Managing Tropical Animal Resources

Butterfly Farming
in Papua New Guinea

Report of an Ad Hoc Panel of the
Advisory Committee on Technology Innovation
Board on Science and Technology for International Development
Office of International Affairs
National Research Council

In Cooperation with the Insect Farming and Trading Agency, Bulolo,
Papua New Guinea

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Panel on Butterfly Farming in Papua New Guinea

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Preface

Butterfly farming is a growing new industry in Papua New Guinea, and by turning birdwings, mauve swallowtails, and other insects into a cash crop villagers are both earning money and practicing sound wildlife conservation. In this unique program butterfly farming is being used to complement the preservation of species and of habitats. In balancing the utilization of common butterflies with the protection of the most threatened species, Papua New Guinea is providing a model for other countries, particularly those in the tropics. The program demonstrates how village development can become an integral part of conservation.

The panel that produced this report convened in Papua New Guinea in May 1981. Its purpose was to investigate the concepts underlying this project and to assess their potential for application elsewhere. Panel members met with staff of the government's Division of Wildlife in Port Moresby and later visited butterfly farms in Popondetta and the insect trading agency in Bulolo. The panel is grateful to Karol Kisokau, Navu Kwapena, and Miro Laufa of the Division of Wildlife for arranging the itinerary in Papua New Guinea and to Peter Clark and Michael Parsons for hosting the Bulolo and Popondetta visits.

This report is one of the National Research Council series, *Managing Tropical Animal Resources*. Current titles in the series are:*

- *Water Buffalo: New Prospects for an Underutilized Animal* (1981)
- *Little-Known Asian Animals with a Promising Economic Future* (1983)
- *Crocodiles as a Resource for the Tropics* (1983)
- *Butterfly Farming in Papua New Guinea* (1983)

These activities have been conducted under the auspices of the Advisory Committee on Technology Innovation (ACTI) of the Board on Sci-

*To obtain copies, see page 31.

ence and Technology for International Development, National Research Council (see page 29). The purpose of ACTI is the assessment of unconventional scientific advances that might prove especially applicable to problems of developing countries. Since its founding in 1971, it has produced about 30 reports covering subjects as diverse as ferrocement construction materials, the winged bean (a high-protein tropical food crop), and techniques to provide more water for arid lands. This study adds the dimension of conservation and ecosystem protection to ACTI's principal concerns of promising but neglected resources.

ACTI activities are supported largely by the U.S. Agency for International Development (AID). Program costs for this study were supported by AID's Bureau for Asia, and staff costs by AID's Office of the Science Advisor, which also made possible the free distribution of this report.

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Introduction and Summary

The international demand for tropical butterflies is much greater than is generally recognized. Each year millions of them are caught and sold throughout the world. Many buyers are scientists engaged in research on aspects of systematics, ecology, ethology, evolution, and conservation. Others are individuals who like expensive curios that incorporate butterflies, such as display cases, coffee tables, wall hangings, or other objects. But increasingly, the fragile, iridescent creatures, mounted in plastic or glass, are used to decorate less-expensive items such as purses, trays, platters, screens, and other common objects in Europe, North America, and Japan. In addition, amateur butterfly collecting, which reached a peak in Victorian times, is again becoming popular.

All this has produced a strong and active market. The current trade is estimated to be between US $10 and $20 million annually, and the demand is rising.

Butterfly Farming in Papua New Guinea

Remote regions of Papua New Guinea are benefiting from this burgeoning interest in tropical insects, and several hundred villagers are rearing or collecting butterflies, beetles, and other insects for export. The Papua New Guinea government now considers insects a national resource, and it has made butterfly farming part of the nation's village economic development. At Bulolo it has established an Insect Farming and Trading Agency (IFTA) to handle the business details of a growing international trade. And Papua New Guinea is the only country so far to specify insect conservation as a national objective in its constitution.

Botanical research is the key to Papua New Guinea's butterfly farming program. Local botanists and ecologists have identified the plants that the various butterfly species use during their life cycle. The butterfly farmers then build up their "livestock" by clearing small areas of ground

and planting leafy food plants for larvae, together with the nectar-producing flowering plants that adult butterflies feed on. The combination of flowering and leafy plants provides a complete habitat where butterflies find everything they need to grow and reproduce. Therefore, most remain, and the farmer retains his livestock without fences or walls.*

They are among the most unusual farms in the world. Around their edges are hibiscus and bougainvillea that attract the adult butterflies, whose mouthparts are adapted for drinking nectar from flowers. And inside are leafy plants, such as the strange Dutchman's pipe vine (*Aristolochia tagala*), on which the caterpillars of several birdwing butterflies feed.

The enriched butterfly habitat in the villager's garden attracts and holds a breeding population that becomes a self-renewing resource. By varying the plant species the farmer can even maintain colonies of different butterfly species. And because insects are so prolific, some butterfly farmers are beginning to have problems with overstocking and have had to shift larvae from plant to plant—rather like moving cattle from one field to the next as the grazing runs out.

Economic Development

The IFTA program started in 1974 with fewer than 30 Papua New Guineans from villages in two provinces. By 1978, more than 500 villagers in 10 provinces had been introduced to farming or collecting butterflies for export. Since then, business has been increasing about 40 percent a year.

Gram for gram, exotic butterflies are far more expensive than cattle. Prices paid by dealers in Europe, North America, and Japan range from 30 cents for individuals of common species to around $10 for the two birdwing species whose export is allowed. A specimen of a rarer species (for example, a female of the mauve swallowtail *Graphium weiskei*) may bring as much as $50.

The project is still an embryonic activity; it is not large, as development programs go. IFTA has only one professional staff person and two local technicians to handle the distribution of specimens. The agency's goal is to export between 5,000 and 10,000 specimens a month, from which the villages can expect a return of $10,000 or more.

The agency purchases butterflies from villagers and uses them to fill

*Technically, the farming of butterflies is "ranching," because the breeding stock are quite free in the bush. It never involves fully captive animals, except as pupae.

orders from overseas buyers. Colorful beetles, strange-looking stick and leaf insects, and some moths and cicadas are also caught in the wild and sent to Bulolo. The profits, less 25 percent, are returned to the villagers. At the time of the panel's visit, IFTA had received about 4,000 shipments of butterflies and other insects from the rural people and had paid out about US $180,000 to purchase them. In 1979, the average farmer or collector received about $37 per box of specimens. By 1980, this had risen to about $50 per box. In 1981 it was estimated that a diligent butterfly farmer could earn an annual income of about $1,200.

Even so small an annual income is substantial in rural areas where th mean annual per capita income may be only $50. In many remote areas it is difficult to create income-producing opportunities because of illiteracy, dispersed population, and, in some cases, resistance to foreign ways.

Through butterfly farming many rural Papua New Guineans are for the first time participating in a cash economy. The product is a high-value, low-volume crop. It brings needed or supplementary income to the people of the predominantly rural areas. Compared with farming coffee, another possible industry in Papua New Guinea's rural regions, it requires far less effort or land, and it involves minimal costs to the producer. And where a few expatriate opportunists once made small fortunes exploiting Papua New Guinea's butterflies, the profits now go to the villagers.

