2005 Blue Planet Prize Commemorative Lectures

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THE ASAHI GLASS FOUNDATION

CONTENTS

2005 Award Winner
Professor Sir Nicholas Shackleton 1

Lecture
"Geological deposits, geological time and natural changes in climate" 3

2005 Award Winner
Dr. Gordon Hisashi Sato 15

Lecture
"Sea Water is Deficient in Nitrogen, Phosphorus and Iron" 17

The Blue Planet Prize 29

The Asahi Glass Foundation 32

Directors and Councillors 34

Dr. Gordon Hisashi Sato (U.S.A.)

Director Emeritus, W. Alton Jones Cell Science Center. Inc.
Chairman of the Board, A&G Pharmaceutical, Inc.
President, Manzanar Project Corporation

Selection rationale: For developing a new mangrove planting technology in Eritrea and through its utilization thus showing the possibility of building a sustainable local community in the poorest area of the world.

Education and Academic and Professional Activities

1927	Born on December 17, in Los Angeles
1944	Graduated Manzanar High School
1951	BA Biochemistry, University of Southern California
1953-55	Teaching Assistant, Microbiology, California Institute of Technology
1955	PhD Biophysics, California Institute of Technology
1958-63	Assistant Professor, Graduate Department of Biochemistry, Brandeis University
1963-68	Associate Professor, Graduate Department of Biochemistry, Brandeis University
1968-69	Professor, Graduate Department of Biochemistry, Brandeis University
1969-83	Professor, Biology Department, University of California, San Diego
1983-92	Director, W. Alton Jones Cell Science Center. Inc.
1987-present	Distinguished Research Professor & Director of the Laboratory of Molecular Biology, Clarkson University
1992-present	Director Emeritus, W. Alton Jones Cell Science Center. Inc.

Major Awards Received

1982	Rosentiel Award, Brandeis University
1984	Member, National Academy of Sciences
2002	The Rolex Awards for Enterprise
2002	Lifetime Achievement Award, Society for In Vitro Biology
2005	Distinguished Alumni Award of the California Institute of Technology

Dr. Sato has long dealt with the task of trying to cultivate food in a harsh environment such as a desert, from his past experience of being relocated during World War II in a relocation camp in the California desert for those of Japanese descent.

Dr. Sato was born on December 17, 1927 in Los Angeles as a child between a first-generation Japanese immigrant father and a second-generation mother. From his upbringing, he grew up with a traditional Japanese values such as social obligations and respect for human feelings. During World War II, he was relocated to Manzanar Relocation Camp in the California desert with his family and this made a significant influence on his future way of life.

After the war, he studied biochemistry at University of Southern California, and later studied at California Institute of Technology under Max Delbruck who later received the Nobel Prize in Physiology or Medicine. Max Delbruck not only taught him academically but also supported him economically, which changed Dr. Sato's life dramatically and he never forgot the indebtedness he owed and nourished an idea that education was fundamental to bringing up people, and he himself also provided opportunities for young people to get an education.

After doing research under Max Delbruck and earning a PhD in biophysics in 1955, he further carried out research at University of California at Berkley and University of Colorado Medical School. In 1958, he became assistant professor of Graduate Department of Biochemistry at Brandeis University in Massachusetts. He served as associate professor and professor at Brandeis till 1969, and moved to University of California San Diego (UCSD) and was professor of biology there till 1983. There he succeeded in cell culturing in hormonally defined medium devoid of serum and clarified that a specific hormone and a growth factor are necessary for cells and made a significant contribution ,scientifically mainly in mammalian cell culture.

While at UCSD in the early 1980s, he began to work on how to produce food in a severe environment such as a desert, and started the research of growing algae in the desert with aquaculture utilizing the food chain in mind. In 1983, he moved from UCSD to the W. Alton Jones Cell Science Center in Lake Placid, New York and began to work in earnest on the Manzanar Project, which targeted to realize a healthy sustainable life even for those people suffering hunger in a severe environment. After testing at production facilities built in the Atacama Desert in Chile and in Fujian Province in China in the mid-1980s, a new location was sought and found Eritrea. Eritrea was under Ethiopian rule at that time and the people were oppressed and suffered from starvation and Dr. Sato felt sympathy in its resemblance to those Japanese Americans during World War II. He began practicing aquaculture in the Northern Eritrean coastline in 1986.

