Six-legged livestock:

edible insect farming, collecting and marketing in Thailand

Yupa Hanboonsong
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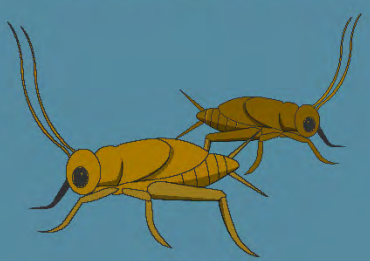
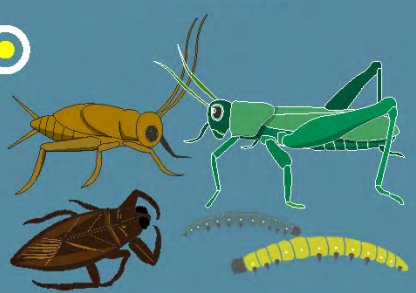
bamboo caterpillars



crickets



various insects

palm weevil larvae

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Foreword

By 2050, the world's population is expected to surpass 9 billion people, adding more than 2 billion individuals to an already crowded planet. Coupled with expanding economic wealth and purchasing power, FAO estimates indicate that global food production will need to expand by an estimated 60 percent from current levels to meet global food requirements in 2050.

Meeting this massive additional demand for food will require concerted action on a number of fronts. While substantially increasing yields and cropping intensities of major cereal crops is an obvious need, efforts will also have to focus on increasing the production and consumption of currently under-utilized and under-appreciated foods. Many of these foods currently lack recognition and appreciation of their potential to contribute to food security; the increased consumption of others is variously constrained by production, processing and trade constraints and challenges.

Edible insects comprise one such category of under-utilized foods that offer significant potential to contribute to meeting future global food demands. Although widely reviled in European and North American society and media, more than 1 600 species of insects are documented as being consumed by humans. Insects traditionally were an integral element of human diets in nearly 100 countries of the world – particularly in Asia and the Pacific, Africa and Latin America (Durst *et al*. 2010).

Insects offer several advantages as human food. Insects are extremely rich in protein, vitamins and minerals, and at the same time are highly efficient in converting the food they eat into material that can be consumed by humans. These high food-conversion efficiencies – up to six times more efficient than beef cattle – coupled with other physiological advantages mean that insects consumed as human food have a far less negative impact on the environment, including greenhouse gas emissions, than conventional livestock. Insects are typically collected from wild habitats or farmed by small-scale producers, thus generating significant income and employment opportunities for rural households.

Like many people throughout Asia and the Pacific, Thai people have a long history and tradition of consuming insects as food. But while the consumption of insects by humans has declined in many areas (due in part to the negative portrayal of the practice in Western media), consumption of insects in Thailand

remains widespread and has actually increased dramatically in recent decades, above historical levels. Insects are clearly a "food of choice" for Thai people, reflected by sustained and growing consumer demand and high market prices paid for edible insects – typically far higher than the price of chicken, beef or pork.

Thailand is also one of the few countries in the world to have developed a viable and thriving insect farming sector. More than 20 000 insect farming enterprises are now registered in the country, most of which are small-scale household operations. Insect farming has emerged as a significant economic activity in Thailand only in the past two decades, driven by strong market demand and effectively supported by university research and extension, and innovative private-sector food processors and sellers. Overall, insect farming, collection, processing, transport and marketing has emerged as a multi-million dollar sector, providing income and employment for tens of thousands of Thai people, and healthy and nutritious food for millions of consumers.

To better understand the phenomenal development and evolution of the Thai edible insect sector, the FAO Regional Office for Asia and the Pacific collaborated with Khon Kaen University to review and assess the trends, current status and practices of insect collection and farming, processing, marketing and trade in the country. *Six-legged livestock: edible insect farming, collection and marketing in Thailand* is the result of that review and assessment, which included nation-wide surveys and interviews with farmers, collectors, processors, and sellers of edible insects at all levels.

It is hoped that by making this information about the thriving Thai edible insect industry accessible and more widely known, others in the region and throughout the world will more fully recognize the potential of edible insects to contribute to food security and nutrition in a sustainable sound manner, increase rural income and livelihoods, and reduce the environmental burden of feeding the growing world population.

FAO encourages other countries to consider the Thai experience and stands ready to facilitate the further exchange of information and technology related to this exciting, but under-appreciated, opportunity to build upon the rich traditions and cultures of eating insects while expanding the options for enhancing food security.

Hiroyuki Konuma
Assistant Director-General and
Regional Representative

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Contents

Executive summary

Eating and selling edible insects are common activities in Thailand where they are harvested in the wild or farmed (cricket farming was introduced to farmers in the northeast more than 15 years ago). However, information remains scant on their current status and on production, technology development, market channels and business ventures as well as future opportunities. This survey analysed the relevant literature and conducted a preliminary quantitative survey of edible insect farming, wild harvesting as well as business and marketing practices. Farmers, collectors and other people involved in the edible insect sector from 26 provinces in the northern, northeastern, central and southern regions were interviewed.

Two types of edible insects (cricket and palm weevil larvae) are commonly farmed in the north and south respectively. Cricket-farming approaches throughout the northeast are similar and breeding techniques have not changed much since the technology was introduced 15 years ago. Small-scale cricket farming, involving a small number of breeding tanks, is rarely found today and most of the farms are medium- or large-scale enterprises. Community cooperatives of cricket farmers have been established to disseminate information on technical farming, marketing and business issues, particularly in northeastern and northern Thailand.

Cricket farming has developed into a significant animal husbandry sector and is the main source of income for a number of farmers. Currently there are approximately 20 000 farms operating 217 529 rearing pens. Total production over the last six years (1996-2011) has averaged around 7 500 tonnes per year.

Palm weevil larvae farming is found mainly in Southeast Thailand. These farms cannot be expanded into other regions owing to the lack of specific food sources such as sago palm trees or lan phru trees. Palm weevil larvae are popular food items among people in the south.

Weaver ants, bamboo caterpillars and grasshoppers are the most popular edible insects collected from the wild and are harvested seasonally. Bamboo caterpillars are mainly collected in the north. Sustainable harvesting, without cutting of bamboo trees, is carried out by local people. Weaver ants are predominantly

found in the northeast. Some farmers maintain weaver ant colonies in their own gardens for breeding purposes.