Conservation

Habitat loss is by far the most critical issue in butterfly conservation. If habitat changes, the animals must change, leave, or die. Usually they die, since alternative habitats are already occupied or too distant.

Nearly all the world's butterfly species have suffered diminished ranges, and an estimated half of the world's butterfly populations face threats from human development. From Britain to Bhutan, the insects' habitats have come under siege. In Europe, perhaps one-third of all butterfly species are threatened, owing chiefly to the reductions in their various habitats. In California, half-a-dozen coastal butterflies have been lost since the 1860s, and an equal number are now endangered. In Madagascar and Rwanda, swallowtails and some species that occur nowhere else are being sacrificed to the clearing of forests.

The losses are much more than aesthetic, for many butterflies benefit people. They pollinate crops, are a major link in the food chain, and serve as sensitive indicators of ecological health.

A striking feature of the Papua New Guinea butterfly farming program is that it is designed to conserve and increase the species being traded. It is a pioneering conservation effort that has been endorsed by

the Lepidoptera Specialist Group of the International Union for Conservation of Nature and Natural Resources. The program helps relieve pressure on endangered populations, because for successful butterfly farms the villagers must retain—and even foster—a healthy wild population on or near their land.

Insect farming also helps preserve habitats because it leaves the bulk of the land intact and it helps landowners earn money without requiring them to cut down the rain forest as they would for timber or for cocoa, coffee, or oil palm plantations. Similarly, villagers can retain their traditional hunting grounds while cropping the insects that rely on these grounds for survival.

The existence of the butterfly farming project has served to focus attention on the status of all butterfly species. In 1968 this led to a law banning the taking of even a single specimen of the seven birdwing species threatened with extinction in Papua New Guinea. These large, brilliantly colored creatures can bring as much as $1,000 each in international trade, but there is a stiff fine in Papua New Guinea for even possessing one.

Enriching habitats with butterfly food plants (notably the Dutchman's pipe vine, *Aristolochia tagala*) has greatly increased the numbers of Papua New Guinea's two common birdwing species, *Ornithoptera priamus* and *Troides oblongomaculatus*. Now the country is taking on the challenge of increasing the seven endangered birdwing species that are protected and banned from trade. Already the IFTA staff has found that at least one of these rare species (*Ornithoptera victoriae*) is easily reared on the Dutchman's pipe vine. Farms are now being designed and sited with a view to building up the populations of this giant endangered species.

Conclusions

At this stage, the importance of this pioneering activity lies not in its size, but in the new vistas it opens up for the use of tropical resources.

Village Development

In farming butterflies, Papua New Guinea is showing that indigenous wildlife resources (especially those being depleted because of their commercial value) can contribute to economic development and that the farming of indigenous animals can be fitted smoothly into traditional village life.

Providing employment in rural areas is a major problem of developing countries. And in a sense, butterflies are an "appropriate" livestock, par-

ticularly for remote areas of the tropics where other income-producing activities are difficult to establish or are harmful to traditional lifestyles and fragile environments.

Butterflies may seem unusual farm animals, but to villagers in the Papua New Guinea jungle it is cattle that are exotic. The villagers live in close contact with their local insects; invariably they know much about butterfly locations, behavior, habits, life cycle, and the food eaten by the caterpillars.

Farming butterflies is proving a business to which villagers quickly adapt. Butterflies do not require the equipment or financing of a conventional farm; no capital is required, except for postage on the first shipment of specimens. Insect farming allows people to participate in the cash economy without causing disruptive changes in traditional village life. The villagers can work long and hard if they wish or they can put in only enough time to produce a little cash for necessities, leaving plenty of time for raising crops and other village activities.

Habitat Conservation

It is often claimed that economic development is necessarily destructive to the environment and detrimental to conservation—that as rural societies develop, their natural surroundings must suffer. The Papua New Guinea butterfly farming project is an innovative program that demonstrates this need not be true.

The program also shows that where human needs are given attention, conservation can be successful. Elsewhere in the tropics, attempts to conserve habitat without considering the needs of the people who live nearby have often failed.

In sum, the butterfly farming program demonstrates that certain natural resources can be used profitably in a way that protects the environment. The program offers a culturally appropriate use of the land; on a broad scale, it could become a force in preventing clear-felling of the forest for timber exports or the wholesale conversion of rain forest to cash-crop monocultures such as coconut, coffee, or oil palm. Most of Papua New Guinea is still covered by primary rain forest; exploiting the economic value of the insects that live there is helping safeguard this increasingly rare habitat, which is fast disappearing in most parts of the tropics.

Species Conservation

The knowledge gained from farming Papua New Guinea's butterflies has already contributed to relieving the threat of extinction from seven endangered species of birdwings. This experience could be replicated in other places where there are endangered butterfly species. Indeed, the

program provides a model for nations that could profitably farm butterflies while protecting their threatened butterfly species.

Extension to Other Organisms

This project has a strategy and organizational structure that could well be applied to plants, such as rare orchids, and animals, such as crocodiles, that are endangered because of their commercial value. Indeed, using similar concepts of combining village income and conservation, the Papua New Guinea Division of Wildlife is farming crocodiles,* rusa deer, wallabies, and two native birds, the megapode and cassowary.

Through such husbandry practices, many species elsewhere might be saved from extinction, while providing income to the local people who traditionally have used the resource. Other countries should look with interest at the way Papua New Guinea is handling its wildlife enterprises.

*See companion report no. 45, *Crocodiles as a Resource for the Tropics.*

2

Butterfly Status and Conservation

About 100,000–150,000 species of butterflies have been described; perhaps half that number remain to be discovered. Although there are important concentrations in the Arctic and temperate regions, most species are found in the tropics. There, the diversity of colors and forms is dazzling; every imaginable combination of hue and color is displayed. And many tropical butterflies are enriched with "structural" colors, which cause the wings to flash iridescently in the sun as they bend the light they reflect.

Although butterflies have long been admired and often depicted in art they have been seriously studied only since the end of the seventeenth century. Linnaeus, in his *Systema Naturae*, placed the small number of butterflies then known in the single genus *Papilio*. Today that genus is restricted to the true swallowtails, and more than 700 genera of butterflies are recognized.

The Butterfly Trade

Last century, as knowledge of butterflies grew and methods of preserving them improved, they become popular collectors' items. Wealthy naturalists such as Rothschild and LeMoult dispatched collectors to all parts of the world for specimens. Today the trade in butterflies is even more extensive.

There are three major kinds of butterfly and insect trade. In one, large numbers of common species are collected in the wild and processed for use in ornamental objects such as coasters, mats, and lampshades. This is a low-value, high-volume industry that is both labor- and capital-intensive. It frequently uses "chipped" or slightly damaged butterflies. It often sells butterflies with paper bodies and only the wings of actual insects, which seem to be acceptable to a large part of the buying public.