After Eritrea became independent, watching the camels eat mangrove leaves gave a hint and led to an idea that by utilizing mangroves as fodder, it will eventually be a more positive approach in enabling people to raise livestock and making them economically self-sustaining.

Mangroves only grew on 15% of Eritrean coastline. By disclosing that the seawater lacked nitrogen, phosphorous and iron among the nutritional elements necessary for the mangrove to grow, he devised the basic technique to provide these elements slowly to the mangrove and enabled the mangroves to be grown easily at low cost in areas where it was difficult to grow in the past. With this method, he succeeded in growing more than 800,000 mangrove trees.

What Manzanar Project is aiming to do is to allow people living in a harsh environment like a desert become self-sustaining by creating a sustainable economy. Dr. Sato's activities are different from the previous aids from developed countries to Africa by not giving goods but providing a mean of food production together with a mean for people to become self-sustaining, which indicates how future aids should be. His achievements which have proved a practical measure to enable economic self-sustainability in the poorest area of the world are significant and are demonstrating to the world the importance of a way of living which regularly uses the technology of environmental conservation and humanity.

Sea Water is Deficient in Nitrogen, Phosphorus and Iron

Dr. Gordon Hisashi Sato

The Manzanar Project, Ministry of Fisheries, State of Eritrea. Massawa, Eritrea

My scientific career was spent predominantly on laboratory research in cell biology. My goal was to gain knowledge of whole animal physiology by studying the basic elements of the body (the cell) in isolation under defined, controllable, conditions which might be achievable in tissue culture. The trouble with this simple minded concept, in 1957 when I began work on tissue culture, was that cells in culture did not display the differentiated properties of the tissue of origin. Apparently cells in culture were different from cells in the animal. It was generally believed that cells in culture underwent "dedifferentiation" to become a common tissue culture type cell. In the only experiment to address this issue, we showed that when liver tissue is put into culture, the small amount of fibroblasts in the tissue selectively grow, and the liver parenchyma die (1). The problem with lack of tissue specific properties in culture was selection not "dedifferentiation". The next step was to develop enrichment culture techniques to favor tissue specific cells over fibroblasts (2). This resulted in a number of tissue cultures which retained differentiated properties, and the "dedifferentiation" hypothesis, virtually unnoticed died a quiet death (3) The next step was to devise defined, controllable conditions in culture. Traditionally, tissue culture media consisted of a nutrient solution of defined composition supplemented with serum. Izumi Hayashi and I devised a system of nutrient medium supplemented with a complex of hormones that was different for each cell type (4). This eliminated fibroblastic over growth in primary cultures, and made it possible to culture cell types never before successfully grown in culture. This method allows one to discover hormone responses by different cell types discoverable in no other way, and catalogues the vulnerability of cancer cells. A case in point, we developed a monoclonal antibody to EGF (epidermal growth factor) receptor. I was led to try this approach from the knowledge of the existence of LATS (long acting thyroid stimulator), an antibody to the TSH (thyroid stimulating hormone) receptor, which mimics the action of TSH. The antibody to the EGF receptor has proven to be an effective anti cancer agent and is a harbinger of future anti cancer agents (5). I believe that my long experience with laboratory, experimental research enabled me to approach applied, field research differently from established workers in the field.

Let me now define the problem that has occupied me for the last twenty years. Hunger and poverty is one of the problems that the human race must solve before it reaches a catastrophic, irreversible state. Eritrea is one of the poorest nations in the world with a per capita gross domestic product of approximately 50 USD per year. Its conventional agriculture in its highlands is insufficient to feed the nation because of frequent and unpredictable droughts. In periods of drought Eritrea would suffer widespread famine were it not for international food aid. How could we produce food and a profitable, sustainable agriculture under such conditions? On its desert shores on the Red sea, I noticed patches of mangrove trees, and watched camels eating the foliage. Could this be a possible solution? But first we had to consider the conditions that limit the growth of mangroves. Sea water is deficient in nitrogen, phosphorus, and iron, elements that are required by all living creatures including plants, animals and micro-organisms. While this fact has been generally known, it has been ignored by those who are concerned about the productivity of the sea and the inter tidal areas. I will try to show how attention to this fact can help alleviate poverty and hunger by making the marine environment more productive.

