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INSECTS AS FOOD: Why the Western Attitude Is Important

Gene R. DeFoliart
Department of Entomology, 545 Russell Laboratories, 16 Linden Drive, University of Wisconsin, Madison, Wisconsin 53706

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ABSTRACT

The traditional use of insects as food continues to be widespread in tropical and subtropical countries and to provide significant nutritional, economic and ecological benefits for rural communities. Westerners should become more aware of the fact that their bias against insects as food has an adverse impact, resulting in a gradual reduction in the use of insects without replacement of lost nutrition and other benefits.

INTRODUCTION

In his *Missionary Travels and Researches in South Africa*, David Livingstone (69:464) described an encounter on the banks of the Zouga:

> The Bayeiye chief Palani visiting us while eating, I gave him a piece of bread and preserved apricots; and as he seemed to relish it much, I asked him if he had any food equal to that in his country. 'Ah,' said he, 'did you ever taste white ants? [winged termites]' As I never had, he replied 'Well if you had, you never could have desired to eat anything better.'

While in Boer country, Livingstone wrote (p. 42):

> In travelling we sometimes suffered considerably from scarcity of meat, though not from absolute want of food. This was felt more especially by my children; and the natives, to show their sympathy, often gave them a large kind of caterpillar, which they seemed to relish; these insects could not be unwholesome, for the natives devoured them in large quantities themselves.

In modern times, Mercer (80) notes that in Papua New Guinea, insects of many species are eaten, and they are an important part of the diet. He proposed

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that nutritional programs in the future should recognize this fact. In a broader context, he concluded that the predicted world protein shortage could be ameliorated by using insect protein, but that an education program would be necessary "to overcome the taboos currently held in the West." Mercer, formerly Senior Lecturer in Entomology at the Papua New Guinea University of Technology, in Lae, further commented (82): "The majority of my students are keen consumers of a whole range of insects when they return to their villages during vacation time. I have come to the conclusion that it is the West which is out of step in its aversion to insects as food."

There is much evidence to support that viewpoint. Food preferences are the result of cultural conditioning [which is influenced by many factors (52)], and insects have long served as traditional foods in most non-European cultures. As the species used are high in protein and/or fat (and thus energy) and many vitamins and minerals (12, 25), the insects have played an important role in the history of human nutrition. In South Africa, early accounts (e.g. 121:363, 367) attest to vast numbers of locusts and winged termites and to Hottentots who with access to either grew "visibly fatter and in better condition than before." More typical, however, is the complementary use of insects with other foods either seasonally or throughout the year. Insects were not only foods for the masses but foods for royalty and other elites, as in Thailand (11), Madagascar (10, 22), and elsewhere. At the court of Emperor Montezuma and the Aztec kings who preceded him, the *ahuahutle* (the famous Mexican caviar, composed of the eggs of several species of aquatic Hemiptera) were specially prepared during the ceremony dedicated to the god Xiuhtecutli and brought into Tenochtitlan by native runners from Texcoco so that the Emperor would have them fresh for breakfast (4).

Even Westerners, when exposed to some of the favorite traditional foods of indigenous populations, often became enthusiasts. Smeathman (119) states that the palm worm (*Rhynchophorus palmarum*) is "served up at all of the luxurious tables of West Indian epicures, particularly of the French, as the greatest dainty in the Western world." Bequaert (8) reports that some planters in the West Indies kept laborers whose sole duty was to go into the woods in quest of the large larvae of the beetle *Stenodontes damicornis*, found chiefly in the plum and silk-cotton trees. Broiled over a charcoal fire, they were considered a rare delicacy by immigrant Europeans and natives alike.

Insects are still widely important as food, and they contribute significantly to local economies. The Western attitude is important because acculturation toward Western lifestyles tends to cause a reduction in the use of insects, frequently in populations that are economically marginal, without affording the means by which the lost nutrition can be replaced. Western recognition of the existing and potentially greater importance of insects as food could also yield

ecological benefits (29, 97). Space limitations preclude referencing numerous pertinent publications cited in previous reviews by this author (23, 25, 28, 29) and papers pertaining to related aspects, such as use of insects in the feeding of zoo animals (31) and in the recycling of organic wastes into high-protein feedstuffs for domestic animals, particularly poultry (35, 116).

CURRENT STATUS OF INSECTS AS TRADITIONAL FOODS

In order to present a picture that is up-to-date, the research and observations cited in this section are largely restricted to work published after 1970. I intend also to provide a forum for the conclusions and recommendations of the investigators involved and their perceptions as to the impact of Western influence on the modern use of insects. The countries described here are not necessarily those with extraordinary insect use but are rather those from which the most recent published information is available.

Africa

Caterpillars and termites (winged sexuals) are the most widely eaten and marketed insects in Africa, but many others are also important from the food standpoint, nutritionally, economically, and/or ecologically. Nutrient analyses have been conducted in several countries, with particularly valuable studies in Angola, Democratic Republic of Congo (formerly Zaire), Zimbabwe, and the Republic of South Africa. Studies in Malawi, Congo, and Zambia have shown that the favored food status of caterpillars can be a factor in achieving better forest management and protection.

DEMOCRATIC REPUBLIC OF CONGO (KINSHASA) More than 65 species of insects in at least 22 families have been reported as food in Congo. Possibly the most comprehensive study anywhere to date on quantitative use as food on a national scale was that of Gomez et al (45), who estimated that insects furnished 10% of the animal proteins produced annually in Congo, compared with 30% for game, 47% for fishing, only 1% for fish culture, 10% for grazing animals, and 2% for poultry. This 10% becomes even more impressive when the data are tabulated for the country's 25 districts and 137 territories. For example, in Kwango District, which is divided into five territories, insects furnished 37% of animal proteins for the district as a whole, and from 22 to 64% in the different territories, showing the great importance locally of insect foods. In the country as a whole, insects furnished more than 20% of animal proteins produced in 4 districts and 32 territories. It is revealing, however, that in projecting the country's future protein needs and how they might be met, Gomez and colleagues

considered possible increases in fish culture, grazing animals, and poultry, but they assumed that the insect contribution, as well as game and fishing, would remain only at then-current levels.

Relative to the Kwango district, LeLeup & Daems (66:1) state that "[l]arge game having become very scarce, it is fish, and especially caterpillars, of which certain species abound, that constitute the most important sources of protein for local consumption." They are also a source of income. Of more than 30 species consumed in the Kwango and Kwilu districts, three (the widely eaten *Cirina forda* and two other saturniid larvae) account for most of the exports. From 1954 to 1958, the dried caterpillar production in the district was estimated at 280–300 tons per year. Because of reduced annual tonnage after that period, Leleup & Daems were commissioned by the territorial administration to determine whether fluctuations and reduced tonnage might be caused by badly timed burning. The three exported species all pupate underground, but the adult moths emerge and lay their eggs at different times. Although other complicating factors were involved, the investigators were able to determine optimum dates for burning that minimize caterpillar destruction. Other recommendations included encouraging resowing attempts on a massive scale by collection of eggs prior to burning and creating "reserves" of some small wooded savannahs in which all harvest for purposes of consumption would be forbidden.