Market channels and business practices for edible insects are diverse and there is still high domestic demand. Some species, such as grasshoppers and giant water bugs, are imported from neighbouring countries. Local markets, wholesale supermarkets and minimarts are all retail outlets. Edible insect products are not only sold precooked by street vendors but can now be purchased, uncooked, in frozen packages from supermarkets.

The edible insect sector in Thailand has progressed rapidly despite the absence of information about best farming practices, product development and optimum marketing channels. Farmers who currently rear insects commercially are starting to experience problems related to management practices that need to be addressed by researchers. In addition, farmers receive little support from extension workers due to the dearth of experience and technical information on farming insects. There is an urgent need to channel funds into research for this growing industry to ensure best practices and sustainable production are achieved.

As insect farming is promoted and management techniques are developed and adopted, less collection of wild insects will occur. This will take pressure off wild populations, which are already diminishing for some species in various regions. However, some species are not receptive to farming and sustainable harvesting protocols are warranted.

Introduction

Thailand is well known for consumption and retail of edible insects. In the past, the tradition of eating insects occurred mainly in northern and northeastern regions. Nowadays this habit has increased in popularity and has expanded nationwide. Edible insects are no longer perceived as food for poor or rural people, indeed urbanites – even high income earners – now consume them. It has been reported that almost 200 edible insect species are eaten in Thailand (Anon n.d.; Klinhom *et al*. 1984; Leksawasdi 2001; Mongkolvai *et al*. 2009). However, only a few insect species, such as bamboo caterpillars (*Omphisa fuscidentalis*), house crickets (*Acheta domesticus*), giant water bugs (*Lethocerus indicus*) and grasshoppers are predominantly consumed and sold regularly in markets (FAO 1983; Nutrition Division 1992). Many species of edible insects are still collected from the wild and can be bought in markets seasonally. In addition, house crickets and palm weevils (*Rhynchophorus ferrugineus*) have been farmed successfully in many provinces of the northeast and south respectively using simple technologies since the mid-1990s. Currently insect farming is spreading in these regions, where it is contributing to household income generation.

Objective

The objective of this publication aimed to compile updated data on insect farming (technical and management aspects) and wild harvesting as well as new information on marketing channels from primary and secondary sources.

Data collection

The primary and secondary sources revealed information on insects most commonly marketed and consumed in Thailand, current farming and

rearing practices for predominant edible insect species, socio-economic aspects of insect farming and wild harvesting, farming and harvesting seasons, processing activities as well as current marketing channels.

The secondary data were obtained from published research articles and reports on edible insects in Thailand. The primary data were obtained from in-depth interviews with farmers, collectors and entrepreneurs in the edible insect sector. This survey only focused on the popular and common edible insect species eaten in Thailand; house crickets, palm weevils, bamboo caterpillars, weaver ants, grasshoppers and giant water bugs. It was undertaken in 26 provinces in northern, northeastern, central and southern regions of Thailand. Sixty farmers and 12 farmer groups from 17 provinces in the northeast were interviewed about issues related to cricket farming. Seven farmers from four provinces in the south were interviewed about palm weevil farming. Twenty collectors from the north and northeast and 12 entrepreneurs and distributors of edible insects in Kalasin, Rong Kluea, Klong Toey, Jatujak and Talad Thai markets were also interviewed.

The interviews were conducted either (1) from the farm to the market (edible insect farmers/collectors, followed by market vendors and others associated with retail) or (2) from the retail business end back to the insect farmers/collectors (Figure 1).