Sea water contains all the elements in sufficient quantity that are essential for life except for nitrogen, phosphorus and iron. So in the following discussion of the importance of nitrogen, phosphorus, and iron, the term fertilizer will refer to these three elements. At the bottom of the food chain in the ocean are microscopic algae. They grow near the ocean surface where they are exposed to sunlight and capture the fertilizer. They sink to the bottom and die from lack of light and the fertilizer is trapped. If upwelling currents bring up the fertilizer, the sea is rich in fish. In the arctic and antarctic, water freezes and the saltier and heavier unfrozen water sinks and stirs up the bottom. The polar regions are rich in fish life. Seas are rich in fish where rivers enter the sea because the fresh water is bringing fertilizer from land. The Red sea has neither upwelling currents nor rivers. Consequently it is poor in fish life.

Eritrea has approximately 1,500 kilometers of desert sea coast along the Red Sea (counting islands). Mangroves grow in only about 15% of the coastal inter tidal zone, and where they grow they form a narrow fringe, usually no more than 100 meters wide. We observed that mangroves typically occur in areas called "mersas" where the seasonal rains are channeled to enter the sea each year. The conventional explanation is that fresh water per se is required (6). This explanation is untenable because the amount of fresh water and the duration of flow are too short to affect salinity to any extent. Our explanation, which is a radical departure from conventional belief, is that the fresh water is bringing nitrogen, phosphorus, and iron from land, and the fringes are no more than 100 meters wide because the fresh water may not be able to carry these minerals in sufficient quantity more than 100 meters from the high tide line. We predicted that the treeless, inter tidal areas of Eritrea, which occupy 85% of the coast, could be successfully planted with mangroves if nitrogen, phosphorus, and iron were provided, and that the mangrove fringes could be widened if the trees were provided with these elements.

Both of these predictions have proven true. Methods were developed to deliver fertilizer at a controlled rate that greatly reduces the possibility of runoff. Experiments were carried out to find ways of rendering mangrove foliage and seeds a complete food for livestock.

MATERIALS AND METHODS

We use predominately the mangrove, *Avicennia marina*, and to a much lesser extent *Rhizophora mucronata*. Both plants are indigenous to the area. *Rhizophora* are almost extinct in Eritrea because of their value as construction timber. Our plantings will contribute to its preservation. *Avicennia* seeds are planted in their final site by placing them in a tin can cylinder constructed by removing the top and bottom of the tin can. The can is embedded in the soil with a centimeter or so above the ground and is held in place with an iron rod. The top of the can is covered with a wire mesh to prevent the seeds from being washed away by wave action. Planting seeds in the final site saves considerably in time and effort by avoiding the necessity of transplantation. To prevent encircling wrasse and wave action from uprooting young seedlings, we build concrete blocks with upwardly protruding iron rods. The dimensions of the blocks are 1 meter long, about 25 centimeters high and about 5 centimeters wide with the protruding iron rods about 60 centimeters above the blocks. A continuous wall of blocks is placed sea ward of the area of planting. The iron rods prevent wrasse from entering the planting area, and the concrete blocks allow the buildup of low lying soil so that adequate drainage can allow air to get to the roots. This allows the extension of the usable planting area.

Our method of providing a slow release fertilizer to trees growing in an area continually awash in sea water is to place 500 gms of a 3:1 mixture of urea and diammonium phosphate in a polyethylene bag, tie the bag so it is sealed shut, and puncture one surface three times with a 0.2 cm diameter nail. The bag is buried next to the tree with its upper surface and the nail hole punctures about 10.0 cm below the soil surface. This arrangement allows the fertilizer to exit the bag by slow diffusion - fast enough to nourish the tree but slow enough not to be wasteful. By digging up bags after various times, we estimated that the bags deliver all their fertilizer in about three years. From the density of planting, 5000 trees per hectare, we estimate that the fertilizer is delivered at a rate of about one ton per hectare per year. This is approximately the desired rate. The desired rate is calculated as follows: a hectare of *Avicennia* drops about 10 tons of litter per year which is about 19% protein, or two tons of protein. We assume that the trees synthesize three tons of protein per hectare per year. To synthesize three tons of protein requires about one ton of fertilizer.