In an important study northeast of Lubumbashi in southern Congo, Malaisse & Parent (75) found that at least 35 species of caterpillars are consumed, 26 of which could be specifically identified after rearing. Certain villagers are very knowledgeable about host preferences of the edible species. Frequently, a branch containing many young caterpillars of an edible species will be cut off, transported to the vicinity of the village, and attached to a tree of the same species. Dried caterpillars of 23 species (including 17 Saturniidae) were analyzed, with samples prepared in a manner identical to that which precedes their culinary preparation. Crude protein content averaged 63.5%, kilocalories per 100 g averaged 457 (ranging up to 543), and most species proved an excellent source of iron, with 100 g averaging 335% of the recommended daily requirement. Kondondi et al (64) analyzed three species of saturniids for vitamins and conducted feeding trials with rats that showed that vitamins supplied by the caterpillars, except for B1 and B6, are sufficient to allow proper growth. The reader interested in Congo-Kinshasa should consult Malaisse (74), which was not available in time for inclusion in this review.

ANGOLA Oliveira et al (94) provide nutrient analyses of four commonly eaten species that show the insects high in crude protein, calories, and many of the vitamins and minerals. The termite, *Macrotermes subhyalinus*, and the palm

weevil larva, *Rhynchophorus phoenicis*, are especially high in energy value, 613 and 561 kcal/100 g, respectively, and the weevil larva and the saturniid caterpillar, *Usta terpsichore*, are high in zinc, thiamine, and riboflavin. The caterpillar is also a rich source of iron.

CONGO REPUBLIC (BRAZZAVILLE) Nkouka (93), noting that in earlier years consumption of caterpillars around Brazzaville was estimated at 30 g/person/day, stated that promoting the use of edible insects merits more attention. Bani (5, 6), as did Nkouka earlier, decried the attitude that insects are "uncivilized" food or a vestige of a time long past and similarly urges greater promotion and popularizing of insects for improving both nutrition and local economies. Some species command a higher price in the market than imported meat. The palm weevil larva, *R. phoenicis*, is the "most appreciated" edible insect in the country (6), and its rarity in the markets and its taste make it a high-priced food (93). Termites and caterpillars of many species are popular and widely sold. Grasshoppers and other Orthoptera are also sold in the markets, allowing people from rural areas to use these insects as a cash commodity (6).

NIGERIA Most Nigerians have had direct or indirect experience with entomophagy, although it is more prevalent in rural than in urbanized areas. As elsewhere in Africa, the more educated persons are more reluctant to admit that indigenous customs, including the eating of insects, still exist. Fasoranti & Ajiboye (38) believe that insects can help significantly in reducing protein deficiency in the country and that entomophagy should be promoted through education. They also stress the need for development of mass-rearing methods rather than continued reliance on harvesting natural populations. Development of mass-rearing is particularly important in the case of *Anaphe venata* because of the loss of its host tree, *Triplochiton scleroxylon*, to logging (3).

The saturniid caterpillar, *C. forda*, is the most widely marketed edible insect in the country and sells for about twice the price of beef. Others widely marketed are palm grubs (*R. phoenicis*), termites, and *Anaphe* larvae. *Anaphe* larvae are among the insects that are an unusually good source of fat (3), with a calorific value of 611 kcal/100 g. Unfortunately, these larvae have recently come under suspicion as the cause of a seasonal ataxic syndrome (1). Although insects are eaten by all age groups, some, such as *Oryctes* beetle grubs and termites, are collected mainly by women and children, and according to AE Akingbohungbe (Obafemi Awolowo University, Ile-Ife, personal communication, 1988), grasshoppers and crickets are eaten mainly by the children.

MALAWI The potential of entomophagy in helping to preserve biodiversity is shown in a study by Munthali & Mughogho (89), which shows that opening

national parks and other wildlife preserves to controlled sustainable use by local populations can reduce the problems of poaching in protected areas. Beginning in 1990, Malawi's Department of National Parks and Wildlife allowed some of the families living around Kasungu National Park to harvest caterpillars within the Park and simultaneously initiated modern beekeeping in the Park, in order to diversify the communities' income base and to win their support for wildlife conservation programs. Formerly, 100% of families practiced beekeeping and utilized caterpillars and other products of the forest, but beekeeping is now greatly reduced outside the Park because of a lack of bee forage. Caterpillars are nonexistent because of the absence of host trees, which have been displaced by extensive agriculture (tobacco estates and maize, beans, and groundnuts grown by smallholder farmers for subsistence and cash).

The caterpillars involved are two species of Saturniidae, *Gonimbrasia belina* and *Gynanisa maia*, which still occur abundantly in the Park; the larvae are in season from mid-October to December, a time of year when food stocks of families in the study area are running low. Using gross margin analysis (output minus the variable associated costs), the authors show that caterpillars and beekeeping produced from twice to several times the gross margin values of maize, beans, and groundnuts, and not only did they have the higher earnings, but they did not directly compete for labor with the existing agricultural enterprises. The authors believe that these results mark a turning point in the history of wildlife management in Malawi.

A wide variety of insects are consumed in Malawi. Shaxson et al (115) provide recipes for many of them and state (p. 21), "It is not generally known in the Western world that insects are a very good and cheap source of protein." Of the lake fly, *Chaoborus edulis*, they say that it is "extremely nutritious, high in protein and calcium and contains six times as much iron as ox liver" (p. 22).

ZAMBIA Nutrient analyses of foods used by the Bemba revealed 65 g protein per 100 g of dried caterpillars, compared with 32 g for dried fish, 30 g for roast venison, and lesser amounts for other foods (111:409). "Caterpillars are obtainable everywhere during the wet season" (111:39), and, according to Richards (111), are the single most important source of nutrients during the "hunger months," November to February, when the other most widely available foods are fresh mushrooms and fruits, which contain on avarage only 2 g and 1 g protein, respectively. Similarly for the Lala tribe (125), caterpillars not only formed a large part of the diet for three or four months of the year (40% of the relishes from November to January) but also could be sold for a good price to traders from the Copper Belt or exchanged for grain, salt, tobacco, beads, soap, or clothes.

Silow's (117) ethnoentomological fieldwork added greatly to knowledge of the importance of caterpillars as food in Zambia, and by inference, in adjoining regions. Caterpillars are eaten as a snack, for which they are mostly roasted, or as a meat course served with porridge at a regular meal. The Mbunda recognize 31 kinds as edible, 7 of which are marketed. This latter group feeds on dominant species of forest trees. Most of Silow's informants were peasants who hunt, fish, and gather for their household requirements, but who were all more or less influenced by changes in modern times, including conflicts between foreign (mainly European) and traditional values and customs. Silow describes how European influence has undermined the traditional attitudes toward caterpillars (117:212–13):

> In connection with the independence movement a reaction spread, especially in the towns, maintaining that caterpillars are excellent African food. The course of development, according to which modern, enlightened people should not eat the larvae, appears, however, to be stronger. Already at the primary schools many children learn from their teachers that caterpillars are bad food. Even if they generally keep the food habits of their parents, they have become a little hesitant about them. The pupils of the secondary schools, who spend their terms at boarding-schools with mainly non-African teachers, often refuse to eat caterpillars....

The high regard in which winged termites are held not only in Zambia but throughout most of Africa is documented by Silow (118:109):

> The Mbunda, Nkangala, Lucazi, Luvale, Cokwe, and Yauma generally agree that the meat of [*Macrotermes* spp. winged sexuals] is better than meat of animals, birds, fish. Perhaps one or another of the edible caterpillars is comparable with them, but most of my informants are of the opinion that [*Macrotermes*] or honey is the best existing food. Some few persons simply do not like them. It is known that some missionaries have condemned winged termite eating as a heathen custom.... Bemba, Namwanga, Nyanja, and Nsenga I have met unanimously declare that [*Macrotermes* winged adults] are more delicious than anything else, or at least among the most delicious dishes.