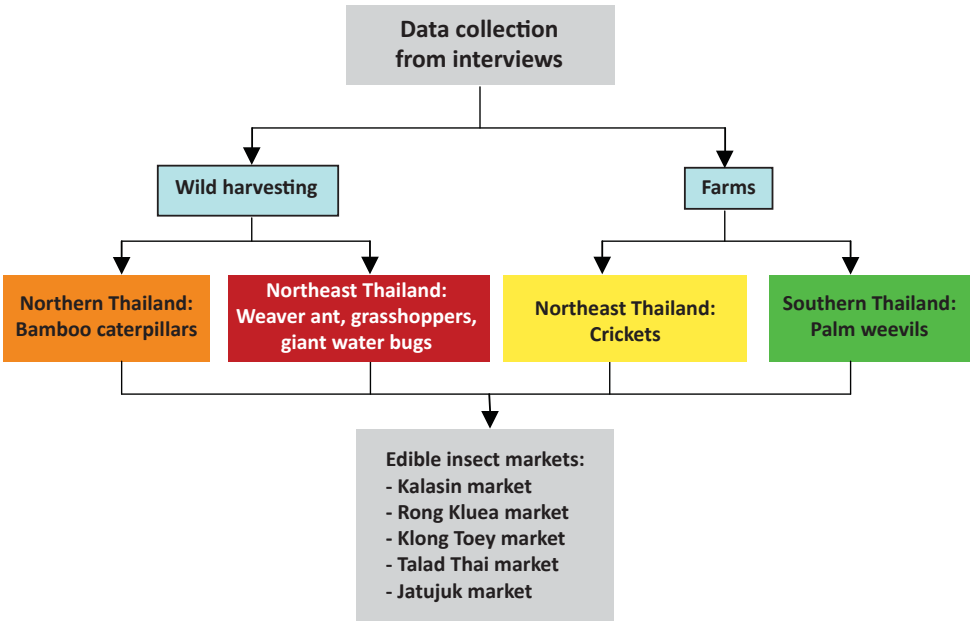

Figure 1. Information collection flow in the study

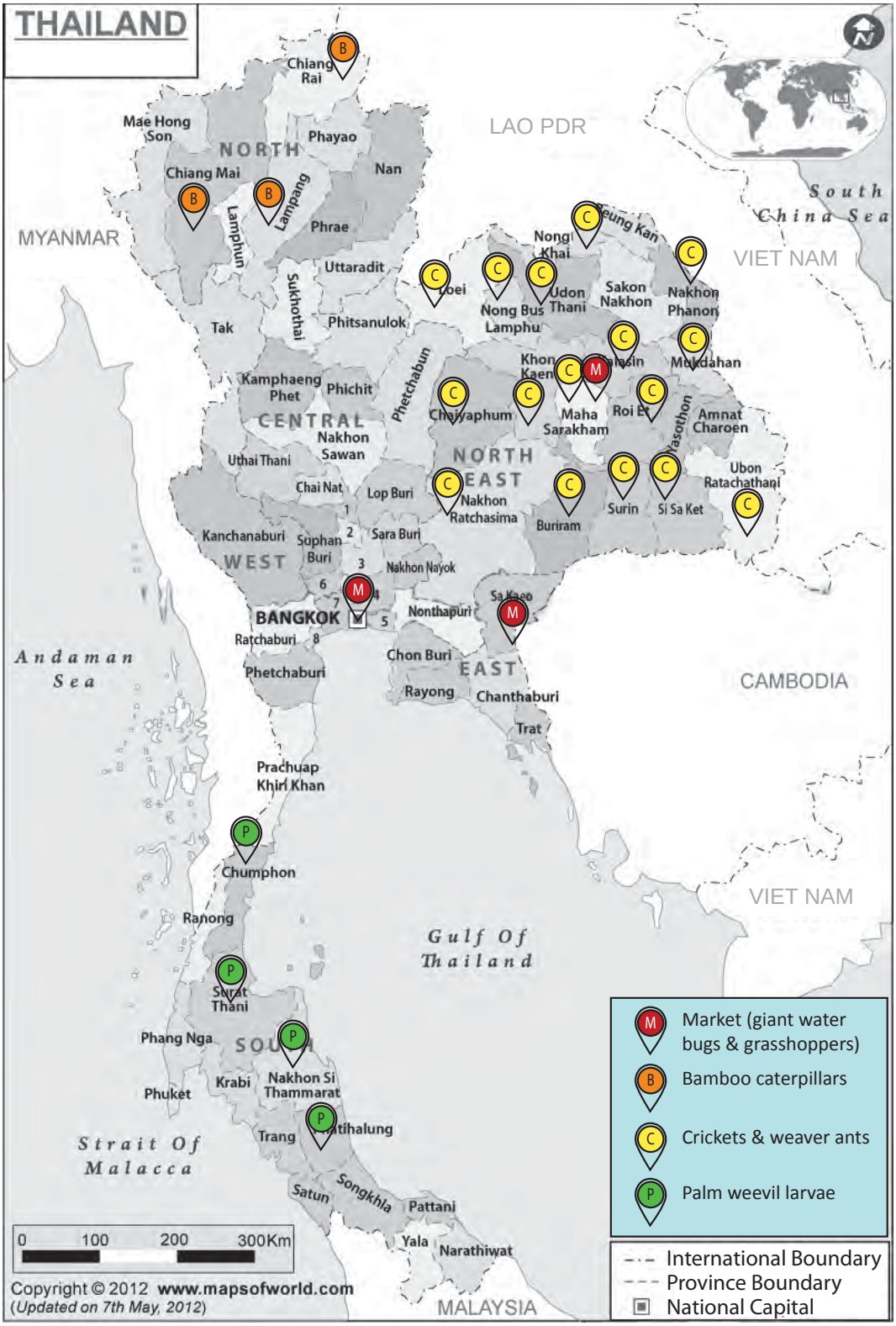

Figure 2. Survey sites in Thailand from January to June 2011

Edible insect consumption

Insects are a good source of nutrients and are comparable to conventional animal sources with high protein content. In general, insects can supply protein (20-70 percent of raw protein), amino acids (30-60 percent), fats (10-50 percent), minerals and vitamins important for human health. Insects are especially rich in phosphorus, potassium, iron, copper, zinc, manganese, sodium, vitamin B1 and B2 and niacin (Nutrition Division 1992). Nutritional values vary according to the species and how they are prepared for consumption. Several studies have established reference nutritional values for various edible insect species (Klinhom *et al*. 1984; Lewvanich *et al*. 1999; Lumsa-ad 2001; Sungpuang and Puwastien 1983).

Almost 200 edible insect species are consumed in Thailand. Over 150 species from eight insect orders (Appendix 1) are eaten in the northeast (Hanboonsong *et al*. 2001). Approximately 50 insect species are consumed in the north and about 14 species are eaten in the south (Lewvanich *et al*. 1999; Lumsa-ad 2001, Appendix 2). The different insect-eating habits in various regions may depend on cultural practices, religion or the availability of different insect species in different regions. The northeast has a harsher environment, with less fertile soils and frequent droughts or floods. As local people live in close proximity to nature, natural foods like insects, which are easy to find and harvest, are an integral part of their lives and culture.

Eating insects is no longer perceived as a habit among poor or rural people. Urbanites, even high income earners, also consume them. People eat insects not only for their nutritional content, but also because of their palatability (Hanboonsong *et al*. 2001).

Although many insect species are eaten by Thai people, some insects are consumed only in particular geographic areas, while others such as the giant water bug and grasshoppers are eaten nationwide. Beetles constitute the largest species group of edible insects. The giant water bug is the most popular edible insect in northern Thailand. Predaceous diving beetles, water scavenger beetles and immature weaver ants are also eaten widely in the country (Hanboonsong *et al*. 2001; Lewvanich *et al*. 1999). Bamboo caterpillars and crickets are popular in the north. Wasps, bees and palm weevil larvae are well-known edible insects in the south (Lumsa-ad 2001). Observation surveys of food carts carrying popular edible insects in Khon

Kaen found that house crickets, bamboo caterpillars, silkworm pupae (*Bombyx mori*) and grasshoppers were commonly eaten. The market retail price of deep-fried insects is around THB20-30/100 grams.[1]

Insects most commonly marketed and consumed in Thailand come from both wild-harvested and farmed sources (Table 1). Farmed insects such as crickets and silkworm pupae can be purchased throughout the year while wild-harvested species such as grasshoppers and weaver ants occur seasonally.