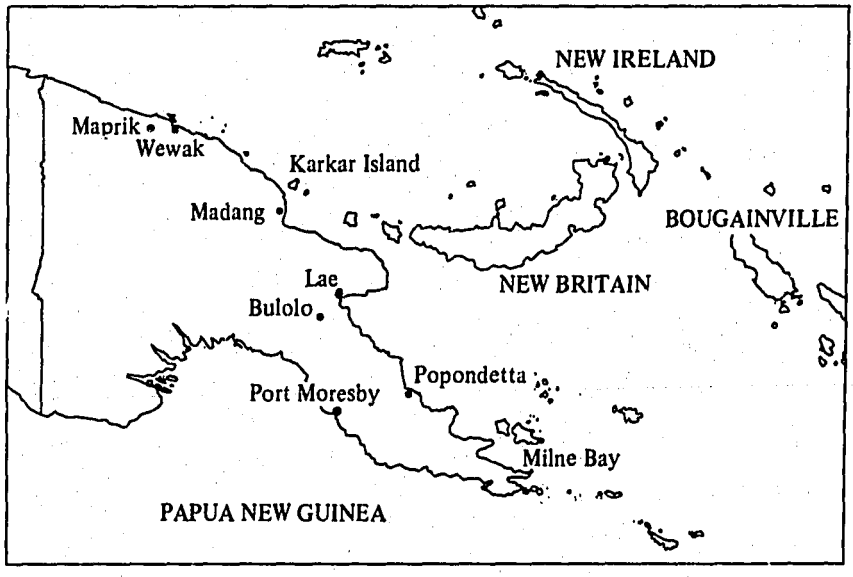
The Taiwanese butterfly trade is an example. It operates on a large

scale. At least a dozen Taiwanese factories employ scores of workers to capture and process butterflies. Estimates of annual sales vary from 15 million to 500 million butterflies. Taiwanese butterfly wings pasted onto paper bodies with pig-bristle antennae are used in ornaments and household objects from wall hangings to clear-plastic toilet seats. The bodies are recycled as pig feed. Despite this massive trade, Taiwan's wild butterfly populations seem to be remaining steady.

Similar, though smaller, industries trafficking in common butterflies are found in Korea, Malaysia, Hong Kong, Brazil, Honduras, and several African nations. The famous blue morpho butterflies of the American tropics enter the trade at the rate of some 50 million per year. Nearly all of these are the brilliant iridescent males, and biologists believe the number sold could be doubled without harming the overall population.

The second type of trade involves higher value and lower volume. This produces a vastly different product from the paper-bodied butterflies bound for novelty stores. It is exemplified by the operation in Papua New Guinea where sales are to collectors, museums, and students, and the specimens are high-quality insects in good to perfect condition, usually bearing scientific data. Because of the relatively high value per specimen, this trade can be carried on by fewer individuals in a nonfactory setting, and it is well suited to village industry, provided there is supervision and a quality-control checkpoint.

The third type of butterfly trade is for high-quality, expensive orna-



Papua New Guinea.

mental items, such as glass cases, domes, wall mounts, or jewelry containing beautiful insects. Brazil, for example, has a thriving jewelry trade based on the iridescent blue morpho butterfly. This type of trade can also furnish high-paying outlets for village-farmed insects.

In all three divisions of the butterfly trade, dealers fulfill an essential role. Few collectors and scientists can travel the world collecting their own specimens. Some dealers have established reputations for honesty, some have not. Exploitation of suppliers and customers alike has been rife. Few dealers are careful to attach accurate locality data to their specimens; some make serious mistakes in identifying them. (To combat this problem, British insect dealers have formed an association to monitor conservation-related activities and improve professional practice.)

Generally, dealers supply specimens bred from the caterpillar or chrysalis and described as "ex pupa." Unless butterflies are caught immediately after emerging from the pupa the fragile wings tear and the scales detach to produce "worn" specimens.

Butterfly Taxonomy

Classifying butterflies is difficult. Their most obvious features, the color and pattern of the wings, vary greatly; individuals and populations of the same species often look quite different. This has led to the dubious naming of many species and subspecies. And the uncertainties it causes have led some biologists, especially those working in ecology and genetics, to name populations rather than species or subspecies. However, populations frequently evolve, and this introduces a further uncertainty. Much additional work on basic butterfly systematics is needed. The knowledge gained should contribute particularly to the conservation of endangered species.

Butterfly Conservation

Butterfly conservation is still in an early state of development, bedeviled by scarce or incomplete information. The conservation status of even the most thoroughly studied butterfly species is known in only a few areas. The distribution and status of most species is essentially unknown, and proposals for conservation measures are largely based on guesswork. Nevertheless, some conservation programs have been enacted. Most have concentrated on designating endangered species and banning their collection.

The greatest threat to butterflies and other insects, however, is habitat alteration. On several continents some species have already become ex-

tinct or endangered when humans altered the special environment they require. The importance of protecting butterfly habitats should not be underrated. Many species are restricted to very small areas, particularly to individual islands (Corsica, Sardinia, Jamaica, Madagascar, Sumba, the Comoros, Fiji, the Solomon Islands, Manus, and the Duke of York Islands, for instance). Such species are vulnerable to extinction because nearly all island habitats are fragile and are changing rapidly.

Although it is uncommon for insect species to be dangerously reduced merely by the capture of specimens, renewed commercial interest in butterflies gives rise to concern for their conservation. Most insects reproduce rapidly, and their high fecundity enables them to replace such losses in a generation or two—provided the basic environment has not been altered.

But there are certain species of butterfly that reproduce slowly and are therefore more threatened by collection. The unusual birdwing butterflies of New Guinea, for example, produce only small broods. Moreover, these rare species command higher prices. Because this makes them particularly vulnerable, legislation to protect birdwing butterflies has been instituted in both parts of New Guinea—Papua New Guinea and Irian Jaya.

Accordingly, to save Queen Alexandra's birdwing (the largest and most threatened of the birdwings) from extinction, several wildlife management areas have been set up in Popondetta on Papua New Guinea's north coast. The government is also setting up refuges, administered by village councils, to preserve and protect other birdwing butterflies and wildlife resources. This habitat conservation is an important adjunct to the butterfly farming program.

3

History and Government Policy

Soon after Europeans discovered New Guinea's remarkable insect fauna around the turn of the century, collectors began arriving, and they have been coming ever since. Many were reputable professional or amateur scientists, gathering modest numbers of specimens for study and for museums, including Papua New Guinea's own national collection. Others, however, were plunderers who carried away large numbers of rare butterflies, giving little or no compensation to the local people and showing no concern for survival of the species.

In 1966 the Papua New Guinea government responded to excessive collecting by designating seven rare birdwing butterflies as protected species. It became illegal to collect these huge, colorful birdwings,* and strong measures were instituted—fines for nationals, deportation of expatriates—to halt black market trade.

In the late 1950s and early 1970s commercial collecting of the other butterfly species continued piecemeal and unsupervised. Income was erratic, and expatriate dealers often paid their Papua New Guinean suppliers only a few cents for specimens that retailed for several hundred dollars in Europe and Japan.