Kumar (65), based on work of the International Food Policy Research Institute, Washington, DC, confirms the importance of insect foods during the hunger season, noting that the nutritional contribution is small on an annual basis but very significant on a seasonal basis. Insect items are included in the Zambian food composition tables that are widely used by nutritionists in the country. While Kumar says there seems to be a trend toward reduced consumption of insects, Mbata (76) states, a few years later, that entomophagy is gaining prominence in recent years as the result of drought and poor economic conditions. Large quantities of insects, especially caterpillars, grasshoppers, and termites, are brought from rural areas for sale in town markets. According to Mbata, entomophagy has undoubtedly played an important role in reducing kwashiorkor in young children.

More than 60 species of insects in at least 15 families and 6 orders have been reported as food in Zambia. Among them are honey bees, which, here as elsewhere, furnish multiple products of value. Mbata (76) mentions *Apis mellifera adansonii* and *Apis mellifera capensis* specifically and notes that there are many smaller species, mainly belonging to the genus *Trigona*. Honey is an important sugar source for rural people, and it is also used to brew local liquor. The wax is used to make candles and to condition animal skins on the traditional drums. The brood (larvae and pupae) may be eaten with honey, or they may be extracted, fried, and consumed as relish with the main meal. White (132) lists eight vernacular names of stingless bees and notes that some Luvale apiarists may have dozens of hives, located up to 30 kilometers from the village. Interference with a person's hives is considered a serious offense.

A saturniid caterpillar known locally as *mumpa* (Bemba term) is highly valued by people in "miombo" woodland areas of Zambia and is the most important source of animal protein in areas where it occurs in abundance (55). It feeds on *Julbernardia paniculata* and several other common trees and is an important source of income. A person can pick about 20 liters per day if the bush is rich in caterpillars, and seven days' picking, if all are sold, can earn the equivalent of a month's salary for a general worker in Zambia. People travel 200–300 km to pick caterpillars, and traders come from Lusaka and the Copperbelt (900 km) to buy them. Forestry officials have considered the caterpillars a pest, not so much because of deforestation, but because of damage done by people collecting them illegally in the national forests. The picking season is regulated by opening and closing dates, usually November 15 and December 15, respectively, but Holden notes that it is difficult to enforce the closing date because people find it "very difficult to stop picking this sweet relish!" (55:3). The opening date is intended to ensure that the caterpillars are large before picking, the closing date to ensure that there is enough "seed" for next season. Silow (117:69) indicates that *mumpa* caterpillars may be *Gynanisa maia*.

Holden suggested that caterpillar husbandry on a communal basis would not only increase the production of *mumpa*, a valuable foodstuff, but would have favorable impact on woodland management. He observed that there are very few late bush fires in areas where the caterpillars are found. Fires late in the dry season when the trees have started to produce new leaves cause a lot of damage by killing trees, reducing regrowth, and increasing erosion. Early burning is the best way to avoid this damage. The caterpillars provide the incentive for people to burn early, thereby protecting the caterpillars and enhancing woodland regeneration. It is relevant to our subject to note that when Holden, as a researcher in agroforestry in Zambia, proposed research on the caterpillars, the administrative response was that "serious researchers cannot come up with such things!" (55:4).

REPUBLIC OF SOUTH AFRICA More than 35 species of insects representing at least 16 families and 7 orders have been reported as foods. The most important species in modern times is the saturniid caterpillar, *Gonimbrasia belina*, widely known as the mopanie worm. According to Quin (107:114), the Pedi (whom he studied extensively) preferred "a 1/4 lb. of these caterpillars to 1 lb. of fresh beef," and the availability of the caterpillars seriously affected the sale of beef. The amino acid composition of dried mopanie worms is relatively complete, with high proportions of lysine and tryptophan (which are limiting in maize protein) and of methionine (limiting in legume seed proteins) (32). From extensive studies, Dreyer & Wehmeyer (33) concluded that "the consumption of mopanie caterpillars can to a substantial degree supplement the predominantly cereal diet with many of the protective nutrients." As reported by these investigators, the South African Bureau of Standards estimates annual sales of mopanie caterpillars through agricultural cooperative markets at about 40,000 bags, each containing 40 kg of traditionally prepared, dried caterpillars. This amounts to 1600 metric tons entering reported channels of commerce, but it is only a fraction of the volume actually consumed.

Cunningham & Peiser (21), authors of the *Primary Health Care Booklet* written for teachers and health care workers, have decried the fact that knowledge of traditional foods is being lost because it is rarely taught in the modern schools. Malnutrition remains a major problem, for which one reason is the lack of a mixed, balanced diet. The authors advise, "Do not forget about wild foods which are available at no cost." The booklet includes insects in the meat group: "amacimbi," or saturniid larvae, mostly *Microgone cana, Bunaea alcinoe*, and *Cirina forda*; and "izinhlwalbusi," winged adults of the ant, *Carebara vidua*. The amacimbi are a good source of protein and thiamin and an excellent source of riboflavin and calcium. Elsewhere, Cunningham (20) states:

> The traditional conservation practice of not felling edible wild fruit producing trees when clearing fields is widespread in Africa, and is a major reason for maintenance of woody plant cover outside of conservation areas. Some of these trees (e.g. *Sclerocarya birrea* [Anacardiaceae]) are also important sources of edible insect larvae (e.g. *Cirina forda*) feeding on *Sclerocarya* leaves, and cerambycid larvae from dead *Sclerocarya* trees. What is also increasingly widespread is the social stigma against gathering of wild food resources, which is locally viewed as 'primitive' compared to buying food from the local store. The result is removal of the incentive to conserve wild fruit bearing trees, and neglect of a nutritionally important food resource in marginal agricultural areas by often poor communities.

Recent newspaper reports from South Africa (e.g. *San Francisco Chronicle*, Sept. 4, 1994) indicate concern that people may be eating the mopanie caterpillar into extinction, and at least one government ministry has shown interest in supporting pilot programs for caterpillar "farming" as a cash crop. One expert was quoted as saying that nature conservation in South Africa has focused on

mammals such as rhino and elephants at the expense of creatures such as the mopanie worm, which are less spectacular but more relevant for rural communities: "Conservation means nothing to these communities if they don't benefit from it."

ZIMBABWE More than 40 species of insects representing at least 25 genera, 14 families, and 7 orders have been reported as foods in Zimbabwe. Gathered wild foods, of which insects are an important part, play a daily role in rural diets and are most important for making the relish that accompanies the characteristic stiff cereal porridge. Chavunduka (13) concluded that insects are the cheapest source of animal protein for the poor rural communities, that insect consumption averted many potential cases of kwashiorkor, and that their use as food should be encouraged. He warned of an imminent decline in insect populations as the result of bush clearance for settlement and agriculture and the use of insecticides.

Where the forest remains, caterpillars provide an important relish during the rains and are dried for use later in the year. They are harvested mainly by women. Chavunduka states (13:219) that in good caterpillar areas, "some families can make a fairly good living from selling caterpillars." Wilson (133:574) noted that there is "an increasing, but still fairly small, number of people who are starting to refuse to eat caterpillars at all on the grounds that they are for 'primitives.' This is not yet widespread in rural areas, and has not been sufficient to make much of an impact on the urban market." While the availability of many species of caterpillars has decreased markedly under deforestation, the decline has not exactly mirrored the decline in food trees, and heavy exploitation by people may be among the factors that have reduced numbers. *C. forda* and possibly *Imbrasia ertli* are among miombo species that complete several cycles in some favorable years; the former is still common but occurs fewer times per year. *G. belina* is a particularly important food item and is collected, transported, and sold on an industrial basis; its price is similar to that of fresh beef.

