care in the last two decades has increasingly adapted to mechanical equipment and computerized technology. Consequently, the nurse:patient relationship has been altered by the very presence of mechanical objects intervening between the nurse and the patient as the nurse provides care. Patients experience a loss of identity from being treated as an object instead of a person, and from being perceived abstractly as a nebulous component of a technological system. Such behavior depersonalizes the nurse-patient relationship and constitutes dehumanized health care. Despite contributions made by medicoscientific discoveries and technologies, developing science must not be allowed to overshadow the individual patient, reduce the patient to an object, or become tyrannical agents untempered by an humanistic value system.[1] There is concern that nurses will be coerced into becoming high-level technicians who seldom have time to give personalized care to people by providing essential care acts to patients and families. Personalized care is very different from technological care. It requires more openness; flexible creative thought, time, direct involvement; and the provision of specific care constructs to meet patients' needs. Diagnostic workups, treatments, and most surgical interventions can be received in the physician's office. What people want and need most in the hospital has been and still remains humanized care from nurses.[2]

Humans have historically demonstrated unusual sensitivity and considerable ability to recognize and treat the needs of the young, the weak, and the helpless. Helpful human behavior includes an essential growth-producing component which encourages individuals in need to accept their need for care, and to participate as actively as they can in the caring process. The goal of nursing as an art, a science, and a discipline, is to promote optimal health through these interpersonal processes, as well as technological activities. Nursing care focuses on human capacities and strengths, so that the nurse and the patient can participate in a therapeutic alliance. This alliance integrates a pattern of caring actions that help improve a patient's health. If, however, the nurse perceives the patient only as an extension of a technological system, the therapeutic alliance will not materialize. While the patient is treated, the patient will not be cared for.

The idea to study the meaning of caring in nursing arose while I was teaching nursing students. Many times I observed how anxious students became during their experiences in intensive care settings and I wondered how can they care for patients when they are so concerned with technical skills. This led to a master's project in which I investigated with students how they got beyond the technology to provide caring to patients. The issue of caring in nursing continued to intrigue me and focused my doctoral research. As I reviewed the literature I noticed that most nursing research which investigated caring looked only at the perceptions of one of the participants, either the patient, or the nurse. No study had looked at the congruence of their perceptions to determine what it means to be cared for, or to care for, by both the nurse and the patient. I next had to determine a method which would allow both the nurse and the patient to experience the same situations, and then to tell me about the caring, or the not-caring. A solution was to videotape nurses caring for patients in health care settings, and then to replay the tape to them separately, taking verbatim notes of their responses to the question: Tell me every time you see something in the tape that shows the nurse cares for or about you. Tell me right away so that I can stop the tape and you can tell me in detail what you see. (The question to the nurses: Tell me every time you see something in the tape that indicates that you care for or about the patient. . .).[3]

In that study, community health agencies were chosen as the sites out of which to collect data. Nurses volunteered to participate in a study of nurse-patient interaction. It was required that all nurse participants be women, be a professional nurse for at least one year, work for their agency at least six months, and speak fluent English. Patients were selected by the volunteering nurses to participate in the study. Informed consent was obtained by the researcher. Thirty-two patients and 19 nurses participated in the study. Data was collected in two steps. First, by videotaping a segment of the nurse caring for the patient at home. Second, by replaying the tape separately to the nurses and the patients to obtain their perceptions of the caring behaviors revealed in the videotape.

Using content analysis and by constantly comparing new data with previously collected data, 20 themes were extracted from the verbatim data.[4] These themes were able to be integrated into the major categories of Watzlawick's[5] communication theory: content and relationship. Of these 20 themes, there was congruence in ten themes between patients and nurses. Three were congruent in content: health assessment, health teaching, and physical care; ten in relationship: concern, trust, progress and hope, listening, laughter and humor, advocacy, and self-esteem.