Table 1. Insects most commonly marketed and consumed in Thailand

Common name	Scientific name	Seasonal occurrence	Wholesale price/kg (THB) fresh
Bombay locust	*Patanga succincta* L.	August-October	220-250
Oriental migratory locust	*Locusta migratoria manilensis* (Meyen)	June-July	220-250
Domestic house cricket	*Acheta domesticus* L.	All year (from farmed sources)	80-100
Common/field cricket	*Gryllus bimaculatus* De Geer	All year (from farmed & harvested sources)	100-120
Common/field cricket	*Teloegryllus testaceus* Walker	All year (from farmed & harvested sources)	100-120
Mole cricket	*Gryllotalpa africana* Beauvois	May-July	150
Short-tailed cricket	*Brachytrupes portentosus* Licht	October-November	120
Giant water bug	*Lethocerus indicus* Lep.Serv.	July-October	10 (male) 8 (female)
Predaceous diving beetle	*Cybister limbatus* F.	July-October	120-140
Water scavenger beetle	*Hydrous cavistanum* Bedel	July-October	120-140
Bamboo caterpillar	*Omphisa fuscidenttalis* Hampson	Aug-Nov	300
Silkworm pupae	*Bombyx mori* L.	All year (from farmed sources)	120
Scarab beetle	*Holotrichia sp.*	May-August	150
Red ant/weaver ant	*Oecophylla smaragdina* F.	March-May	300
Palm weevil larvae	*Rhynchophorus ferrugineus* Oliver	All year (from farmed sources)	250-300

1US$1.00 = THB30.00 approx. (March 2013).

Figure 3. Commonly marketed and consumed edible insects in Thailand: (a) grasshoppers, (b) bamboo caterpillars, (c) house crickets, (d) weaver ants, (e) silkworm pupae and (f) water scavenger beetles

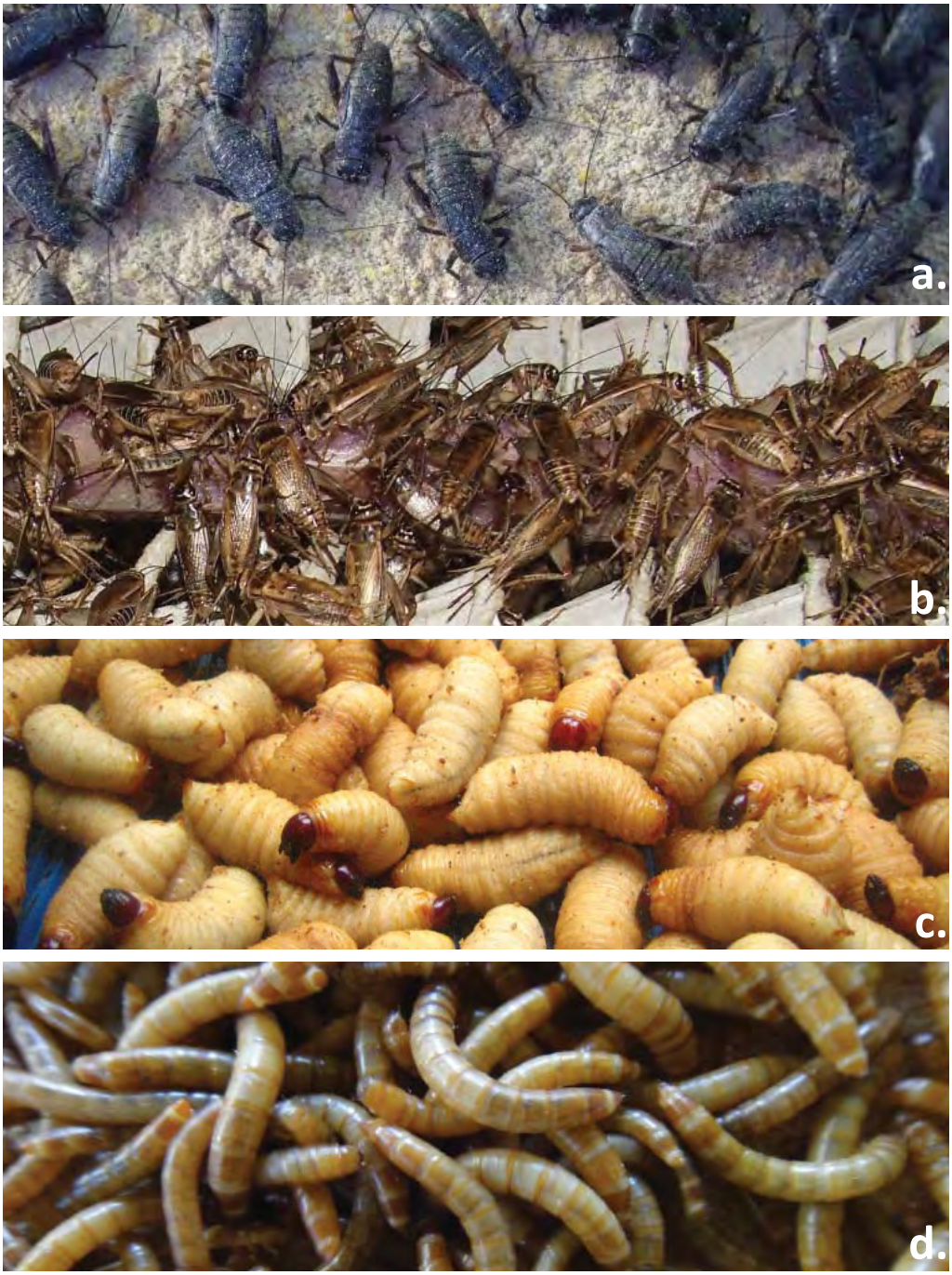

Figure 4. Commonly farmed species: (a) common cricket, (b) house cricket, (c) palm weevil larvae and (d) mealworm (*Tenebrio molitor*)

Farmed edible insects

In the past all edible insect species were harvested in the wild, but today farming techniques have been developed for some species. House crickets, palm weevils and mealworms are successfully farmed in Thailand. House crickets and palm weevil larvae are used mainly for human consumption, while mealworms are commonly used as pet food (for fish, birds and geckoes or lizards).