Winged termites emerge in tremendous numbers during the rains; they are grilled or fried without additional fat (or may be eaten raw) after removal of the wings by winnowing. They are storable for later use. Sales are considerable (133:572), and they are "consumed in very large amounts by people of all wealth and age categories." Soldier termites, collected mainly by older women and small children, are eaten during the hot dry season. Used as relish for sadza porridge, they are considered a food for the poor and the elderly (77, 78, 133). As a snack, fried and salted, they do not have this association, however, and are widely eaten, especially in beer halls. McGregor (77) remarked that they can be an important source of income and that "school teachers are as enthusiastic

as anyone else about their collection and consumption" (p. 270). Phelps et al (102) analyzed alates of *Macrotermes falciger* and found protein and fat composition to be 41.8 and 44.3%, respectively (dry weight), and an extremely high energy value, 761 kcal/100 g on an ash-free basis. In rat feeding trials, the protein efficiency rating (PER) and digestibility for lightly fried termites were somewhat low compared with casein.

In the deforested areas, several caterpillar species that consume grasses and herbs and certain edible crickets and other orthopterans are regularly consumed. For example, the sphingid caterpillar, *Herse convolvuli*, which feeds on weeds of the genus *Convolvulus*, is abundant in southern Zimbabwe (133). *Brachytrupes membranaceus* is the most common cricket eaten and has increased in numbers because it is well suited to the new kinds of agro-ecosystems (133). It is now a significant pest in sand-soil fields. McGregor (77, 78) also noted that this species is increasingly abundant and is sold in urban markets. The crickets are usually collected by women and children, and as many as 100 can be collected from their burrows in a day (43:171). Chavunduka (13:219) states of this species, "When well prepared it is considered a delicacy, for it turns an ordinary meal into a dinner." The tettigoniid *Ruspolia differens* swarms in grassy woodland fields, particularly millet, and is sold in urban markets (77, 78). In addition, many types of grasshoppers are eaten. Wilson (133), as did Chavunduka earlier, pointed out that governmental control of migratory locust species, while relieving the country of a serious menace, also deprived the people of a major source of food.

Asia and Oceania

Increased consumption of grasshoppers/locusts has coincided with decreased pesticide use in the Philippines and several of the countries discussed below.

INDIA More than a dozen species of "wild silk" producers in Asia and Africa have pupae that are available as a high-protein food byproduct, but for the tribal peoples in northeastern India, the pupa of one species, the eri silkworm, *Samia ricini*, is so highly regarded as a food delicacy that "the cocoon is more or less a byproduct" (15:1). About 40,000 families in northeastern India are involved in ericulture. It is practiced as a cottage industry and carried on traditionally by village women during leisure hours; the women also do the spinning and weaving. The production of eri cut cocoons in Assam and six other states in northeastern India was estimated at about 183 metric tons in 1979, and the government of India is currently attempting to expand ericulture to the states west of Assam (98). *S. ricini* and its host plant, castor, offer an excellent example of a multiple product crop and of sustainable agricultural practice.

Castor grows on poor soils, helping to prevent erosion; castor bean oil is sold for medicinal and industrial uses; excess leaves are fed to the caterpillars, which produce silk and a pupa that is a high-protein food or animal feedstuff; and the caterpillar frass and other rearing residue can be used for pond fish culture. In Nepal, Neupane et al (91) have investigated the production biology of *S. ricini* on both castor and on cassava, which can also serve as a host plant. Quality leaves of both castor and cassava are available throughout the year. Farmers can use their extra time for silkworm rearing, and very little monetary investment is required; even low-skilled children and older people in a family can participate in the rearing, thus enhancing employment and the economic status of poor and subsistence farmers. If cassava is the host plant, rather than castor, the roots are used as food and animal feed and the old plants as fuelwood.

Based on proximate analyses conducted on 8 of the nearly 20 species commonly used among tribes in the State of Manipur in northeastern India, Gope & Prasad (46) concluded that insects represent the cheapest source of animal protein in Manipur and that their consumption should be encouraged because many of the people cannot afford fish or other meat.

THAILAND Sungpuag & Puwastien (122) provided results of proximate, mineral, and vitamin analyses on 12 of the species of insects consumed in north and northeast Thailand. In the villages of Ubon where the samples for analysis were collected, 20–60 g of insects are consumed per day, making them an important source of protein, energy, vitamins, and minerals for the rural farmers of the region. The researchers concluded that insects should be recommended for consumption by the rural people and information should be provided that would make their use as food as efficient as possible. Restraint should be exercised in the use of pesticides so that insects remain available as a food source. Six insect species are included in an attractive booklet, *Manual for Using Food Which Provides High Protein and Fat in Rural Areas*, published by the Ministry of Public Health (85). It is intended to be helpful in selecting foods for malnourished infants and preschool children.

More than 80 species of insects in at least 35 families have been reported as food in Thailand. Vara-asavapati et al (129) provided valuable information on many of them, such as specific identity, habitat, and methods of collection, preparation, and marketing.

Watanabe & Satrawaha (130:325) provided data on 15 species found in the public market at Khon Kaen (northeast Thailand) and stressed that "to ensure a continued supply...collection methods will need to be improved and rearing methods established." Somnasang et al (120) reported villagers saying that "nowadays insects are difficult to find," and, in one village, that there are not many insects now because there are not many trees in the woods. Continuing

dependence on the forest by many families in the Phu Wiang watershed is illustrated by a government report (92) that shows 25 species of forest insects are gathered for consumption and 8 species for sale; 93% of households gather insects for consumption, and forest-gathered insects are sold by 9.3% of households.

In urban areas, although many are squeamish about eating insects, they are purchased and well accepted as food by people of various economic levels. Some insects, such as wasps, bamboo caterpillars, crickets, and locusts, are sold as delicacies in the finest restaurants and food shops (134). The Thai government has played a role in promoting insect consumption, especially during locust plagues, and, as a result fried locusts and locust fritters appear widely in city markets. Thai farmers began collecting grasshoppers/locusts as food in 1983 as an alternative to ineffective government spraying programs (37), and the price increased from 12 cents per kg in 1983 to $2.80 per kg in 1992; a small farmer could earn up to $120 per half-acre, twice as much as he could from corn. The trade in grasshoppers averaged about $6 million per year. According to Gorton (47), reports of villagers dying or being injured by ingesting insects killed by pesticides caused some districts and villages to give up spraying in favor of grasshopper catching. Gorton notes that "those who can catch the insects in mass quantity are able to sell them on the village roadside or become involved with the lucrative 'export' trade to Bangkok."

CHINA Luo (72) gave a brief summary of past and present use of insects as food in the country and concluded that encouragement of insect foods, including industrial development, may be desirable, while harvested insects should be monitored to prevent over-collection. Xinhua, the official Chinese news agency, has issued several reports in the past few years on efforts to mass-produce two insects as food, the ant *Polyrhachis vicina* [believed to have health benefits (14)] and larvae of the house fly, *Musca domestica vicina*. According to the *Asahi Evening News*, annual sales of ant foods in China amount to approximately $100 million (61).