A barbed wire fence is erected around the trees and guards are employed to prevent camels from destroying the trees.

To measure possible fertilizer runoff, water was collected a few meters offshore from our plantings and from a natural mangrove forest about a half hour before the tide reached its lowest level. The water was analyzed for nitrogen and phosphorus content by the analytical laboratory of the Ministry of Fisheries by the method of Parsons et al (7).

Avicennia seeds are soaked in sea water for three days to remove the cover and facilitate drying. They are then placed in the sun to dry resulting in a grain-like material that is avidly eaten by animals up to a year after drying.

RESULTS

Figure 1 shows a planting that is about 1 year old. No trees grew in this area before we planted it. Before we realized the need for fertilizer, over a hundred trees were planted in this area and all died. After the need for fertilizer was understood, virtually all trees grew successfully with our method of fertilization.

Figure 2 shows the same area about two years later. Growth is rapid.

Table 1 shows the measurement of nitrogen and phosphorus offshore from our plantings and offshore from a natural mangrove forest which was not fertilized by us compared to the fertilizer content of water from the open sea. It can be seen that offshore from our plantings where three tons of fertilizer is applied per hectare no evidence of nitrogen or phosphorus runoff is found. Offshore from a natural mangrove forest, nitrogen and phosphorus levels are appreciably higher than the open sea. This tends to support our assumption that natural mangrove forests are provided with fertilizer by the seasonal rains.

Figure 3 shows the concrete blocks with their protruding iron rods. They prevent wrasse from entering the planting area and cause the build up of soil. Waves bring sand over the blocks and the sand is prevented by the blocks from returning seaward. By building up low lying soil the usable planting area can be extended seaward.

Figure 4 shows our method of drying mangrove seeds to make a stable grain-like product that can serve as animal food several months after drying.

Figure 5 shows the drying of fish wastes to form fish meal that is an essential supplement to mangrove foliage and seeds for the feeding of livestock.

Figure 6 shows sheep eating mangrove foliage. They are also fed mangrove seeds and fish meal. They have been kept on such a diet for 8 months and produce babies and milk to feed them. When the fish meal is omitted, they produce lambs but not the milk to feed them.

Figure 7 Camel lusting after mangrove trees.

Figure 8 A grove of trees in the village of Hargigo, our principal site of work. We have planted over 800,000 trees mainly in areas where trees had not grown before.

Figure 9 Typical housing in Hargigo reflective of the poverty in the region.

Figure 10 The water supply of the village which is shared with animals. One of our most urgent needs is a supply of healthy water.

Figure 11 Passengers from the Japanese peace boat visiting our work site in Hargigo.

DISCUSSION

Sea water is deficient in nitrogen, phosphorus, and iron . It follows that plants growing in the inter tidal area must have a source of these minerals. This is almost always furnished by fresh water from land. In arid countries, areas where fresh water enters the inter tidal area are limited. It is in these areas where mangroves grow naturally. We have developed new ways of substantially increasing the mangrove forests in tropical coastal deserts by making it possible to grow mangroves in the tree less mud flats by artificially providing these elements. Such mud flats make up the greater part of the inter tidal area of these coastal deserts. Even in tropical countries with plentiful rain, we can increase mangrove forests by widening the growth area by fertilization and the use of concrete blocks. This can potentially reduce the damage due to tsunamis. We have also shown that mangroves can provide the bulk of the food for sheep with small and inexpensive supplementation of fish meal. This last finding renders mangrove planting a profitable business. We estimate that a hectare of mangroves can produce a metric ton of meat per year. This compares favorably with pasture land in temperate climates. This should provide the economic incentive to plant mangroves as well as the disincentive to destroy them. Each of these findings is very simple but new and original. We believe that our approach has the potential to create a cost effective sea water agriculture and eliminate hunger and poverty in many regions of the world.

We believe that discoveries made in Africa can help solve problems in the developed world, such as in Japan which produces only forty percent of its food. Algae in the ocean divides about once a day. Simon Tecleab Gebrekiros and I discovered, in Eritrea, that we could add nitrogen, phosphorus, iron, and sugar to sea water and get micro-organisms, bacteria or algae, to divide every half hour. These micro-organisms were consumed by brine shrimp which could then be fed to fish. By this method, we could make the coastal waters of any nation rich in fish by essentially converting sugar to fish. Japan, for instance, could be made self sufficient for fish. The coastal, inter tidal zones of Japan's southern islands is nearly bereft of plants, and their fish catch is declining. Japanese control their fresh water so well that natural flows into the sea is diminished. We can grow native plants in these inter tidal areas with fertilization and increase fish life.