One conclusion of the study is that caring was an interpersonal communication between nurse and patient which is experienced through the content and the relationship aspects of the nurse-patient situation. And caring consists of both aspects. It is holistic. For instance, physical care may be present with concern. One cannot exist without the other; otherwise it is not caring.[3]

The present study continues to investigate the meaning of caring. High technology health care settings were chosen because this was the area where I first noticed student nurses' extreme anxiety, and also in the doctoral research, the area where patients talked about specialized care, not personal care. Settings will consist of medical intensive care units (ICU'S), surgical, pediatric and neonatal ICU'S. There will thus be an opportunity to determine congruence between nurses' and patients' perceptions, and an opportunity to determine if the patterns of caring identified as significant differ from setting to setting. Four general hospitals have agreed to participate in the study. Qualifications for the nurses remain essentially the same except the nurses need to have worked in ICU settings for at least six months. Patient qualifications are similar to the first study: fluent in English, sighted, and not confused so that a valid informed consent can be obtained. In the case of children under six and infants, informed consent will be obtained from parents. All participants will volunteer.

Videotaping will take place in the hospital settings. Playbacks to the patients will occur at home; to the nurses in the hospital. Participants will be informed at the time data collection begins that nurse-patient interactions are being studied. The research question remains the same, except for the addition of the following questions to the nurse: "How do you get beyond the technology to provide caring to the patient?" and to the patient: "What did the nurse do to get around the tubes and the machines so that you felt cared for and about?"

Analysis of the data will be similar. Content analysis of the verbatim data will be done to identify themes and to categorize themes using the constant comparative method. Reliability and validity are assured by using this method, and by the principal investigator and the research assistant acting as a panel to review the themes and the categories which emerge. Internal consistency, face, content and construct validity are thus established.[4]

Part of the strength of doing qualitative research is in the rich data you obtain from participants. Each category emerges from statements made by the patients and the nurses. For example, the category, Health Teaching, from a statement by a nurse in the 1985 research:

> I'm teaching her (the young mother of twins, both born prematurely, and delayed in their growth and development) about their growth and development, that the twins differ from each other, and from her sister's baby. I'm teaching her how to manage her day with two babies with different schedules. I'm teaching her at the same time to learn about her own needs for growth and development. I'm giving her hope that the twins will grow up, that she will also grow and change.[3]

This study will have immediate impact on the project participants. It was found in the 1985 research that the process of reviewing the videotape brought about an increase in self-esteem for both nurses and patients.[3] From a patient with a stroke, "She makes me feel like a whole person, not a bumbling person."[3] Such feelings about the self increased this patient's and others' sense of worth and self-esteem. For the nurses it brought about a clearer sense of what they do and often how well they provided that care:

> "I see here myself, totally involved with the patient. . . Despite the fact that I find this patient hard to deal with, I see that the kind of care I give is more than adequate."[3]

The study will also impact on the nursing profession and the general public. As a result of the findings of the 1985 research, one nursing curriculum has increased the amount of time devoted to teaching about caring.[6] There is ongoing discussion with a hospital to set up a unit using the knowledge about caring which has been gained and will be gained from the Lindbergh Fund's support.

The project will contribute toward a better balance between medicotechnological growth and preservation of our human environment by identifying which interpersonal behaviors are important to patients in life-threatening, high technology health care situations. This study will shed light on the kinds of caring behaviors nurses use in highly mechanized treatment settings. It will clarify if the nurses' behaviors are perceived as caring by the patients. If they are not, it will provide information about the types of behaviors patients do perceive as caring. For it is in our relationships with one another that we become more or less human.

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Seafloor Mineral and Geothermal Resources Video Tape Production to Promote the Education of High School Students (Project HEAT)

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ABSTRACT

Within the last twenty years earth and ocean scientists have discovered a dramatically new source of energy on the seafloor. This is geothermal energy and it far outstrips any type of geothermal energy known on land. The discovery was made by the use of advanced deep-sea sonar technology which has revolutionized our perspective of the birth and growth of the ocean basins. This advancement in technology has provided us with new theories about the formation of some of the most valuable minerals known to man and the mechanisms by which petroleum is emplaced within seafloor sediments. The video production HEAT is about the discoveries and the discoverers. We will cover the implications that mineral and petroleum resources have on our lives, and will follow during the stages of their formation and maturation within the sea. The aim of this project is to educate people about the origin and the fragility of the resources that we use today, and the balance that must be upheld between advanced technology and the preservation of our deep-sea environment. This is particularly important today where oil and mineral economies rule the stability of the world.