For this publication two species that are farmed (house crickets and palm weevils) were surveyed in the northeast and south of Thailand.

Cricket farming

Cricket farming in Thailand was initially started in 1998. The farming technology was developed by entomologists at Khon Kaen University in the northeast. The technology was then disseminated to interested farmers nationwide, mainly from northeastern provinces, through training courses. In order to promote public awareness of cricket farming, including their consumption and to stimulate the market demand for crickets, many related activities were undertaken. One example is the introduction of small-scale cricket farms to students at primary schools. This activity not only provided education by integrating cricket-farming activities with extracurricular subjects, but also produced additional protein for the school lunch programme. These integrated cricket-breeding lessons at the school level were quite successful and the students enjoyed the cricket farms at their schools. Cricket cooking fairs and competitions were also organized occasionally for public awareness promotion.

When cricket farming started, around 22 340 cricket farmers were recorded. Since then, the number of farmers has declined by about 10 percent to around 20 000 in 2011. Cricket production in Thailand was approximately 6 523 tonnes in 2006 but increased to 7 500 tonnes in the last five years despite the slight reduction in farmers (Sanewong Na Ayudtaya 2011).

At the start of technology development for cricket farming in the northeast, three common cricket species (*Gryllus bimaculatus* DeGeer, *Teleogryllus testaceus* Walker and *T. occipitalis* (Serville)) all native to Thailand, especially in the northeast, were introduced to farmers. However, a few years later, the house cricket or '*Sading*' (*Acheta domesticus* L.) was introduced to replace the native crickets and is now commonly farmed in the northeast and other parts of Thailand. House crickets were introduced to Thailand from temperate regions in Europe and the United States. Farmers prefer to breed house crickets rather than native cricket species even though the period of development from egg to adult of the two cricket species is similar (45 to 60 days). The main reason is because house crickets have a better taste, particularly the females owing to the large number of eggs inside their abdomens; the eggs are delightfully crunchy.

Farming practices have changed over 15 years to suit farmers' circumstances. The following sections describe common methods, feeding and farming techniques, marketing approaches and other relevant details.

Breeding containers

Four types of breeding containers are found in cricket farms. The advantages and constraints of each type of container are discussed below.

Concrete cylinder pens: Concrete cylinders, usually employed for water drainage, are approximately 80 centimetres in diameter and 50 centimetres high. They can produce around 2 to 4 kilograms of crickets. They are inexpensive, easy to maintain and suitable for small- and medium-size farms. One person can easily take care of 20 to 30 units. The number of units per farm ranges from 20 to 150 pens. However, they cannot be moved easily and need considerable space.

Concrete block pens: Concrete pens have become quite popular and are commonly found on many farms. They are rectangular and interconnected. The sizes vary depending on space availability; 1.2 x 2.4 x 0.6 metres is common. The number of blocks varies from 5 to 100 per farm. Each pen can produce 25 to 30 kilograms of crickets. They are suitable for medium- and large-scale farms. The rectangular shape is an efficient way of using space. But there is risk of disease outbreak or overheating as the cricket population is always crowded. If one colony is infected by disease or any

pests such as mites, this can easily spread and wipe out the whole farm.

Plywood boxes: These boxes resemble the concrete blocks and are usually made from plywood or gypsum board. They are about 1.2 x 2.4 x 0.5 metres in size and produce 20 to 30 kilograms of crickets. The bottom section is elevated off the ground by four 15-20 centimetre-high legs, so the unit is movable. It is easy to clean and does not build up as much heat as the concrete block pens. However, the boxes are less durable than the concrete blocks. Moreover, plywood is sensitive to hot, cold or damp weather conditions that cause deterioration.

Plastic drawers: These are made from plastic sheets. Each drawer is square and around 0.8 x 1.8 x 0.3 metres in size. A set of three to four drawers is stacked on a shelf ('condo' containers) and can produce 6 to 8 kilograms of crickets. They need very little space and are suitable for small- and medium-size farms. They are easy to look after and can be moved. But plastic deteriorates and needs replacing. Furthermore, crickets stored in the top drawers have a high mortality rate due to overheating. This type of container is commonly used in the southern part of the northeast region such as Buri Ram, Sisaket and Ubon Ratchatani Provinces.

Insect feed

Commercial high protein animal feed, particularly chicken feed, is widely used in cricket farming. Chicken feed with 14 or 21 percent protein content is widely used. The 21 percent protein feed is used for feeding crickets after hatching until they are 20 days old. Subsequently they are fed with mixed 14 and 21 percent protein feed until harvesting at 45 days old. A few days before harvesting, the high protein feed is replaced with vegetables such as pumpkins, cassava leaves, morning glory leaves and watermelons. This is to improve taste and to reduce use of the more expensive protein feed.

Farming techniques

Cricket-breeding techniques have not changed much since they were first introduced. House crickets are bred in the various containers described, sometimes with mosquito nets to keep crickets in and predators out. The bedding is often made from a layer of rice husks but some breeders do not use any material. Cardboard egg cartons can be used. As soon as the male crickets stridulate, bowls containing a mixture of husk and sand are placed in the breeding enclosure in which females can lay eggs (within 24 hours); egg-laying duration is seven to fourteen days. Daily, the bowls are moved to another breeding tank for

incubation and hatching, usually after about seven to ten days, in a stable temperature. This reproduction cycle can be repeated one to three times for each generation. After the mating period occurs (between days 40 to 45 of the life cycle in normal climatic conditions) the crickets can be collected. Eggs to start a cricket farm can be bought from other cricket farmers who sell them at THB50/bowl, or by catching adult male and female crickets from the wild and keeping them in a closed container with bowls containing a mixture of husk and sand for egg-laying purposes. The number of egg bowls needed to begin a cricket farm will depend on how many pens and the size of pens involved; for example 35 egg bowls for one concrete breeding container of 2.2 x 4.8 x 0.6 metres. One egg bowl can produce 3 kilograms of adult crickets.