Mangroves seem to be limited by latitude. This fact is not well understood (6). In north Africa and southern Europe mangroves cannot grow because the tidal variation in the Mediterranean and Aegan sea is too small to provide drainage and air to the roots. This raises the possibility that mangroves could be grown inland, the Sahara desert for instance. Some crop plants like millet and barley can grow with sea water irrigation, but the value of the crop is less than the cost of fertilizer and pumping water. Our trees have economic value, and we have solved the problem of economic use of fertilizer. Can we pump sea water economically with for instance wind mill pumps. If so it is thinkable to convert the deserts of the world to mangrove forests. It is time to consider such far out solutions. Glacial ice is breaking off the polar ice caps, the arctic tundra is melting, and typhoons and hurricanes are increasing in frequency and intensity. I believe global warming is upon us.

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Figure 1. Mangrove planting in area where mangroves had not grown before. About a year after planting.

Figure 2. Same scene as in previous slide, but three years after planting

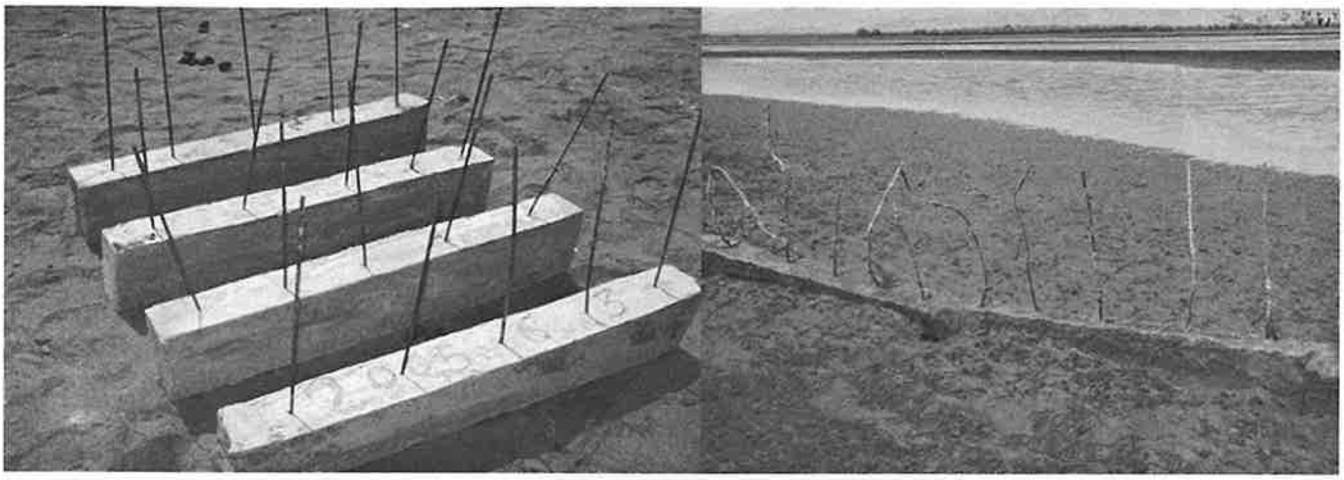

Figure 3. Concrete blocks with protruding iron bars. In final position they build up soil on landward side.