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Developing a Solar Energy System Using Seasonal Earth Thermal Storage (SETS) at the Smithfield Academy (Hatfield, MA)

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ABSTRACT

An investigation was conducted to determine the performance of a solar system which uses earth as a seasonal energy medium. A comprehensive computer analysis based on our experimental data showed that the performance of the system exceeded the performance of the same system without seasonal storage capability by a minimum of 10%. The results also showed that it is practical to store solar energy all summer and that it will still be available for heating the building as late as November. An economic analysis was carried out using simple payback and life cycle costing and assuming a discount rate of 9.1% and fuel inflation rate of 12%. The analysis showed that the payback time will be 12.5 years. Simple guidelines for the design of similar storage facilities have been prepared. These guidelines discuss the type of system suitable, the need for top and side insulation over the storage volume, and steps for the design of different system components.

Introduction

Most of the world's energy needs are derived from the sun. Coal, oil and natural gas owe their existence to solar energy but are not renewable resources. Seasonal energy sources of one type were used extensively before widespread use of mechanical refrigeration occurred. Ice was cut from lakes and rivers and stored in ice houses. Saw dust was often used for insulation and ice could be stored all summer. The subject of the current investigation also is involved with seasonal storage of thermal energy. However, we are concerned with storing solar energy during the summer and using it for heating purposes in the fall and winter. The system we have studied also will store excess energy not needed to heat the building on sunny days during the heating season. The solar storage system is 85 ft by 100 ft by 8 ft deep. It is insulated on all sides and the top and bottom by polyurethane foam. The top and bottom thicknesses are 6 in and 2 in respectively.

The insulation thickness of the vertical sides ranges from 2 in at the bottom to 6 in at the top. The top and sides are covered with polyurethane sheets. The storage is charged by 1840 sq ft of solar collectors. The earth storage and collectors are coupled to 40 water-to air heat pumps which provide heating for a school with 178,000 sq ft of floor area. This system is located in Hatfield, MA, a small town about 30 miles north of Springfield. Energy is exchanged with the storage volume via 252 Ethylene-Propylene Diene Monomer tubes of 1/4 in diameter which are installed in the storage mid-plane.

Experimental Investigation

Data was gathered with a computer based data acquisition system. Thermocouples were located in and around the storage volume. Storage temperatures, solar insolation, and collected energy were measured and recorded every five minutes. From May to October 1983 the solar energy collected provided a maximum energy content in the storage of 36,000 kWh. The reference value for energy storage is 55 F which is the lowest operating point for the heat pumps. The maximum temperature achieved in the storage to date is 126 F.

The data was stored initially on a microcomputer and then transferred to a main frame computer where it was stored and analysed.

Figure 1 shows the site plan of the building and the adjacent underground storage area. As shown, the solar panels are located on the roof of the school. Figure 2 shows a section of the storage space. In this drawing, the dimension c equals 8 ft and L is 4 ft. Figure 3 presents a schematic drawing of the entire system. The pyranometer which is attached to one of the collectors is used to measure solar insolation (incident solar radiation). There are four modes of operation. In Mode A, energy goes from the collector to the storage volume. This mode is used during warm weather when no building heating is needed. In Mode B, energy is removed from storage and used to heat the building. Mode C is used if the collectors supply more energy than is needed by the building. In Mode D, energy is transferred from the collectors to the building.