JAPAN In both historical and modern Japan, the most popular and widely eaten insects have been the rice-field grasshoppers (mainly *Oxya yezoensis*, some *Oxya japonica*), which, fried and slightly seasoned with soy sauce, are known as inago. After near depletion, populations of these grasshoppers have increased in recent years as the result of reduced pesticide use, and inago is reappearing on dinner tables and in supermarkets and restaurants, although it is still sold as a luxury item (86, 88). The second most widely eaten insect food in modern Japan is "hachinoko," bee or wasp larvae, which may be eaten raw, boiled down in soy sauce, or served over boiled rice. Bee and wasp brood (and even wasp adults) are

among the many canned insects available, and the canned wasps are expensive, a can (about 65 g) selling for 1000 yen (about $8.00 in 1988). The late Emperor Hirohito, following surgery in 1987, reportedly "finished the wasp-rice dish even when he had no appetite and left most of the other dishes" (87). Pemberton & Yamasaki (101) reported that canned "child hornets" were being sold for about $20 per 100 g can in the prestigious Mitsukoshi Department Store in Tokyo in 1990. Another widely available product, both canned and in restaurants, is "zazamushi," the name for aquatic insects inhabiting gravel beds in rivers and usually consisting mainly of larval Trichoptera. All three of the above foods, inago, hachinoko, and zazamushi, are found on the menu of restaurants in Tokyo that specialize in foods of the Japanese Alps. Mitsuhashi (88) furnished up-to-date information on prices of the edible species and quantities processed annually in Japan.

SOUTH KOREA As in Japan, Pemberton (100) has documented for South Korea the increased marketing of the rice-field grasshopper (*Oxya velox*, known as metdugi) following reduced use of pesticides. Canned silkworm (*Bombyx mori*) pupae are also popular (as they are elsewhere in East Asia) and are found in the markets in Seoul. They are also exported.

PAPUA NEW GUINEA AND IRIAN JAYA A great variety of insects is eaten in Papua New Guinea, one species of which is the famous sago grub, *Rhynchophorus ferrugineus papuanus*, which is not only widely eaten and widely marketed but is the center of annual "grub festivals." They are "tender and sweet with a slightly nutty flavor" and are bought by Europeans as well as Papua New Guineans (80). They are important nutritionally, making up 30% of the protein intake of some Sepik peoples (79) and are a good source of fat and other nutrients such as iron and zinc. The grubs breed in the rotting pith of sago palms, and Mercer (81) has described in detail the production process. It is one of the better examples of environmentally efficient food production, and the grubs are a significant source of rural income. Sago grubs are among the wild biota most widely eaten by Pacific Islanders.

Another environmentally efficient system, although on a smaller scale, is found in the Gabensis logging area near Lae, Papua New Guinea (80), where villagers harvest large numbers of the cerambycid grub, *Hoplocerambyx severus*, from *Anisoptera polyandra* logs. To indicate the abundance of grubs, Mercer was able to extract nearly 100 from a single log in little more than 15 min.

In 1973, Meyer-Rochow (83:676) wrote: "If the new Papua and New Guinea government can be persuaded not to accept the European attitude toward insects as human food, it would act to the benefit of vast numbers of natives." Twenty years later, Orsak (96) lamented that New Guineans, to their economic and

nutritional disadvantage, are coming to believe that eating insects is "bush behavior" to be discarded in their progress toward development.

Tommaseo & Paoletti (127) updated information on entomophagy in Irian Jaya, the western (Indonesian) half of New Guinea, and described the various feasts that are dedicated to the sago larvae. Various artistic objects are also devoted to them, such as special bowls for use on ritual occasions. Noting, as did Meyer-Rochow earlier in Papua New Guinea, that people in their study at first were reluctant to admit they eat insects or other small animals, the authors stated (p. 327): "This attitude may be ascribed to the contact with western cultural agents (missionaries or administrative officers), who consider this use backward or primitive."

AUSTRALIA There is a voluminous literature on insects used as food by the Aborigines. Among the most prized were witchety grubs (Cossidae), the bogong moth (Noctuidae), the bardee larva (Cerambycidae), honeypot ants, honey and brood of the stingless bees, and the sweet manna of various lerp insects (Homoptera). The influence of European intrusion is discussed by Macfarlane (73:61), who wrote, "The overall picture of these [hunter/gatherers] as they made contact with European foods and culture, was that of well fed infants and adults." Their social organization, which dictated the sharing with other members of the group anything that was caught, also tended to reduce malnutrition. An interesting recent development in Australia is the explosion of interest in native, or "bush tucker," foods, including insects such as witchety grubs. As reported in the *Christian Science Monitor* (1991), bush foods are "increasingly appealing to hotels and restaurants frequented by tourists," including the Australian chain Country Comfort Inn, which has made native foods the signature of its restaurants. "Bush food has taken to the air on Australian Airlines and the Australian Broadcasting Corporation," while bookstores are well stocked with books on bush tucker. Witchety grubs are on the menu of the posh Rountrees on Sydney's North Shore (60) and a growing list of other restaurants in Australia. According to Tindale (126), the taste of *Xyleutes* (witchety grub), "when lightly cooked in hot ashes, would delight a gourmet."

Latin America

On the basis of her studies in Colombia, Dufour (34) suggested that "a consideration of the role of insect fauna in the diet needs to be included in any evaluation of the adequacy of protein resources in Amazonia." Based on studies in Brazil (70), Colombia (34, 114), Paraguay (59), and Peru (30), women and children spend more time than men in foraging for insects. Insects also comprise a higher proportion of the diet of women and children than of men. Men are more likely to engage in the heavier work of insect collection, such as

felling trees to obtain honey and bee or wasp brood or splitting logs for harvest of *Rhynchophorus* (palm weevil) larvae.

Numerous references provide ample evidence that many insects were (and are) considered great delicacies by indigenous populations. Roasting is the usual method of cooking. Leafcutter ants (*Atta* spp.), palm weevil larvae (*Rhynchophorus* spp.), and bee and wasp brood (Apidae and Vespidae) are among the insects that are most notable for their flavor and quality, not only among indigenous populations but among Europeans and other Westerners who have sampled them. Of the edible insects in South America, the palm weevil, *R. palmarum*, would appear to have the greatest mass-production and marketing potential (27). This insect has long been "semi-cultivated" by indigenous populations in Brazil, Colombia, Paraguay, and probably other countries. The fungus-feeding *Atta* ants, which like the palm weevil larvae, are a widely favored food in South America, exert an immense ecological impact that is beneficial within the rainforest but destructive when rainforest is cleared for citrus, cocoa, or other agricultural crops (29). As noted by Hodgson (54), feeding on a cultured fungus has given *Atta* spp. a preeminent position among rainforest fauna by allowing them to tap the virtually inexhaustible supply of cellulose in their environment.

In Mexico, prior to the intensive studies initiated by Ramos-Elorduy (formerly de Conconi) and colleagues in the early 1970s, the specific identity was known for fewer than 20 species used as food, but, in 1997, Ramos-Elorduy (108) reported that the taxonomic identity was known for 348 species. In a similar illustration of the value of taxonomic attention, there was little published information on entomophagy in Ecuador prior to studies from 1980 to 1995 by Onore (95), which revealed the use of at least 83 species and the specific identity of 74 of them.

MEXICO de Conconi (22a) proposed that the "industrialization" of insects (the establishment of small industries in the countryside for the mass-culture of insects as food) works both to the benefit of rural economies and nutritional stability in the country as a whole. Relative to their exploitable attributes, she pointed out that insects are adapted to a wide variety of ecological conditions, and many have high reproductive capacity and short life cycles. Edible insects are not only prominent in the rural markets, but some species command high prices in Mexico City and other urban areas, where they are purchased by people of various economic levels and are sold as delicacies in the restaurants. For example, in 1981, the demand for "escamoles" (immature stages of the ants *Liometopum apiculatum* and *Liometopum occidentale* var. *luctuosum*) was so great that the price per kilogram went up to 1000 pesos (more than $2 at the then-prevailing rate of exchange). The author states that they are best when served fried with

onions and garlic. According to recent newspaper stories, restaurants are now charging as much as $25 per plate for escamoles and also for white "gusanos" or maguey worms (larvae of the skipper butterfly, *Aegiale hesperiaris*).