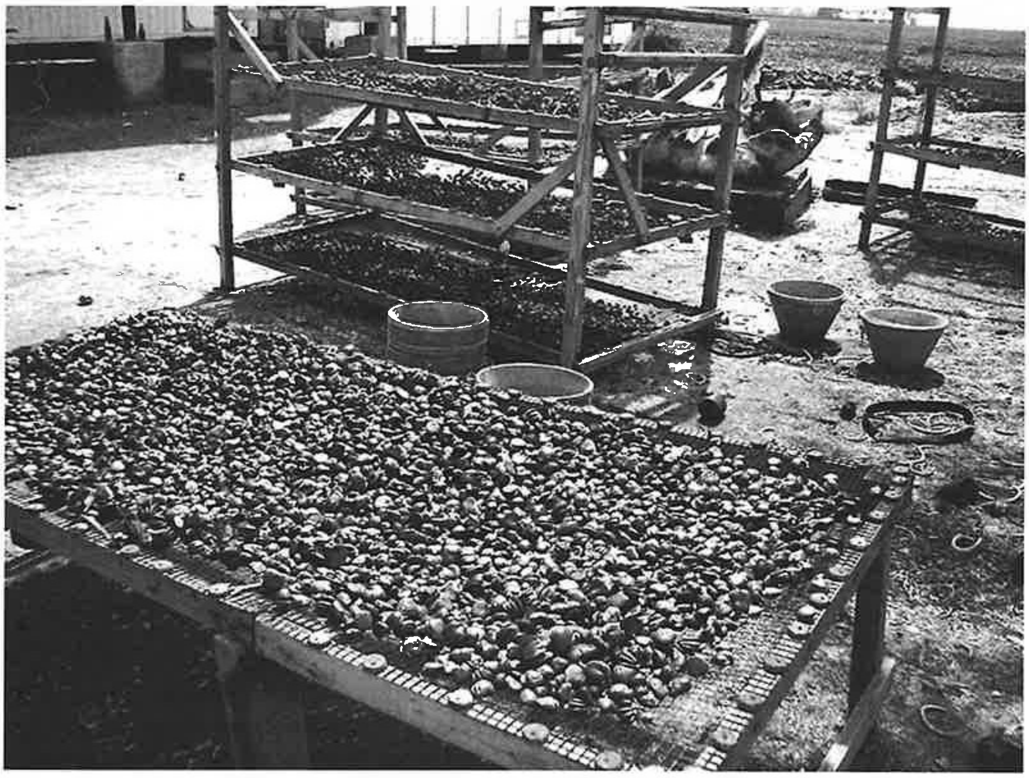

Figure 4. Peeled Avicennia seeds drying in the sun

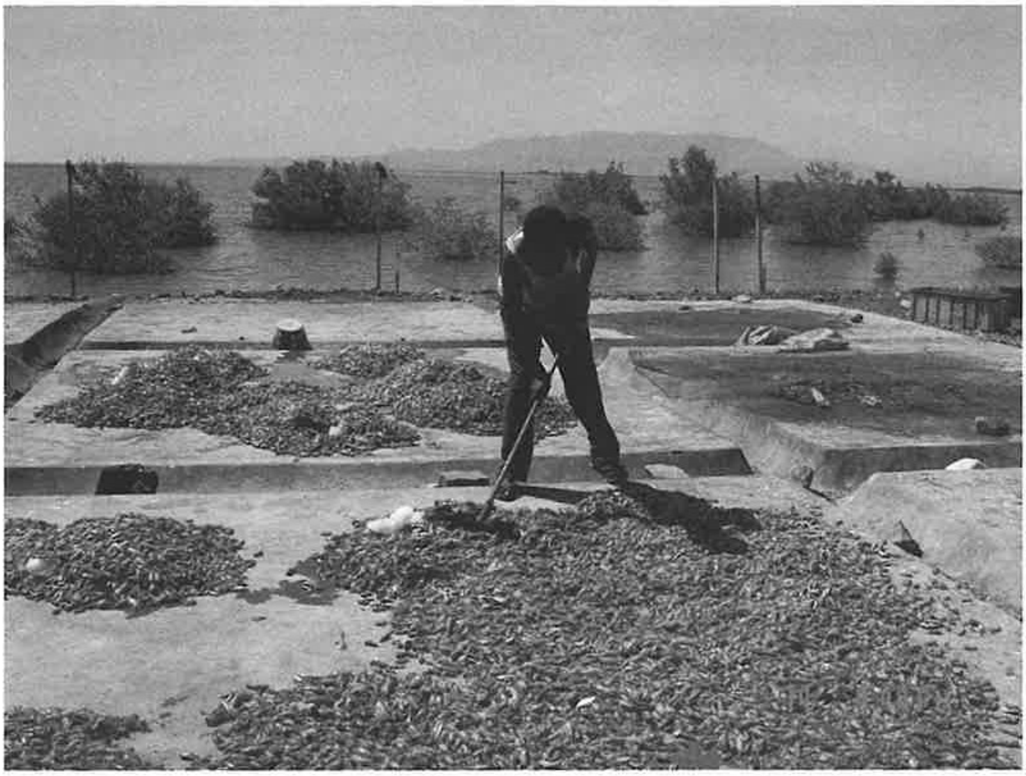

Figure 5. Fish wastes being sun dried after brief boiling.