The Insect Farming and Trading Agency

When Papua New Guinea achieved independence in 1975, the new government decreed that only nationals should profit from the country's butterfly resource. Since that time only Papua New Guineans have been able to export butterfly specimens (nonprotected species) for profit.†

**Ornithoptera alexandrae, O. allotei, O. chimaera, O. goliath, O. meridionalis, O. paradisea,* and *O. victoriae.*

†There are no objections to foreign residents and visitors collecting butterflies for their own pleasure and study. However, to take or to send specimens out of the country requires an export license and a declaration that the specimens will not be sold. The permit is readily obtainable and there is a minimum of red tape. Export of live insects is not allowed—a form of trade protection to ensure that breeding stocks are not established elsewhere.

In 1978, to guarantee Papua New Guineans fair prices and stable sales, a marketing agency was established. Its purpose was to protect the resource, to foster butterfly farming, and to ensure a high-quality export product.

Modest in its beginnings, the Insect Farming and Trading Agency (IFTA) was organized by Angus Hutton, a former tea planter and amateur lepidopterist. The business side of the agency was later developed by Peter Clark, who had worked with Hutton. Identification and production of food plants was advanced by Michael Parsons, Robert Pyle, and others.

IFTA provides a market for those Papua New Guinea nationals who farm and collect butterflies and other insects. The agency allows them to obtain fair and fixed prices, maintains quality control, and ensures that current data accompanies all specimens. It also pools the insects from many sources and fills large orders from overseas dealers.

Of the butterflies IFTA exports, about 30 percent are from village farms and 70 percent are collected in the field. However, more than 50 percent of the revenue is made up of the farmed butterflies because of their better quality.

Quality Control

The agency strives to sell only highest-quality insects; it rejects many butterflies as substandard. Most specimens are sold as named subspecies and to identify and name them requires much skill. Staff members have been specially trained to do this. (To a large extent, the area of origin, particularly in the case of the offshore islands, defines the subspecies concerned.) Locality data, usually consisting of village, province, and month and year of collecting or emergence, is affixed to all butterfly envelopes before they are pooled at the agency.

IFTA stores its collection by species, in simple wooden boxes kept in cupboards lit from below (to lure potential pests away from the insects and to warm the cupboards and prevent mold).

Marketing

The agency makes up orders and dispatches them (with the required export permits) to customers "on trust." Although this is open to abuse, most buyers pay promptly and the system is easy and convenient. Careful records are kept of all suppliers, customers, and species in stock.

At the time of the panel's visit, about 80 percent of the agency's business consisted of responding to requests from dealers. However, less than 10 percent of the orders received from all sources could be filled.

Some requests were too small and others too specialized; in some cases the agency simply didn't have the specimens on hand (for example, a request for all the subspecies of a given butterfly). Furthermore, the agency has neither the office staff nor space to cope with every order in a business whose volume is almost doubling every two years.

Field Extension

Wildlife extension officers periodically visit clients and new villages to sustain or develop enthusiasm for insect farming. They explain and demonstrate the procedures of butterfly farming and collecting and teach potential farmers how to recognize a valuable species in each of its life stages. Above all, they demonstrate how to prepare specimens for sale. This is because it is often difficult to convince farmers of the need for extreme care and delicacy in handling, and many inexperienced farmers send in bruised or hopelessly damaged specimens. Although about 500 villagers were farming butterflies at the time of the panel's visit, fewer than 50 were supplying good material regularly.

These contacts are also important because the butterfly farmers easily become discouraged if no interest is shown in their work. In the Papua New Guinea countryside there is often little need for cash; people can obtain all their food, clothes, shelter, and resources from their gardens or from the bush. Money received from one shipment of butterflies may last a subsistence farmer for months, making it difficult for the agency to sustain his interest in providing regular shipments.

The agency's extension officers have initiated a number of butterfly farming projects at primary, secondary, and vocational schools. These projects have proved most successful. Apart from the practical education they give students, they provide early insight into one of Papua New Guinea's most useful resources. Several vocational schools also provide training in mounting butterflies and beetles as souvenirs for tourists, as well as in the construction of hatching cages and solar driers. Beautiful wooden cabinets to hold butterflies have also been made by some teenage students.

Research and Monitoring

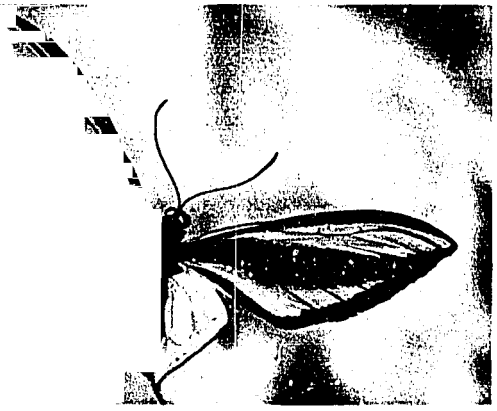
In addition to teaching Papua New Guineans to collect and farm insects, IFTA promotes research both to conserve species and to make them available in quantity. Success has already been achieved in farming the common birdwing butterflies by planting large numbers of the Dutchman's pipe (*Aristolochia tagala*) vines that they feed on.

The agency's staff includes an ecologist, indicating the importance of

the scientific basis for conservation in this project. The ecologist is at hand to conduct research on life histories, farming methods, and management measures for rare species.

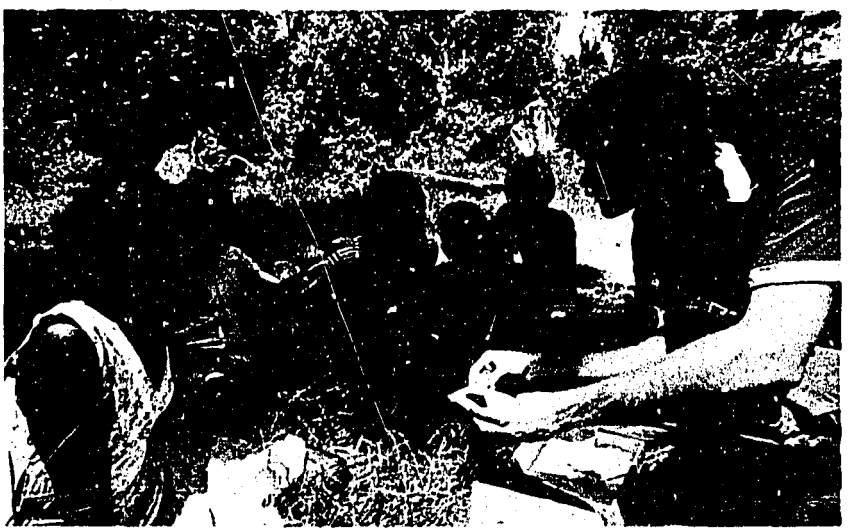
IFTA staff are now identifying new food plants that will permit more species to be farmed. Research into the life histories of many butterflies with economic potential is well under way, so that an increasing number of species will become "farmable" and will be available in future in perfect ex pupa condition.