Cricket farmers

When cricket farming was first introduced, it was estimated that there were over 22 000 cricket farms scattered throughout the northeast; most farms were small with one to ten concrete breeding containers. Today cricket farming has become a small and medium enterprise. Farms can have up to 150 concrete cylinders with production of 450 to 750 kilograms at each harvesting cycle (45 days); crickets are retailed at THB 110-150/kilogram. Cricket farming no longer serves as a source of additional income for these farmers because it has become the primary income source. However, some farmers still grow rice and other field crops for their own food security. It was noticed that 60 percent of cricket breeders in the northeast were women. Usually one or two people can take care of a cricket farm, large or small. A large farm will have about 60 to 80 breeding containers (2.5 x 8 x 0.5 metres) with about two to three hours of labour needed every day to feed and take care of the cricket colonies.

Farming nurseries

As cricket farming has become more commercial, the breeding nursery for crickets has changed from a simple area where cricket colonies were kept under the house, to a special farm or nursery pen. The breeding nursery is now a separate area apart from the farmer's house. Nursery sizes vary depending on the farm size and in some cases are 5 x 10 metres in size. Some farmers have even converted their cattle nursery areas into cricket farms.

Production cost, profit and marketing

Three kinds of products (mature crickets, cricket eggs and fertilizer from waste produced from the cricket farms) can be sold. However, the main product is the adult cricket. Cricket breeders usually sell their crickets through wholesale buyers who supply market vendors or restaurants, and sometimes directly to local consumers or to gecko or fish breeders for feed (Figure 8).

The production cost for each harvesting cycle comes from fixed costs such as the breeding nursery, materials (egg cartons, plastic bottles, tape) and variable costs (cricket eggs and cricket feed). The main cost (about two-thirds of the production cost) is cricket feed, which usually is high protein chicken feed obtained from various commercial sources. The net profit for each harvesting cycle is about 50 percent of the gross income if farmers sell directly to wholesale buyers. However, farmers can earn more profit if they sell their products directly to retailers (Table 2 to 7). Therefore, farmers can reduce production costs, particularly for cricket feed, by using the appropriate ratio of protein feed (21 percent protein feed is more expensive than 14 percent protein feed) to suit cricket growth development. In addition, a supplementary diet using vegetables can result in a reduction in the amount of commercial chicken feed required.

The profit from cricket farming is dependent on the farm size. For a medium-size farm producing 500 to 750 kilograms of harvested crickets every harvesting cycle (45 days), the revenue can be THB30 000 to 70 000 and THB150 000 to 350 000 per year if four to five harvesting cycles are involved. Some large-scale farms can produce 1.5 to 2 tonnes of crickets in each harvesting cycle.

One wholesale buyer in Maha Sarakham receives 2 to 3 tonnes of freshly-harvested crickets from local cricket farmers each day for processing and packing before sale to the retail markets (Figure 7).

The cricket price rises at each stage of the sales path. Farmers sell the crickets to wholesale buyers for around THB80 to 100 per kilogram. The wholesale buyers wash and boil the crickets and then package them in 5 kilogram packs. These packs are sold for about THB120-150 per kilogram to the retail markets. Street vendors who buy at the retail markets sell the precooked crickets for THB25-30/100 grams, the equivalent of THB250-300/kilogram.

Figure 5. Types of breeding containers: (a) concrete cylinder, (b) concrete block, (c) plywood box and (d) plastic drawers

Table 2. Total expenses for cricket production (harvesting cycle per concrete block) by a farmer in Loei Province with seven years' farming experience since 2001

Expense items	Amount/ unit	THB/unit	Total cost/unit	Usable life (year)	Depreciation/ one harvesting cycle (THB)
Fixed costs					
Concrete block pen (size 2.2 x 4.8 x 0.6 m)	1	1 000	1 000	15	16
Cricket nursery/shed	1	70 000	7 000 (10 pens)	20	87.50
Variable costs					
Rearing materials					
Egg cartons	500	1	500	1	125
Plastic bowls for egg	35	10	350	2	43
Harvesting					
Food trays	16	10	160	2	20
Food grinding machine	1	4 500	4 500	10	112
Tape	1	28	28	1	7
Nylon net	1	250	250	5	12
Cricket eggs		50	1750	2	218
Miscellaneous costs					
Electricity, water, packing		500	50		50
Cricket feed	9	400	3 600		3 600
Labour	1	7.5 THB200/ 3hr/day used	337.50 (45 days)		337.5
Total cost					**4 682**
One pen can produce 100 kilograms of crickets; production cost = THB46/kg					

Note: Farmer can carry out four harvesting cycles/year.

Table 3. Income and net profit per harvesting cycle by the same farmer

Sales	Total production (kg)	Sale price/ kg (THB)	Cost/kg (THB)	Gross income (THB)	Total cost (THB)	Net profit per one harvesting cycle (THB)
Wholesale	950	110	46	104 500	43 700	60 800
Retail	50	150	46	7 500	2 300	5 200
Total	**1 000**			**112 000**	**46 000**	**66 000**

Table 4. Expenses for cricket production (harvesting cycle per plastic drawer) by a farmer in Ubon Ratchatani Province with seven years' farming experience since 2001

Expense items	Amount/ unit	THB/unit	Total cost/pen	Usable life (year)	Depreciation/ one harvesting cycle (THB)
Fixed costs					
Plastic drawer container (size 0.8 × 1.8 × 0.3 m)	1	125	125	5	5
Cricket nursery/shed	1	25 000	367.64 (total 68 pens)	20	11.35
Variable costs					
Rearing materials					
Egg cartons	20	2	40	1	8
Food trays	2	10	20	2	2
Tape	1	25	25	1	5
Cricket eggs	2	80	160	2	16
Miscellaneous costs					
Electricity, water, packing material		500	7.35		7.35
Cricket feed	0.5	450	225		225
Labour	1	1.10 (THB200/ 3hr/day used)	49.63 (45 days)		49.63
Total cost					**329.33**
One pen can produce 6 kilograms of crickets; production cost = 55 THB/kg					

Note: Farmer can carry out five harvesting cycles/year.