Digging out the underground nests where escamoles are found is hard work. The nests are regarded as private property and are well cared for. After ants are harvested from the nest (two or three times per year between February and June), the nest is covered with nopal, dried grass, or fresh weeds, in order to maintain an environment suitable for survival and regrowth of the colony (109). People who collect escamoles, escamoleros, can earn more money during the ant season than most rural persons do during the entire year (22a). Although called ant eggs, the escamoles are mainly pupae. They are eaten by all social classes in Mexico and are considered such a special treat that they are the subject of songs, dances, and festivities. According to Ramos-Elorduy & Pino (109), they are exported to the United States, Japan, and elsewhere, and, in 1988, a Mexican company was exporting canned escamoles to Canada, where they sold for $50 (Canadian) per 30-g can.

Husbandry and conservation are practiced relative to the harvest of several other edible species. Stingless bees of the genera *Melipona, Scaptotrigona*, and *Trigona* are cultivated in small clay jars kept near the walls of houses and in small hollowed trunks placed to face east (22a). Both the honey and the brood are utilized. Wasp brood is sold in the market while still in the combs (22a). The nests are collected in nature when there is only a small amount of foundation comb and hung from the roofs of farm homes until they reach a large size. Among the largest combs with edible brood are those of *Polybia occidentalis bohemani*, which may become 1 m in width. Wasp brood, with pepper, either fried or roasted, has the flavor of almonds or walnuts (JRE de Conconi, personal communication). Other hymenopterans include the honey ants (*Myrmecocystus* spp.) and the leafcutter ants (*Atta* spp.). There is no established commerce in these ants, as there are no middlemen, but they are sold in local markets.

Aquatic hemipterans that produce "ahuahutle" or Mexican caviar (five species of Corixidae, one species of Notonectidae) formerly bred in tremendous numbers in the alkaline lakes and have been the basis of aquatic farming for centuries (22a). The bugs and their eggs are harvested by oviposition trap lines. Bundles of shore grass are tied together, weighted with a stone and distributed by canoe. After about three weeks, during which the eggs are laid on the submerged vegetation, the bundles are collected, brought ashore to dry in the sun, and then shaken to remove the eggs. Harvests are now reduced because of lake pollution, but the ahuahutle is still harvested the same way as in the past, sold in many markets, eaten in tortillas with eggs and also in tamales, eaten daily in large restaurants in the capital, and exported to Germany and Great Britain as fish and bird feed (109).

The agave or maguey cactus hosts two important lepidopterans. The larva of the giant skipper butterfly, *Aegiale hesperiaris*, mentioned above and known as gusano blanco de maguey or the white agave or maguey worm, is in high demand by people of all social classes in Mexico. It is processed, canned, and exported to various countries such as the United States, Canada, France, and Japan, where it is sold as gourmet food (109:85–86). Supplies are somewhat reduced now because of over-collection. *Comadia redtenbachi*, known as the pink worm of the maguey, the red agave worm, or gusano rojo de maguey, is sold in the markets and is the larva seen in mezcal bottles. In addition, it is eaten fried in butter or its own fat, eaten in tortillas, cooked in rice soup or in tomato sauce, or roasted and ground with salt and red chile (109). The eggs are laid in groups that are easily seen, and their protection and development is encouraged by placing them in plots of magueys set aside for their production (2). A plant may have 15–30 larvae, and people know that yellow-tipped leaves contain larvae. The larvae move out of their plant sites when it rains and are easily collected (109). A third lepidopteran, *Eucheira socialis* (Pieridae), which feeds on madrone trees, is also the object of husbandry practices (62).

More than 20 species of grasshoppers and locusts are used as food. They are sold widely in village markets, and species of the genus *Sphenarium* are particularly important (22a). They are frequently mixed with onion, garlic, and chili powder, then boiled (during which they turn pinkish-brown in color) and dried in the sun or fried. They generally assume the taste of the condiment with which they are cooked. According to Long (71), methyl parathion, most of it applied by backpack sprayers, was the Mexican government's method of choice in combatting outbreaks occurring in the early 1990s, but grasshopper harvest as food was among alternatives being studied.

de Conconi & Pino (22b) suggested that some plants that are widespread and characteristic of arid regions but of limited food value, such as mezquite, madrone, and some cacti, could be used for cultivation of their associated insects. The insects, as shown by proximate analyses, are many times higher in protein and fat than are the plants on which they feed, with some of the insects (edible stages) ranging above 60% protein or 50% fat on a dry weight basis. The study was conducted in eight counties of the high, semiarid Mezquital Valley (State of Hidalgo), which has long been considered one of the areas of poorest nutrition in Mexico.

Ramos-Elorduy & Pino (110) summarized data from proximate analyses and calculated the energy values of 94 of the insect species used as food. Caloric values for edible stages ranged (dry weight basis) up to 7769 kcal/kg. Excluding pork, soybeans at 4660 kcal/kg was the highest ranking noninsect Mexican food, plant or animal. Maize had a caloric value of 3700 kcal/kg. Of the 94 insect species analyzed, 50% had a higher caloric value than soybeans,

87% were higher than maize, 63% higher than beef, and 70% higher than fish, lentils, and beans. The 5 Lepidoptera species with the highest caloric value averaged 6594 kcal/kg; the 5 highest Coleoptera (beetle grubs), 5964 kcal/kg; the 5 highest Hemiptera (mixed nymphs and adults), 5646 kcal/kg; the 5 highest Hymenoptera, all of which were ants (samples varied from adults to mixtures of immatures), 5361 kcal/kg; while the 5 highest Orthoptera (grasshopper nymphs and adults) averaged 4168 kcal/kg. Only 9 of the species analyzed contained less than 30% protein. Thus, Mexican insects constitute a rich source of both protein and energy. According to Mexican newspapers, there is interest in enriching basic foodstuffs with insect flour.

COLOMBIA The leafcutter ants (*Atta* spp.), known as hormigas culonas or big-bottomed ants, are a national delicacy, equivalent in price and gastronomic value with Russian caviar or French truffles; Contesti (19) stated that the toasted ants constitute the highest attainment of Colombian cookery. Only the alates are eaten, the large females being especially prized. A campesino, by collecting and selling *Atta* ants, can earn during the three-month season the equivalent of a year of day wages. A pound of ants sells for about $20, the equivalent of six days of work at the minimum wage. In addition to local use, some are exported to Japan. Historically, Contesti noted that the conquering Spaniards, after their initial repulsion, soon came to appreciate the ants and tried to monopolize their cultivation. This provoked such grave conflicts with the Indians that the Spaniards finally desisted.

Ruddle (114) found that insects of 7 orders and 22 genera are used by the Yukpa, a Carib tribe along the Colombia-Venezuela border region, as a complementary food source throughout the year. The Yukpa prefer certain insect foods to fresh meat. They are discriminating in their insect choices; although dobsonfly (*Corydalus*) adults are abundant, weak fliers, and easily caught, they are only infrequently used as food. While acculturation was tending to decrease insect use, the reduced availability of game because of forest destruction and a great aversion to consuming recently introduced domestic animals (most of which the Yukpa regarded as pets) were tending to increase it. Thus, despite "the steady encroachment of more modern subsistence systems...insect foods have retained their importance in the less acculturated communities" (p. 94).

Dufour (34) found that the most important insects in the diet of Tukanoans are those that form large, highly predictable aggregations in nature, and their inclusion in the diet is frequent and inversely related to the consumption of fish and game. Based on food-intake records obtained for November–January and May–June, fish was by far the most frequently consumed animal food, and insects were second. Fish also contributed most of the animal protein in the diet, but insects contributed 12% in men's diets and 26% in women's diets during the

May–June record-keeping period. Insects also contributed significant amounts of fat to the diet, 18 and 20% for men and women, respectively, in May–June, and 23 and 7%, respectively, in November–January.