The sources of all specimens received by IFTA are recorded on a map so that a butterfly's range and rarity or abundance can be assessed and conservation measures implemented where necessary. In this way, even insects too damaged for sale at least have value to conservation efforts. All specimens of unusual scientific interest are lodged in the national insect collection for future study.



Butterflies and moths of Papua New Guinea (like those of most of the tropics) are richly colored and highly prized for their fragile beauty. Clockwise from top: *Ornithoptera paradisea, Papilio ulysses, Spilosoma ougarra.* (All, K.B. Sandved) *Ornithoptera caelestes.* (A. Hutton)





Clockwise from top left: Young collectors move through a rain forest, Karkar Island, seeking specimens. (S.A. Hughes) Larva of common Green Birdwing in butterfly garden near Maprik. (S.A. Hughes) Isekiel Eisolomi of Misima Island, Milne Bay Province, with his *Aristolochia* vines carrying butterfly larvae. (A. Hutton) (Although only 18 years old, Eisolomi has earned enough from this butterfly farm on his family's coconut plantation to set up a bicycle-hire business.) IFTA ecologist Michael Parsons shows school children how to collect and prepare specimens. (J.P. Blair, ©National Geographic Society) Specimens folded in wax paper ready for mailing to IFTA. (N.D. Vietmeyer)

14C

Butterfly farmer Blue Rairi of Maprik. What looks like a garden here is actually a pasture for butterflies. Each plant is chosen for its value as food or shelter for the insects. (R.M. Pyle)

4

Operating a Butterfly Farm

Planting the Farm

The key to farming butterflies is to establish a garden of the plants the various species need for their life cycles. The ideal farm area is about 0.2 hectares. This is spacious enough for growing food plants for adults and larvae and small enough to keep the plants watered, weeded, pruned, and generally well tended. Such a farm can contain about 500 vines, grown like bean plants on poles or shade trees.

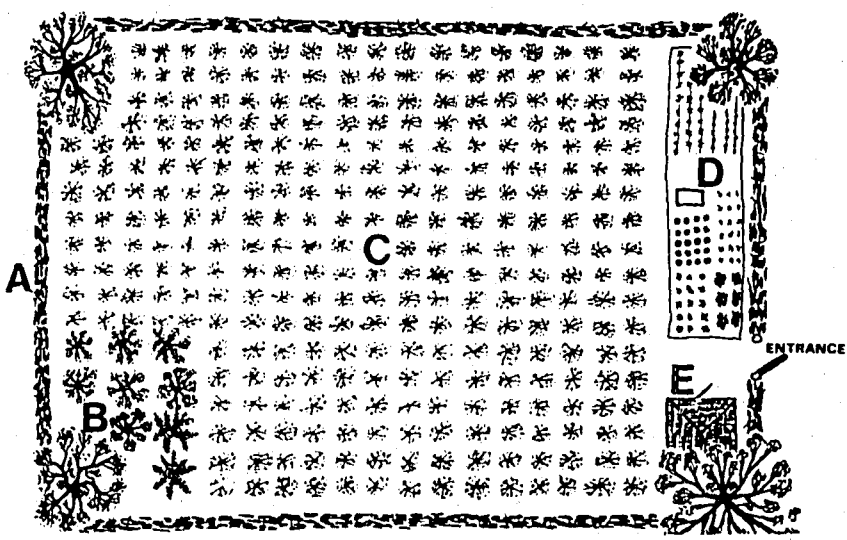
It is important to surround the site with a thick hedge of hibiscus, bougainvillea, ixora, poinsettia, or other nectar-bearing plants whose flowers attract adult butterflies and encourage them to remain in the area. The hedges also keep out pigs and other livestock that may damage the leafy plants inside the farm.

A good way to start a farm is to establish it in a vegetable garden. (Papua New Guinea butterfly farmers often plant butterfly vines between their rows of sweet potato or taro.) By the time the vegetables are ready to harvest, the area already has some thriving butterfly food plants and probably some winged livestock as well.

One of the most successful butterfly food plants in Papua New Guinea is *Aristolochia tagala*, a vine on which the larvae of more common birdwing butterflies feed. Another is *Evodea*—a food plant of the large blue ulysses swallowtail and many colorful weevils.

Shade trees also can be food plants for butterflies other than birdwings and for beetles or weevils. Examples are species of *Annona* (such as soursop), *Citrus* (such as lemon), *Cerbera*, and *Graptophyllum*. Wallace's Longhorn Beetle feeds on breadfruit (*Artocarpus communis*).

Normally, one area of the farm is kept aside for growing seeds or cuttings. (IFTA sells seed of some suitable species.) In this nursery the butterfly food plants are watered and cared for, and unhealthy ones are easily spotted and weeded out.



Stylized diagram of a butterfly farm:
A Hedge of hibiscus, ixora, and poinsettia to keep pigs out and provide nectar.
B Fruit trees (such as lemon).
C The aristolochia vine grown on the branches of other trees (such as leucaena), to feed caterpillar larvae.
D Nursery area.
E A hut for tools.
(Diagram courtesy IFTA, Bulolo)

The Life Cycle

Normally, each butterfly species has a preferred food plant for its larvae. After the female has mated she searches for the correct plant and lays her eggs on or near it. In a few days the eggs hatch, and the young caterpillars usually eat their own eggshells and begin feeding on the softer leaves and shoots of the food plant.

As they grow, the caterpillars shed their skins. Each molt is called an instar, and five instars occur before a larva is big enough to pupate. Pupation is a resting stage during which the adult butterfly develops inside the hard, protective chrysalis. For pupation the larva selects the underside of a stem or leaf to protect it from rain and predators.

After 10 days to 3 weeks, depending on the type of butterfly, the pupal case splits open and the adult insect emerges. This usually occurs before 9 o'clock in the morning. The freshly emerged adult then takes from 3 to 4 hours to expand and dry its wings before flying off to feed on nectar and to search for a mate to begin the life cycle once again.

Harvesting

Once the farm is well established, pupae can be collected daily. Ideally, about 50 percent should be left or released. At least as many females as males should be released. Pupae that are too high to reach are usually left to emerge naturally and repopulate the farm. Others are left because they are not quite perfect.

The farmer can usually see that emergence will occur on the next day, since the pupa becomes darker in color as the adult wing and body colors develop. He then plucks off the stem or leaf to which the pupa is attached. (The soft, new pupae are not touched because this damages the adult.)

He pins the leaf to a board or puts it in a net or in a small cage. Often these are kept inside to protect the pupae against pests and large predators. However, some farmers construct small houses out of bush materials to hold pupae ready for hatching. Others keep their pupae in the open and count on being able to collect the adults before they have flown away.

Care is taken to protect the specimens from ants and rats. For example, the legs of the cage are placed in bowls of water to deter ants from climbing up. The pupae are sprayed with water 2-3 times a week to speed up the hatching process and to prevent them from drying out. (Only a light spray is used; otherwise the pupa develop mold.)

The pupae are best kept in a shady place so the butterflies will remain calm after hatching and will not flap and damage their wings.

Processing

When the newly emerged butterfly has completely dried its wings, it is carefully caught by the thorax and injected with a small amount of a killing agent such as ethyl acetate or boiling water.