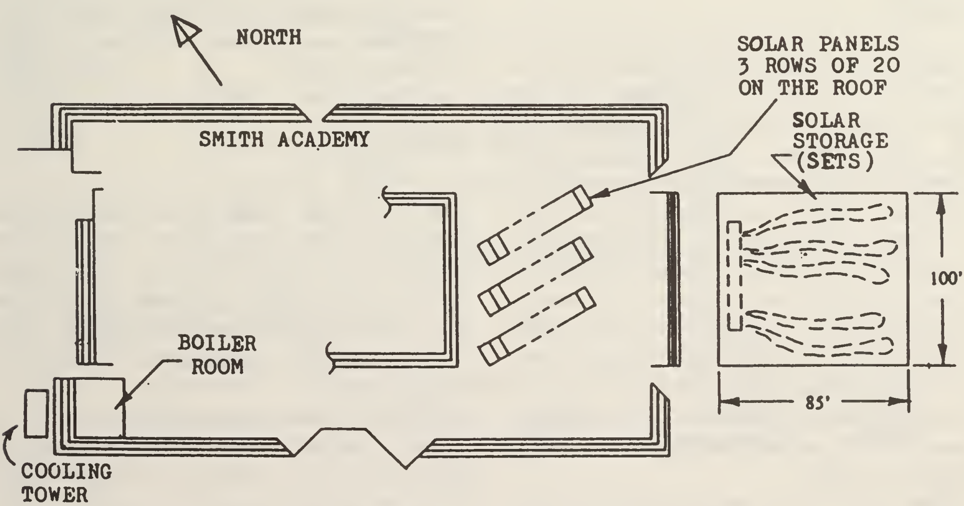


Fig. 1.

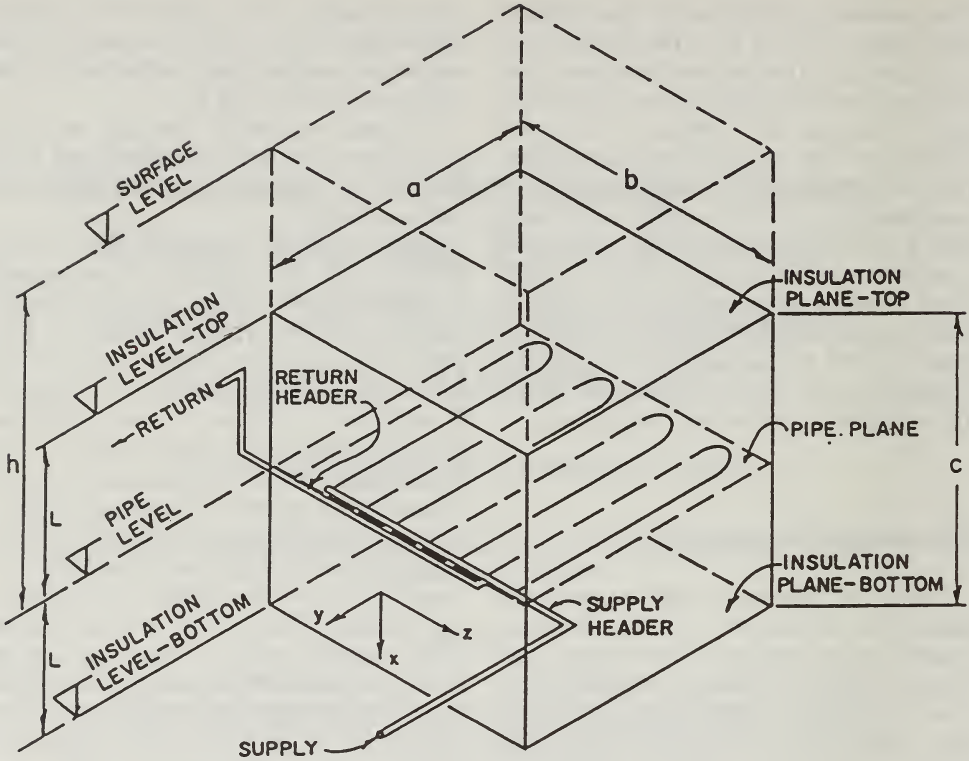


FIGURE 2 SETS — ISOMETRIC

NOTE: DIMENSION "C" EXAGGERATED FOR CLARITY

Fig. 2.