Table 5. Income and net profit per harvesting cycle by the same farmer

Sales	Total production (kg) for 68 units	Sale price/ kg (THB)	Cost/kg (THB)	Gross income (THB)	Total cost (THB)	Net profit per one harvesting cycle (THB)
Wholesale	200	130	55	26 000	11 000	15 000
Retail	208	200	55	41 600	11 440	30 160
Total	**408**			**67 600**	**22 440**	**45 160**

Table 6. Expenses for cricket production (harvesting cycle per concrete cylinder) by a farmer in Nakhon Phanom Province

Expense items	Amount/ unit	THB/unit	Total cost/ pen	Usablelife (year)	Depreciation/ one harvesting cycle (THB)
Fixed costs					
Concrete cylinder pen (size 1 m diameter, 0.5 m height)	1	170	170	10	4.25
Cricket nursery/shed	1	5 000	50 (total 100 cylinders)	20	0.62
Variable costs					
Rearing materials					
Egg cartons	5	2	10	1	2.5
Food trays	2	10	20	2	2.5
Tape	1	25	25	1	6.25
Water sprayer	1	7.5	750	5	0.37
Nylon net	1	50	50	5	2.5
Cricket eggs	3	50	150	2	18.75
Miscellaneous costs					
Electricity, water, packing material		500	5		5
Cricket feed	0.3	650	195		195
Supplementary food (pumpkin)	1	15	15		15
Labour	1	0.75 (THB200/ 3hr/d used)	33.75 (45 days)		33.75
Total cost					**286.49**
One pen can produce 4 kilograms of crickets; production cost = THB71/kg					

Note: Farmer can carry out four harvesting cycles/year.

Table 7. Income and net profit per harvesting cycle by the same farmer

Sales	Total production yield (kg) for 100units	Sale price/ kg (THB)	Cost/kg (THB)	Gross Income (THB)	Total cost (THB)	Net profit per one harvesting cycle (THB)
Wholesale	350	150	71	52 500	24 850	27 650
Retail	50	200	71	10 000	3 550	6 450
Total	**400**			**62 500**	**28 400**	**34 100**

Figure 6. Cricket-rearing sheds at different sites in the northeast: a) Loei Province, b) Buri Ram Province, c) Maha Sarakham Province and d) Khon Kaen Province

Figure 7. Cricket processing by a wholesale buyer in Maha Sarakham Province: (a) first washing, (b) boiling, (c) washing, (d-e) packing and (f) cold storage and delivery to market

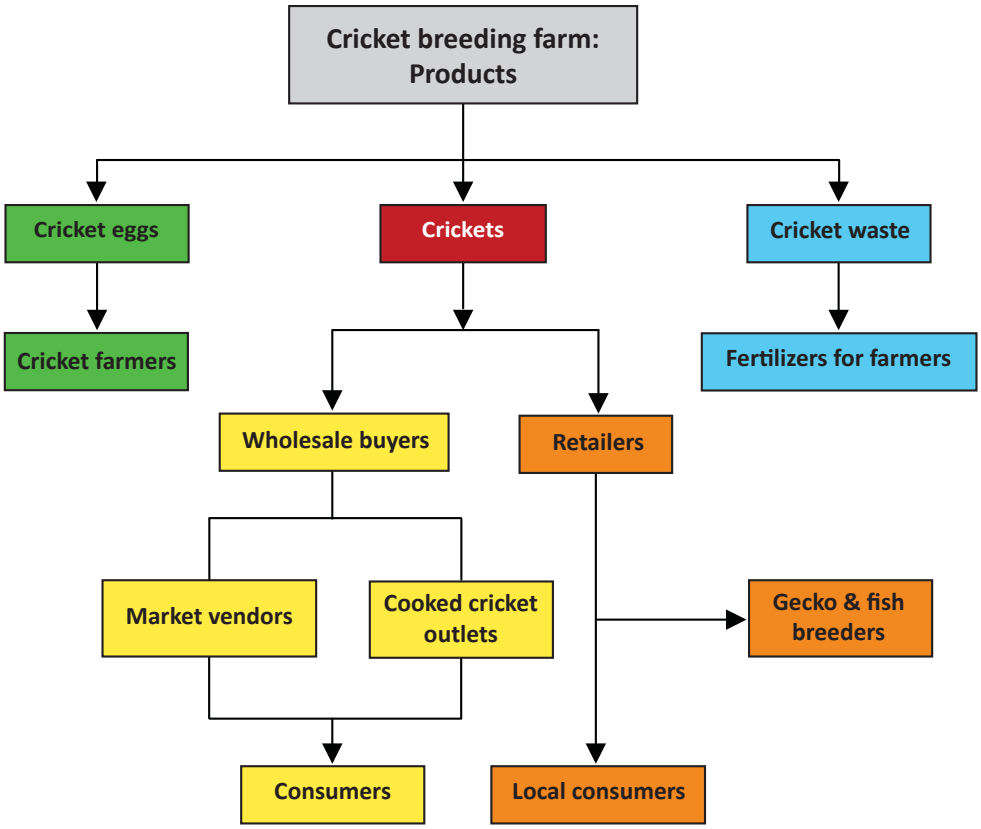

Figure 8. Product and marketing network for crickets

Small and microcommunity enterprises for cricket farmer groups

Promoted by the government, the small and microcommunity enterprise (SMCE) scheme was established in 2004 under the administration of the Secretariat Office of the Community Enterprise Promotion Board, Ministry of Agriculture and Cooperatives. The SMCE assists in strengthening community enterprises and establishing farmer groups and business networks. The products come under the OTOP (One Tambon One Product) label. Cricket farming is also registered under the SMCE. From 2010 to 2011 the SMCE for cricket farming was mostly located in the northeast, particularly in Khon Kaen, Kalasin, Nong Bua Lam Phu, Loei, Udon Thani, Roi-Et and Ubon Ratchatani, but also in other provinces in the north such as Petchabun,

Lamphun and Phrae. A total of 19 961 cricket farmers with 217 529 cricket pens were recorded and 1 087 645 kilograms of crickets were produced per year. Annual gross income was around THB108 764 500 (Sanewong Na Ayudtaya 2011).

Constraints and threats to cricket farming

High cost of high protein feed: Approximately half of the production cost is feed, which is commercially produced by the chicken industry. Therefore, cricket farming is vulnerable to price increases in the chicken feed industry, which undermines profitability. Research is needed to find low cost or free protein sources to develop into a special feed formula for crickets.