Small butterflies are particularly easily damaged if handled, so they are placed for about 10 minutes in a killing jar containing cotton (cotton wool) soaked with a little ethyl acetate. A layer of cardboard is placed above the cotton so that the butterflies are not stained by the solvent.

The farmer places the dead butterflies in paper envelopes, being careful at all times not to touch or damage the wings. The envelopes are easily made from grease-proof paper, which the agency supplies on request.

To ensure that the butterflies will not mold, they are placed on a black plastic tray and dried in the sun, in their papers, for about 4 days. During this time they are protected from pests such as ants, and the drying trays

have a screen on top to prevent the envelopes from blowing away or from being rained on.

Once properly dried, the insects, still in their envelopes, are stored in boxes, preferably airtight to prevent condensation and molding. When enough specimens have been collected, the villager packs them carefully in strong cardboard boxes (which the agency also supplies) with cotton or kapok. A few naphthalene crystals are added to keep away pests, and the box is wrapped and sent to Bulolo.

5

Application to Other Nations

As noted, the essence of the Papua New Guinea approach is the cultivation of food plants that the butterflies need to complete their life cycles. This is a process that could be replicated elsewhere, and the potential for butterfly farming exists in many countries. In fact, although Papua New Guinea is rich in butterfly species—some 700 of them—it is not unusually so. Other countries also have large numbers of species. There are, for instance 2,500 species known in Costa Rica.

There are some 14,000 species of true butterflies in the world. Although there is possible competition, many countries have no overlap in species at all. As collectors and specialists usually want butterflies from many different parts of the world, the likely competition among countries exporting farmed or wild-caught butterflies is minimal.

Butterflies are supplied to the trade from nearly every part of the world. But because they are most diverse in the tropics, it is likely that the best chance for success in farming them lies there. However, some temperate countries also have an abundance of particular species, and in Europe, the United States, and Japan, butterfly farming is already established on a small scale. This is mainly because many collectors like to rear their own material and they purchase eggs, caterpillars, or chrysalids instead of killed adults. Many dealers in these countries supply a few tropical species that are easy to rear, such as the orchard swallowtail (*Papilio aegeus*). However, this trade is generally low in volume and value, and temperate-zone butterfly farms are little more than a sideline to normal dealerships.

Some general comments follow on the potential of butterfly farming in various parts of the world.

- Temperate regions of the Old World (*Palaearctic Realm*). East palaearctic species are in great demand internationally and obtainable with great difficulty. China, in particular, has species of both *Parnassius* and *Papilio* that might be farmed. However, all *Parnassius* species are montane to some degree and none has been farmed yet. Eurasian arctic

satyrids, lesser fritillaries, and sulphurs are also in great commercial demand and could perhaps be farmed. Swallowtails are few and are frequently protected.

- Tropical Africa and associated islands (*Afrotropical Region*). The potential for butterfly farming has not yet been considered in Africa, although the diversity of desirable species is great and the potential market extensive. This area has important swallowtails and *Charaxes* species (Nymphalidae), but so far as is known, no farming enterprises exist. Experimental or trial farms for butterflies are needed in different parts of Africa.
- Indian subcontinent and Southeast Asian tropics (*Oriental Realm*). Silk moths, such as *Bombyx mori*, are commercially farmed in Asia, and butterfly farming would seem to be a natural extension of this. Many Asian butterflies are supplied to dealers, especially from Taiwan and the Philippines, but there is little farming. A very large trade originates in Malaysia, especially for Rajah Brooke's birdwing (*Trogonoptera brookiana*). Farming is reputed to take place, but most specimens are actually collected. Desirable species of swallowtails, including the black and gold birdwings (*Troides* species), occur throughout the region. Species belonging to the families Nymphalidae and Pieridae are good candidates for farming, as they are in much demand from dealers.
- Australia, New Guinea, and associated islands to the west (*Australasian Realm*). Australia is not rich in butterflies, but it has some important endemic species. At least one "farm" exists in Australia, but this appears to be an offshoot of a normal dealership, which rears a few local species to supply at early stages to collectors. Farming is to be encouraged here.

New Guinea's most coveted butterflies, which it shares with Irian Jaya, are the *Ornithoptera* birdwings. But almost equally desired by collectors and specialists are the *Troides* birdwings, concentrated to the west of New Guinea.

- Temperate regions of the Americas (*Nearctic Realm*). There is a considerable trade in New World butterflies from nearly every family (few Lycaenidae and Hesperiidae), but almost all are caught in the wild. There is a strong market for far-northern species (*Boloria, Colias, Erebia, Oenesis*). Farming these might be possible among Canadian and Alaskan Indian or Eskimo groups.
- Tropical regions of the Americas (*Neotropical Realm*). This is a likely area for the development of butterfly farming, particularly as its species are completely different from those of the tropics elsewhere. The *Morpho* and *Agrias* species of South America are much desired by collectors. It is possible that some of the highly prized morpho butterflies are already farmed (as the law, in fact, requires), but evidence is conflicting, and most biologists believe that the major supply of specimens is from

wild populations. Other groups that lend themselves to farming include the swallowtails, nymphalids (including *Agrias*), and certain members of the family Satyridae. There are large fauna of Riodinidae and Lycaenidae that are potentially suitable for farming.

A dealer in preserved butterflies has recently set up business in the Dominican Republic, and butterfly farms have been established in Costa Rica.

- General. Butterflies in the family Riodinidae and, especially, Lycaenidae seem to be a neglected resource. Many species are relatively small but brightly colored. A major difficulty is that many Lycaenidae have to live with ants for part of their lives and this complicates their rearing.

Butterfly Parks

Some regions with tourist industries are showing interest in establishing "butterfly zoos" or "butterfly jungles." These displays have live butterflies (usually farmed or reared) in artificial habitats resembling the natural ones. Some species, such as the orchard swallowtail (*Papilio aegeus*), respond well to such conditions. One British dealer has a "tropical jungle" in an enclosed environment in which both temperature and atmospheric pressure are regulated. A large British butterfly zoo has been established and a smaller one has been proposed. The New York Zoological Society is developing a butterfly component in its Wild Asia Hall at the Bronx Zoo, and San Francisco, Portland, Cincinnati, and Tokyo all have thriving insect zoos. Also, the Colombo Zoo in Sri Lanka has a live display and a successful program of butterfly rearing. Similar enterprise could be shown in other places with tourist industries.

Starting a Butterfly Farm

Butterfly farming is initially an ecological and botanical challenge. One must first observe, identify, and propagate the plants that the various species use for food.

Success for butterfly farmers rests on their choosing commercially attractive species. Unfortunately, ecological details of the life histories of suitable species are known in only a few cases. The prospective farmer will be largely on his own and must first develop this information.

Many of the most desirable species are native to primary tropical forests, and they may need protection because of the rate at which their habitat is being destroyed.