Results

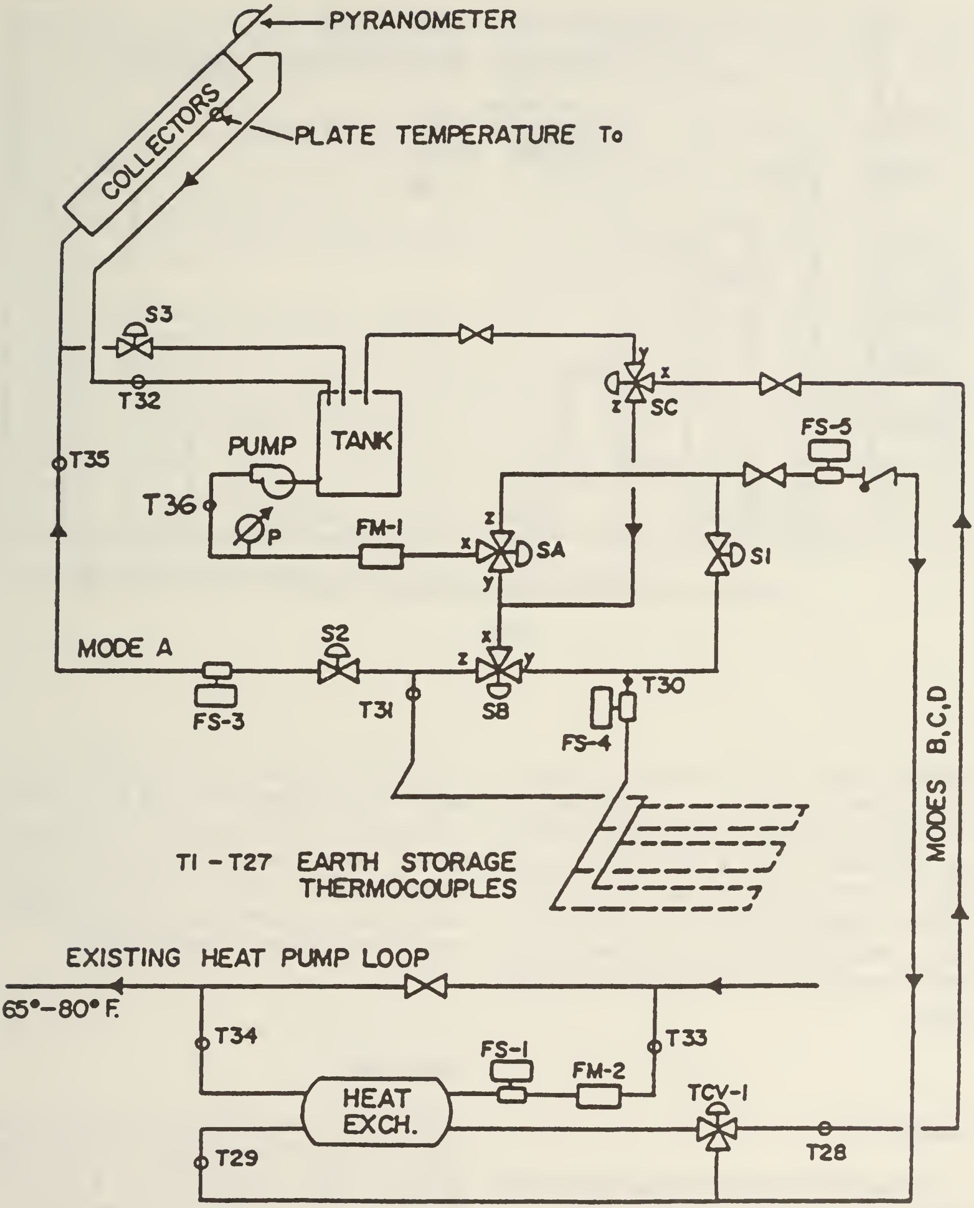
Figure 4 is a bar chart which shows the heat load of the building and the predicted savings which can be achieved with the solar system. The period of time shown is for September to December of 1983 and January through March of 1984. The chart is based on a combination of experimental measurements and computer simulations obtained by using a comprehensive computer program called DOE 2.1. The actual savings were lower due to a combination of difficulties experienced during the first year of operation. For the period considered the degree days were 6834.

The cost of the earth storage is shown below:

Excavation and backfilling	\$29,800
Insulation	9,800
Concrete trench	4,400
SolaRoll tubes	12,240
Total:	\$56,240

The computer analysis showed that the storage system was over designed by about 25%. Consequently, the system could handle 25% increase in collector size. Also, the system will operate more efficiently if the sizing corrections are accomplished.

In order for systems of this type to receive widespread use, it is important to determine their costs and compare these costs with conventional systems. Our comprehensive study predicts that the



MODES OF OPERATION		S_1	S_2
A	STORING HEAT	CLOSED	OPEN
B	HEATING FROM STORAGE	OPEN	CLOSED
C	HEATING AND STORING HEAT	CLOSED	OPEN
D	HEATING FROM COLLECTORS	CLOSED	OPEN

Fig. 3.