BRAZIL Insects make a valuable contribution to the diet of indigenous populations (70, 84, 103). Posey (106) reported that stingless bees (Meliponinae) are kept by the Kayapó simply because they are keen observors of nature and are fascinated by insect behavior. The Kayapó recognize 56 species of bees, mainly on the basis of ecological niche and behavioral characteristics; 9 species (including 8 species of Meliponinae) are semidomesticated or to some extent manipulated, and the larvae/pupae of 7 species are used as food (104, 105). There is a particularly voluminous literature on the *Atta* ants in Brazil (67:276–82).

THE WESTERN BIAS AGAINST INSECTS

Vincent Holt (56), author of *Why Not Eat Insects*?, was undoubtedly one of the most outspoken critics of the Western bias against insects as food. Holt begins (p. 12) by comparing the clean feeding habits of herbivorous insects to the foul feeding habits of "the lobster, a creature consumed in incredible quantities at all the highest tables in the land." Then (p. 16), "It may require a strong effort of will to reason ourselves out of the stupid prejudices that have stood in our way for ages." Holt called attention to the consumption of insects by the peoples of distant lands, the consumption of cicadas by the Greeks and of "cossus" (cerambycid beetle) grubs by the Romans of yore, and asks (p. 47): "We pride ourselves on our imitation of the Greeks and Romans in their arts; we treasure their dead languages: why not, then, take a hint from their tables?" Finally, he introduces a number of insects in Britain that would be suitable for the table: "What a godsend to housekeepers to discover a new *entrée* to vary the monotony of the present round!" *Why Not Eat Insects*? was recently reprinted by the British Natural History Museum.

Despite the strong public bias against insects as food, numerous Western scholars (including entomologists) have commented on the subject, generally favorably, or at least noted its occurrence: e.g. Aristotle, Pliny the Elder, Reamur, Kirby & Spence, Cuvier, Bequaert, Fabre, among others. Fabre liked to test for himself Greco-Roman dishes and admired the refinement of the Roman gourmets in their appreciation of the cossus. On one occasion, however, after following the published advice of Aristotle in preparing cicada nymphs, but with disappointing results, Fabre resolved never again to try a dish recommended by Aristotle.

Bodenheimer (10), in his classic *Insects as Human Food*, summarized the pertinent writings of the early scholars and gathered the scattered reports

of insect consumption in France, Germany, Italy, and elsewhere in Europe (pp. 39–69). Particularly numerous in the older literature from the Continent are recipes for May beetle larvae or cockchafers. Bias against insect fare may have been stronger among the British and Americans than among other Westerners, especially the French. Freeman (42:524) described an amusing incident involving French troops on American soil:

> One of the commissioners named above related to the writer that, when on this service at West Point, the attention of the commissioners was arrested by certain inexplicable movements among the French troops encamped at some distance from the American. Perceiving that they had kindled numerous fires in the adjoining fields, and were running about in strange disorder, Maj. Osgood...accompanied by Gen. Washington and other officers, mounted horses and rode to the encampment. It was found that the Frenchmen were enjoying rare sport in a campaign against the grasshoppers which were unusually numerous at that time. These insects, as soon as captured, were impaled upon a sharpened stick or fork and held for a moment over the fire and then eaten with great *gusto*.

Several of the early pioneers of American economic entomology, among them AS Packard, CV Riley, and LO Howard, had a strong interest in the potential of insects as food. Their awareness of the deep American bias is evident in their writings. In 1876, Riley (112:145) wrote of the Rocky Mountain locust, *Melanoplus spretus* (which is believed to be a swarming phase of *Melanoplus sanguinipes*):

> It had long been a desire with me to test the value of this species (*spretus*) as food, and I did not lose the opportunity to gratify that desire, which the recent locust invasion into some of the Mississippi Valley States offered. I knew well enough that the attempt would provoke to ridicule and mirth, or even disgust, the vast majority of our people, unaccustomed to anything of the sort, and associating with the word insect or 'bug' everything horrid and repulsive. Yet I was governed by weightier reasons than mere curiosity; for many a family in Kansas and Nebraska was last year [1874] brought to the brink of the grave by sheer lack of food, while the St. Louis papers reported cases of actual death from starvation in some sections of Missouri, where the insects abounded and ate up every green thing the past Spring.

On many occasions, and seemingly unafraid of confronting prejudice, Riley experimented with various ways of preparing locusts as food (112:146):

> I shall not soon forget the experience of my first culinary effort in this line—so fraught with fun and so forcibly illustrating the power of example in overcoming prejudice. This attempt was made at an hotel. At first it was impossible to get any assistance from the followers of the *ars coquinaria*. They could not more flatly have refused to touch, taste or handle, had it been a question of cooking vipers.... There was no other recourse than to turn cook myself, and operations once commenced, the interest and aid of a brother naturalist and two intelligent ladies were soon enlisted. It was most amusing to note how, as the rather savory and pleasant odor went up from the cooking dishes, the expression of horror and disgust gradually vanished from the faces of the curious lookers-on, and how, at last the head-cook...took part in the operations; how, when the different dishes were neatly served upon the table and were

> freely partaken of with evident relish and many expressions of surprise and satisfaction by the ladies and gentlemen interested, this same cook was actually induced to try them and soon grew eloquent in their favor; how, finally, a prominent banker, as also one of the editors of the town joined in the meal. The soup soon vanished and banished silly prejudice; then cakes with batter enough to hold the locusts together disappeared and were pronounced good; then baked locusts with or without condiments; and when the meal was completed with dessert of baked locusts and honey *a la* John the Baptist, the opinion was unanimous that that distinguished prophet no longer deserved our sympathy, and that he had not fared badly on his diet in the wilderness....

Howard (57), aware of Riley's work on locusts and cicadas, lamented that there had been very little work on the edibility of insects, and reported the results of tests conducted at his suggestion by JJ Davis and DG Tower at Lafayette, Indiana, on the eggs and larvae of *Phyllophaga* (=*Lachnosterna*) (May or June beetles). The eggs, fried in butter, were excellent, with a taste much like bacon. The larvae, also fried in butter and eaten with bread as a sandwich, were found to have a fresh fatty taste. Howard stated, "This line of experimentation seems to me very well worth while, and field agents having the opportunity and disposition are urged to experiment in this direction when it can be done easily and without loss of time." The statement suggests that Howard was acutely aware of how taxpayers would view such research by a government agency.

Howard (58) suggested that, with many nations facing food shortages because of war conditions, it was a propitious time to consider new and cheap food supplies. He noted that although there is an extensive literature on the historical use of insects as food, there had been little modern experimental work (p. 389): "These facts point out the desirability of just such experiments, and practically all our colleges of agriculture, with their departments of home economics and of entomology, are in excellent position to do just this work." Howard described a salad and a broth prepared by Dr. CF Langworthy, Chief of the Office of Home Economics, US Department of Agriculture, from *Phyllophaga* larvae shipped from Madison, Wisconsin, by Davis and Professor JG Sanders. The informal taste panel assembled included, in addition to Howard, CH Popenoe, WB Wood, FH Chittenden, EB O'Leary, RC Althouse, WR Walton, CE Wolfe, and Herbert S Barber of the Bureau of Entomology and Vernon Bailey of the Bureau of Biological Survey.