Any program to commercially exploit butterflies and other insects must either bypass the rarest, most restricted, and slowest reproducing

species; farm them cautiously with a high percentage of adults released; or take them with the greatest of care. Further, there must be adequate habitat protection both in the natural state and in mixed land uses (rather than just agricultural croplands) to support the insects and furnish a continuing supply.

Some competition could occur if live butterflies were exported between countries and used to establish farming enterprises. In general, however, butterflies are easier to farm in their native habitats.

Appendix A

Selected Readings

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Appendix B

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Appendix C

Biographical Sketches of Panel Members

EDWARD S. AYENSU, Director of the Office of Biological Conservation, Smithsonian Institution, Washington, D.C., is currently the Secretary-General of the International Union of Biological Sciences. He received his B.A. in 1961 from Miami University in Ohio, M.Sc. from The George Washington University in 1963, and his Ph.D. in 1966 from the University of London. His research interests are in comparative anatomy and phylogeny of flowering plants, commercial timbers, histology of monocotyledons, economic botany, and tropical biology. An internationally recognized expert on tropical plants, he has published extensively in these areas and on topics relating to science, technology, and development, especially in developing countries. Dr. Ayensu was co-chairman of the Panel on Underexploited Tropical Plants of the Advisory Committee on Technology Innovation and chairs and serves as a member of many international bodies.

ARCHIE F. CARR, JR., is Graduate Research Professor in the Department of Zoology, University of Florida, Gainesville. As Technical Director of the Caribbean Conservation Corporation, he has directed a seasonal research program at the breeding ground of the green turtle at Tortuguero, Costa Rica, since 1952, with continuous grants from the National Science Foundation from 1955 to 1980, and has carried out investigations of marine turtle ecology and navigation in various parts of the world. The author of numerous papers, articles, and books, he received the Daniel Giraud Elliot Medal of the National Academy of Sciences for *Handbook of Turtles* and the John Burroughs Medal for *The Windward Road*. He is Research Associate of the American Museum of Natural History; Affiliate Curator of Natural Sciences, Florida State Museum; Chairman of the Marine Turtle Specialist Group of the Survival Service Commission, International Union for the Conservation of Nature; Honorary Consultant of the World Wildlife Fund; Fellow of the Linnean Society of London; Fellow of the

American Fisheries Society; and a member of Phi Beta Kappa and Sigma Xi.

In 1973 he was awarded a gold medal from the World Wildlife Fund for the application of scientific findings to the conservation of marine turtles. In 1975 he received the Edward W. Browning Award for achievement in biological conservation. In 1978 Dr. Carr was awarded the Gold Medal of the New York Zoological Society for contributions to natural science and conservation; in 1978 he became Officer of the Order of the Golden Ark (The Netherlands).

F. WAYNE KING is the Director of the Florida State Museum, Gainesville. He received a B.S. in 1957 and an M.S. in 1961 from the University of Florida and a Ph.D. from 1966 from the University of Miami. His research interests are in wildlife conservation and habitat preservation, impact of international trade on wildlife populations, and ecology and behavior of reptile populations. He worked at the New York Zoological Society from 1967 to 1975. As an international wildlife consultant, Dr. King has received honors from the Dominican Republic, the American Association of Zoological Parks and Aquariums, and from H.R.H. Prince Bernhard of The Netherlands. He has served on committees advising the State Department and the International Union for Conservation of Nature and Natural Resources on policies regarding the trade of crocodile skins, turtle products, and other wildlife materials.

FRANÇOIS MERGEN, Pinchot Professor of Forestry and Professor of Forest Genetics, Yale University, was Dean of the School of Forestry and Environmental Studies at Yale from 1965 to 1975. He received a B.A. from Luxembourg College and a B.Sc.F. from the University of New Brunswick in 1950, an M.F. in ecology in 1951, and a Ph.D. in forest genetics from Yale in 1954. He is especially knowledgeable about francophone Africa and was chairman of the Sahel program of the Board on Science and Technology for International Development and a member of the Advisory Committee on Technology Innovation. From 1960 to 1965 he was research collaborator at the Brookhaven National Laboratory. In 1966 he was the recipient of the Award for Outstanding Achievement in Biological Research from the Society of American Foresters and in 1975 was Distinguished Professor (Fulbright-Hays Program) in Yugoslavia. Before joining the Yale faculty, he served as project leader in forest genetics for the U.S. Forest Service in Florida. He has served as a consultant to FAO, various foreign governments, and private forestry companies, and he has traveled extensively in the tropical countries of Asia, Africa, and Latin America.

MICHAEL G. MORRIS is head of the Furzebrook Research Station of the Institute of Terrestrial Ecology (National Environment Research Council, U.K.). He received a B.A. in natural sciences (zoology) at the University of Cambridge of 1958, M.A. in 1962, and received his Ph.D. from London University in research on the integrated control of orchard pests. Dr. Morris worked at Monks Wood Experimental Station on the effects of grassland management on populations of invertebrates and developed a strong interest in community and applied ecology, particularly the conservation of insect populations. Recently he has become involved with problems of butterfly conservation and resource utilization. He is Secretary of the Joint Committee for the Conservation of British Insects, a Vice-Chairman of the Lepidoptera Specialist Group of IUCN's Survival Commission, and Chairman of the Habitat and Species Protection Committee of SEL (Societas Europaea Lepidoptero-Logica).

HUGH L. POPENOE is Professor of Soils, Agronomy, Botany, and Geography and Director of the Center for Tropical Agriculture and International Programs (Agriculture) at the University of Florida. He received his B.S. from the University of California at Davis in 1951 and his Ph.D. in soils from the University of Florida in 1960. His principal research interest has been in the area of tropical agriculture and land use. His early work on shifting cultivation is one of the major contributions to this sytem. He has traveled and worked in most of the countries in the tropical areas of Latin America, Asia, and Africa. He is past Chairman of the Board of Trustees of the Escuela Agricola Panamericana in Honduras, Visiting Lecturer on Tropical Public Health at the Harvard School of Public Health, and a Fellow of the American Association for the Advancement of Science, the American Society of Agronomy, the America Geographical Society, and the International Soils Science Society. He is Chairman of the Advisory Committee for Technology Innovation and a member of the Board on Science and Technology for International Development.

ROBERT MICHAEL PYLE, a writer and consulting lepidopterist based in Gray's River, Washington, has served since 1979 as Co-Compiler of the IUCN Invertebrate Red Data Book. In this capacity he is consultant to the Conservation Monitoring Centre in Cambridge, England. After receiving his B.S. and M.S. at the University of Washington, he took his Ph.D. through the School of Forestry and Environmental Studies at Yale University in 1976. He worked for the Government of Papua New Guinea on the conservation and utilization of insect resources and then with the Nature Conservancy as Northwest Land Steward. A

former Fulbright Scholar to the United Kingdom, Dr. Pyle subsequently founded the Xerces Society for conservation of beneficial insects and their habitats. He has been chairman of IUCN's Lepidoptera Specialist Group (Species Survival Commission) since 1976. His publications include the *Audubon Society Field Guide to North American Butterflies.* A comprehensive book on insect conservation in his next project.