Figure 6. Sheep eating mangrove foliage.

Figure 7. Camel lusting after mangrove trees.

Figure 8. Mangrove grove in village of Hargigo.

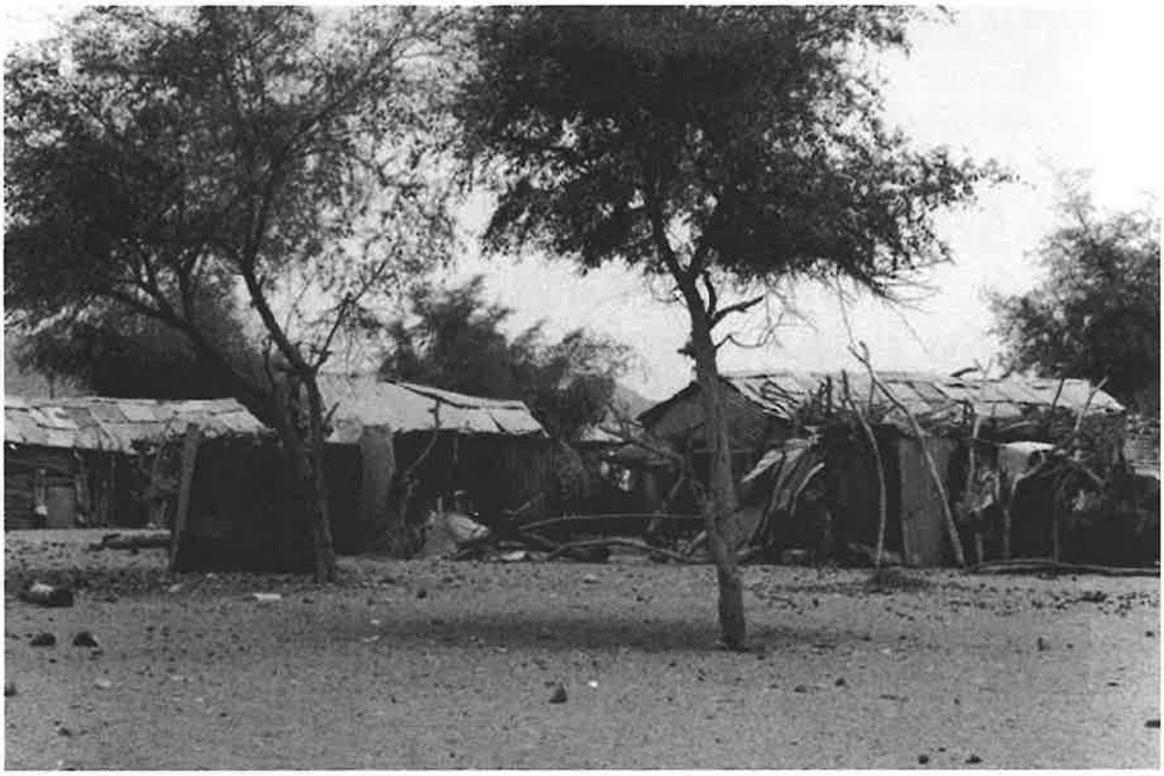

Figure 9. Typical housing in Hargigo

Figure 10. Source of village water.

Figure 11. Passengers from Japanese Peace Boat visiting the work site in Hargigo.

Table 1. Analysis of fertilizer content of seawater offshore from our plantings, offshore from a natural mangrove forest, and from the open sea.

	Nitrogen content	Inorganic phosphate
Area A in Hargigo with 3 tons of fertilizer per hectare	Not detectable	.04 mg/liter
Area B in Hargigo with 3 tons of fertilizer per hectare	Not detectable	.03 mg/liter
Natural mangrove forest unfertilized	.02 mg NH_3/liter .01 mg NO_3/liter	.04 mg/liter
Water from open sea	not detectable	.06 mg/liter

ACKNOWLEDGMENTS

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