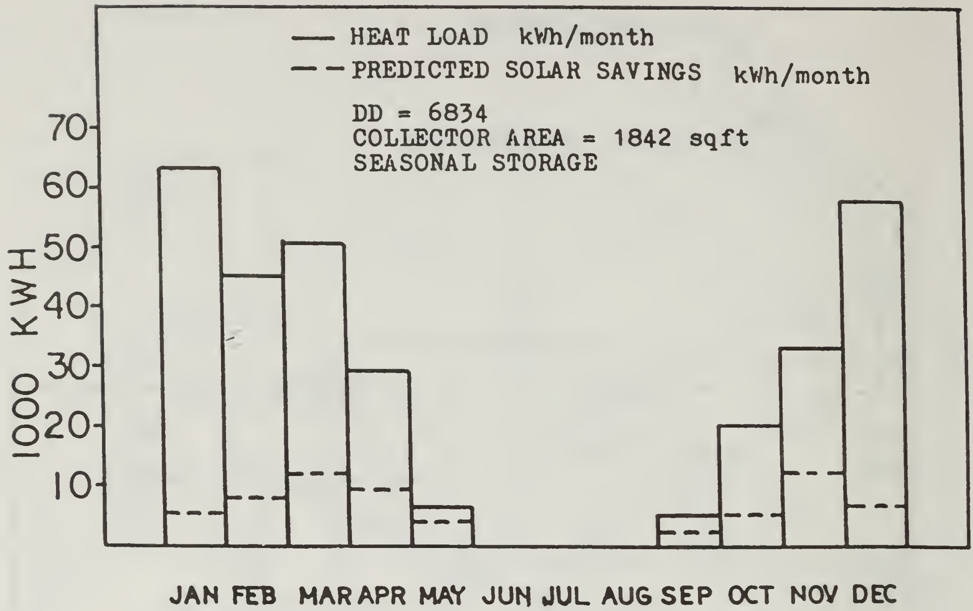


Fig. 4.

payback period of 12.5 years will result. This payback results on a comparison of the savings resulting in the existing building that has a very efficient heat pump system. The heat pump system has a coefficient of performance which exceeds two. Thus if straight electrical resistance heating were used, much faster payback would result.

Conclusions

Although the savings we calculated and measured are not spectacular, they are substantial and we believe that they clearly justify the need for continued work. We would have liked to present a more favorable prediction of savings through the use of seasonal earth storage facilities. It is our opinion that seasonal storage systems will provide the link that is necessary to make solar energy become an economically sensible alternative to conventional heating systems. We are not sure if the configuration will be the same as the one we have studied, but with continued research and development we are convinced that seasonal storage systems will provide a most important contribution to the Nation's energy needs.

Addendum:

Since the completion of our work in 1984, the Smith Academy in Hatfield has enjoyed lower heating costs as a result of the use of this seasonal earth storage system. One additional graduate student conducted research at the site, using it as the subject of his thesis for his MS degree. Subsequent research and development at Hatfield led to corrections in some basic design and construction difficulties, improvement in the control systems, and further confirmation of the economical value of such projects. An added benefit comes from the fact that some students at Smith Academy have continued to participate in measurements of the performance of the seasonal storage system, thereby gaining some first-hand educational experience. The Hatfield project, which was supported in part by The Lindbergh Fund, remains the only operating seasonal storage system in the United States.

Dr. Sunderland has become involved with the International Energy Agency Task on Central Solar Heating Plants with Seasonal Storage. This agency is involved with the study and implementation of seasonal storage systems. One of the engineers who has worked directly with this agency has recently joined Dr. Sunderland at the University of Massachusetts and together they have been developing plans for a major seasonal solar storage system at the University of Massachusetts. A proposal was written to obtain support for this ambitious project, which will involve heating a large dormitory complex. Support for the proposal has been approved by the U.S. House of Representatives and is pending before the Senate. It is our expectation that funding will also be approved. The funding level is $250,000 for two years. The proposed investigation will build on the work at Hatfield. Without the help of The Lindbergh Fund, we would not have had the base of understanding and experience necessary to conduct the work proposed on this much larger scale. There continues to be the need to develop seasonal storage solar energy systems.

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