SHELDON R. SEVERINGHAUS received his Ph.D. from Cornell University in 1977 in natural resources management. He has worked on various wildlife research projects in Asia since 1964 and is representative for the Asia Foundation in Taiwan. He has published articles on butterfly conservation and wildlife industries in Taiwan, where he has been studying the butterfly and wildlife farming projects.

NOEL D. VIETMEYER, staff officer for this study, is Professional Associate of the Board on Science and Technology for International Development. A New Zealander with the Ph.D. in organic chemistry from the University of California, Berkeley, he now works on innovations in science that are important for developing countries.

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Technology Options for Developing Countries

8. **Ferrocement: Applications in Developing Countries.** 1973. 89 pp. Assesses state of the art and cites applications of particular interest to developing countries—boat building, construction, food and water storage facilities, etc.

14. **More Water for Arid Lands: Promising Technologies and Research Opportunities.** 1974. 153 pp. Outlines little-known but promising technologies to supply and conserve water in arid areas. (French language edition is available from BOSTID.)

21. **Making Aquatic Weeds Useful: Some Perspectives for Developing Countries.** 1976. 175 pp. Describes ways to exploit aquatic weeds for grazing, and by harvesting and processing for use as compost, animal feed, pulp, paper, and fuel. Also describes utilization for sewage and industrial wastewater treatment. Examines certain plants with potential for aquaculture.

28. **Microbial Processes: Promising Technologies for Developing Countries.** 1979. 198 pp. Discusses the potential importance of microbiology in developing countries in food and feed, plant nutrition, pest control, fuel and energy, waste treatment and utilization, and health.

31. **Food, Fuel, and Fertilizer for Organic Wastes.** 1981. 150 pp. Examines some of the opportunities for the productive utilization of organic wastes and residues commonly found in the poorer rural areas of the world.

34. **Priorities in Biotechnology Research for International Development: Proceedings of a Workshop.** 1982. 261 pp. Report of a 1982 workshop organized to examine opportunities for biotechnology research in developing countries. Includes general background papers and specific recommendations in six areas: 1) vaccines, 2) animal production, 3) monoclonal antibodies, 4) energy, 5) biological nitrogen fixation, and 6) plant cell and tissue culture.

Biological Resources

16. **Underexploited Tropical Plants with Promising Economic Value.** 1975. 187 pp. Describes 36 little-known tropical plants that, with research, could become important cash and food crops in the future. Includes cereals, roots and tubers, vegetables, fruits, oilseeds, forage plants, and others.

22. **Guayule: An Alternative Source of Natural Rubber.** 1977. 80 pp. Describes a little-known bush that grows wild in deserts of North America and produces a rubber virtually identical with that of the rubber tree. Recommends funding for guayule development.

25. **Tropical Legumes: Resources for the Future.** 1979. 331 pp. Describes plants of the family Leguminosae, including root crops, pulses, fruits, forages, timber and wood products, ornamentals, and others.

37. **The Winged Bean: A High Protein Crop for the Tropics.** (Second Edition). 1981. 59 pp. An update of BOSTID's 1975 report of this neglected tropical legume. Describes current knowledge of winged bean and its promise.

47. **Amaranth: Modern Prospects for an Ancient Crop.** 1983. Before the time of Cortez grain amaranths were staple foods of the Aztec and Inca. Today this extremely nutritious food has a bright future. The report also discusses vegetable amaranths.

Innovations in Tropical Reforestation

26. **Leucaena: Promising Forage and Tree Crop for the Tropics.** 1977. 118 pp. Describes *Leucaena leucocephala*, a little-known Mexican plant with vigorously growing, bushy types that produce nutritious forage and organic fertilizer as well as tree types that produce timber, firewood, and pulp and paper. The plant is also useful for revegetating hillslopes, providing firebreaks, and for shade and city beautification.

27. **Firewood Crops: Shrub and Tree Species for Energy Production.** 1980. 237 pp. Examines the selection of species suitable for deliberate cultivation as firewood crops in developing countries.

35. **Sowing Forests from the Air.** 1981. 64 pp. Describes experiences with establishing forests by sowing tree seed from aircraft. Suggests testing and development of the techniques for possible use where forest destructions now outpaces reforestation.

40. **Firewood Crops: Shrub and Tree Species for Energy Production.** Volume II. 1983. A continuation of BOSTID report number 27. Describes 27 species of woody plants that seem suitable candidates for fuelwood plantations in developing countries.

41. **Mangium and Other Fast-Growing Acacias for the Humid Tropics.** 1983. 63 pp. Highlights ten acacias species that are native to the tropical rain forest of Australasia. That they could become valuable forestry resources elsewhere is suggested by the exceptional performance of *Acacia mangium* in Malaysia.

42. **Calliandra: A Versatile Small Tree for the Humid Tropics.** 1983. 56 pp. This Latin American shrub is being widely planted by villagers and government agencies in Indonesia to provide firewood, prevent erosion, yield honey, and feed livestock.

43. **Casuarinas: Nitrogen-Fixing Trees for Adverse Sites.** 1983. These robust nitrogen-fixing Australasian trees could become valuable resources for planting on harsh, eroding land to provide fuel and other products. Eighteen species for tropical lowlands and highlands, temperate zones, and semiarid regions are highlighted.

Managing Tropical Animal Resources

32. **The Water Buffalo: New Prospects for an Underutilized Animal.** 1981. 118 pp. The water buffalo is performing notably well in recent trials in such unexpected places as the United States, Australia, and Brazil. Report discusses the animal's promise, particularly emphasizing its potential for use outside Asia.

44. **Butterfly Farming in Papua New Guinea.** 1983. 36 pp. Indigenous butterflies are being reared in Papua New Guinea villages in a formal government program that both provides a cash income in remote rural areas and contributes to the conservation of wildlife and tropical forests.

45. **Crocodiles as a Resource for the Tropics.** 1983. In most parts of the tropics crocodilian populations are being decimated, but programs in Papua New Guinea and a few other countries demonstrate that, with care, the animals can be raised for profit while the wild populations are being protected.

46. **Little-Known Asian Animals with a Promising Economic Future.** 1983. Describes banteng, madura, mithan, yak, kouprey, babirusa, Javan warty pig and other obscure, but possibly globally useful wild and domesticated animals that are indigenous to Asia.

General

29. **Postharvest Food Losses in Developing Countries.** 1978. 202 pp. Assesses potential and limitations of food-loss reduction efforts; summarizes existing work and information about losses of major food crops and fish; discusses economic and social factors involved; identifies major areas of need; and suggests policy and program options for developing countries and technical assistance agencies.

30. **U.S. Science and Technology for Development: Contributions to the UN Conference.** 1978. 226 pp. Serves the U.S. Department of State as a major background document for the U.S. national paper, 1979 United Nations Conference on Science and Technology for Development.

The following topics are now under study and will be the subjects of future BOSTID reports:

- **Leucaena: Promising Forage and Tree Crop for the Tropics** (Second Edition)
- **Jojoba**

For a complete list of publications, including those that are out of print and available only through NTIS, please write to BOSTID at the address above.

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