A short time later, as Howard reports, Davis collected a sample of *Phyllophaga* grubs in Lafayette, Indiana, more than 100 of which were sent to Washington and the remainder of which were made into a stew, which Davis and his colleagues, Fenton and Mason, pronounced as delicious. The scene is described by Howard (58:391):

> They prepared the grubs as they thought oyster stew was prepared, and of course ate the grubs as well as the broth. Mr. Mason thought it tasted very much like boiled crab meat and not much different from lobster. Mr. Fenton thought that it tasted much like lobster, but had not

> eaten crab and so was not in a position to judge whether they were more like the latter. Mr. Davis had never eaten either fresh crab or lobster, but thought that they had a decided seafood taste. All thought it 'agreeable' and 'were sorry when it was all gone.'

From Harvard University, Bequaert (8:191) commented on the suggestion by Howard that the food value of insects should be ascertained: "Favorable as the results may have proved, one can well imagine the storm of protest that would have resulted had the adoption of such a program by the general public been advocated."

Vane-Wright (128:2) stated that "the very fact that eating insects belongs to the hunter-gatherer stage of human evolution may be a major factor in their rejection by western people; we may unconsciously reject entomophagy as primitive." Left unexplained, however, is why insects, which were so important to hunter/gatherers in most of Africa, Asia, and the Americas, were not brought under domestication along with plants and animals as agriculture developed. It may be that insects were not competitive as food items because the agriculture that initially spread to Europe originated mainly in the Fertile Crescent of the Middle East, where crops such as wheat, barley, and various legumes among others and sheep, goats, pigs, and cattle were first domesticated. Insects were of minor food importance in the Middle East, restricted mainly to locusts and a few "manna"-producing species of Homoptera. Not surprisingly, given the location, no insects were domesticated specifically for food use with the exception of bees for honey production. Thus, as plant and animal agriculture gradually developed greater productivity and efficiency and spread westward through Europe, establishing dependable supplies of those foods and leading to more sedentary human populations and increasingly larger settlements, insects gradually disappeared as a staple because of continued unpredictability of supply. Further, it seems likely that as more and more crops became widely dispersed from their centers of domestication and less reliance was placed on wild foods of all kinds, insects were less frequently encountered as food and increasingly viewed primarily as threats to the efficient production of crops and livestock. Later, the spread of European civilization resulted in a reduction of diversity. Gelfand (43:1–7) notes that British experts, in addressing problems of nutritional inadequacy in Africa, were apt to condemn outright traditional foods while favoring a European-style meal; the adverse impact of both colonialism and modern transnational corporate agriculture in supplying a reasonable diet for smallholder farmers, landless laborers, and other poorer segments of Third World populations has been well documented (41, 51, 113). As discussed by Féron (39:234):

> The useful species were those over which the winners of the larger slices of the planet had the most knowledge and control. These were a handful of herbivores. The useless were all the others! The latter would have to make room for the former in the name of 'development.'

Considering their efficiency in converting plant biomass to animal biomass, the failure to domesticate edible insects on any significant scale (except as a byproduct of silk and honey production) may have been a greater calamity in the global development of agriculture than we yet realize.

FUTURE NEEDS AND SIGNS OF PROGRESS

The primary need is to eliminate or greatly reduce the Western-driven stigma that has been cast over the use of insects as food, thus providing opportunities for more research on large- and small-scale mass production, more efficient harvest of wild populations, and optimization of ecological benefits and the nutritional complementarity of insects with other locally produced foods. There are indications that progress is being made and that Westerners are becoming more comfortable with the subject. There recently has been much more exposure in the Western mass media , and it is much more favorable than formerly.

Public reeducation is also being advanced by a proliferation of public events featuring or including edible insects, such as open houses or field days sponsored by zoos, nature centers, state fairs, museums, universities, and professional societies. Details on such events, many of which are held annually, can be found in the pages of *The Food Insects Newsletter*, which began publication in 1988 and has proven valuable as an international forum and networking mechanism for researchers, educators, and others having an interest in the subject. While the public information advances are important, even more important is the apparent foothold that the subject is gaining in the US educational system. As editor of the *Newsletter* for its first eight years, I received hundreds of contacts from teachers and students, elementary to university levels, indicating greatly expanding coverage of the concept in US classrooms. Entomology textbooks and books written in a more popular vein, including very recent ones (9, 48), continue to devote space to a discussion of entomophagy. In Europe, Comby's (16) *Délicieux Insectes* sold so well that German and Italian translations have been published.

Insect snacks known as Larvets and insect-imbedded lollipops are now manufactured and sold by a US company, Hotlix in Pizmo Beach, California. For Americans wanting recipes, cookbooks are available, including the attractive *Entertaining with Insects* by Taylor & Carter (124), which was long out of print but recently reprinted. Commercially grown edible insects include mealworms (*Tenebrio molitor*), crickets (*Acheta domesticus*), and waxmoth larvae (*Galleria mellonella*). Field guides or supplements to existing field guides are needed for use by those with little or no entomological background who want to collect edible insects in the wild. The more than 60 species of insects that were used as food by Native American tribes serve to identify genera of interest. Grasshoppers, Mormon crickets (*Anabrus simplex*), and certain coleopterous,

dipterous, and lepidopterous larvae were among the most important wild foods, especially of tribes in western North America (24, 36, 123). The protein quality of *A. simplex*, a tettigoniid, is equivalent to that of soy protein when fed to weanling rats (40), and that of the true cricket, *Acheta domesticus*, superior to soy protein at all levels of intake. The wild foods of the Native Americans could provide the inspiration for development of an American equivalent of "bush tucker" in Australia.

Another avenue by which Americans may gain increasing exposure to edible insects is via importation of ethnic or regional foods: At least two insects are now found in Asian food shops in the United States, the giant water bug (*Lethocerus indicus*) from Thailand (99) and canned silkworm pupae (*B. mori*) from South Korea.

The rising profile of food insects within the scientific community is indicated by their inclusion in such recent international gatherings as the *Seminar on Invertebrates (Minilivestock) Farming* held in La Union, Philippines, in November 1992; the *International Symposium on Biodiversity in Agriculture for a Sustainable Future*, held in Beijing, China, in September 1995; and the Africa-wide *Exhibition on Indigenous Food Technologies*, held in Nairobi, Kenya, in December 1995. At the symposium in China, almost one third of the papers presented were devoted to edible insects. As minilivestock (7, 44, 49, 50), insects are ideally suited for a leading role (26, 28). They offer all of the features of small size deemed desirable and have a distinct advantage over warm-blooded minilivestock. Whereas the latter must spend large amounts of energy and nutrients in maintaining constant body temperatures, insects are poikilothermic and more efficient in transforming plant biomass into animal biomass (68). When fed the high-quality diets used to bring conventional livestock to market condition, the food conversion efficiency of the cricket, *A. domesticus*, is many times higher than that of beef cattle, with the cricket having not only a higher efficiency of conversion of ingested food (ECI), but higher fecundity (1200–1500 offspring per female cricket) (90). In addition, some insects may prove suitable for industrial-scale mass production (63).

The increasingly frequent mention of the food importance of insects by authors addressing other aspects of entomology is indicative of widening awareness. Weissling & Giblin-Davis (131), for example, whose work in Florida on developing artificial diets for *Rhynchophorus cruentatus* was motivated by its vector potential, stated in passing (p. 9), "The culture of *R. cruentatus* on artificial diets could be a potential advancement in developing a niche for consumption of our indigenous species by palm weevil gourmets or feeding burrowing owls in captivity." And Howarth (53) noted: "Classical biological control may be an inappropriate technology in some Third World countries" because insects may provide 10% or more of the protein source. "Alien entomophages or entomopathogens could significantly reduce local food resources."

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