Disease: Currently, disease risk is almost non-existent. However, in the future, with continuing high density cricket populations, disease problems are likely to arise. There have been a few a cases of crickets dying without any disease symptoms or pathogens. It is suspected that overcrowding or contamination by fungi in the feed may have been the cause.

However, in the future, with increasing intensive insect farming and no proper farm management guidelines, potential virulent diseases could wipe out an entire cricket farm.

In-breeding is another risk as many cricket farms are closed units using breeding stock produced on the farm. Already on some cricket farms the effects of in-breeding are visible with less active and slow-maturing crickets. The problem seems to arise after three generations, so sourcing breeding stock and eggs outside the farm should be a recognized best practice for all farmers.

Early involvement of research institutes that address high density populations, potential disease risk and management will help to identify potential risks and develop control methods.

There is a need for standard farm management practices for cricket rearing from nursery to harvest. Many cricket famers do not understand best practices with regard to breeding management, nutrition, pest/disease control and farm hygiene. Therefore, extension workers or technical staff with relevant experience and knowledge are needed to train the farmers.

Informal industry: Cricket farming today is a commercial venture, but officially the sector is not well recognized by government agencies.

Therefore, with little or no monitoring or support for the sector, disease, marketing and trade issues are left to the farmers to resolve. Currently, any disease outbreak is unlikely to be detected early enough to stop its spread. Because little research has been conducted on commercial production, there are no production and management standards for cricket farming such as hygiene recommendations to minimize disease outbreak.

Price and marketing: Currently it is common for insect farmers to sell fresh farmed produce to an agent (wholesale buyer). The agent boils, packages and freezes the products and then sells and delivers them to various markets. The price paid to the farmers for fresh unprocessed crickets therefore depends on the agent or wholesale buyers and whether there are other competing agents nearby. But effectively the farmer is a 'price taker' with little control over the retail price. Most of the profit is likely to be made by the agent rather than the farmer. The SMCE scheme has already promoted village production based on cricket farming under the OTOP label. But in reality the groups are often set up by an entrepreneur who is still likely to make most of the profit.

A better system for farmers would be to form a cooperative operation based around a village, similar to an OTOP village. If, say, 20 farmers were interested in rearing crickets, one could be appointed as the marketing agent. He/she would supply products to the cooperative agent for processing as usual, but profits from the sale would be divided among all farmers.

Farmed cricket products are now available in local fresh markets and supermarkets in frozen bulk packs.

As the cricket food industry is still relatively new there is considerable potential to raise awareness among potential consumers of this new food item. Many people who consume crickets regard them only as a deep-fried snack food. However, there is plenty of potential to develop the idea of crickets as an ingredient for restaurant-level dining. Commissioning a top chef to develop new recipes for restaurant dishes would be one way to raise the profile and awareness of food uses of crickets.

Palm weevil or sago larvae farming

Background

Palm weevil (*Rhynchophorus ferrugineus* Olivier) or sago larvae farming is found mainly in the southeast region of Thailand. Palm weevil larvae have been farmed on lan phru trees (cabbage palm or Gebang palm) and sago palm (*Metroxylon sagu* Rolth.) since 1996 for home consumption by local people. Palm weevil larvae became a popular food item for people in the south and other areas around 2005. Therefore, palm weevil farming has been expanding into a commercial venture in southern provinces such as Chumphon, Phatthalung, Nakhon Si Thammarat, Songkhla, Yala, Krabi and Surat Thani.

Production data on palm weevil larvae are only available for 2011, indicating that 120 farmers in the south produced 43 tonnes of palm weevil larvae using 4 289 rearing basins (Sanewong Na Ayudtaya 2011).

Palm weevil breeding still depends on natural plant food so at this juncture palm weevil larvae farming cannot be expanded into other regions due to the absence of lan phru trees (*Corypha utan* Lam. syn. *C. elata* Roxb.) and sago palm (*Metroxylon* spp.). In Thailand there are three species of the lan tree and they have specific geographical distribution. The lan phru species *Corypha utan* Lam. is widely distributed in the south, while *C. umbraculifera* Linn. occurs in the north. *C. lecomtei* Becc. is found in Thap Lan National Park of Prachin Buri and Nakhon Ratchasima Provinces (Anon n.d.). Two species of sago palms (*Metroxylon sagu* Rottb. and *Metroxylon rumphii* Mart) are widely distributed in Indonesia, Malaysia and southern Thailand (FAO 1983).

Palm weevil farming technology

Two breeding methods are used for palm weevil farming (Figure 9):

• The traditional method is farming directly in palm trunks or stems. Cabbage palm or sago palm trunks or stems are cut into 50 centimetre lengths, then ten holes are drilled 5 centimetres deep in the trunk. Five pairs of adult males and females are released and the top is covered with sago tree bark. Water is applied twice a day until harvesting. After 40 to 45 days palm weevil larvae can be harvested. The total yield is around 2 kilograms of fully grown palm weevil larvae per cabbage palm or sago palm trunk. The same palm trunk can be used to breed the palm weevil larvae

for the second generation and can be used for up to eight months.

• Breeding in a plastic container: A round plastic container (approximately 45 centimetres in diameter and 15 centimetres high) filled with ground palm stalk and mixed with pig feed is used for breeding. Five pairs of adult male and female weevils are released into the container. After 25 to 30 days about 1-2 kilograms per container of fully grown palm weevil larvae can be harvested.

Palm weevil farmers

Palm weevil farmers are from the south where their main income comes from rubber plantations and other agricultural crops such as rice and coconut. Most farmers have palm weevil farms for secondary income. Some farm palm weevils as their main household income.

Production cost, profit and marketing

Interviews with seven farmers of medium-size farms revealed that five farmers bred palm weevil larvae in basins and fed the larvae with ground sago palm. The other two farmers bred palm weevil larvae using 400 sago palm trunks and 350 lan phru trunks, 50 centimetres long. The production cost of 1 kilogram of palm weevil larvae (200 individuals) bred in basins containing ground sago palm was about THB15/kilogram (Table 10,11). One basin can produce 2 kilograms. The sale price is THB200-250/kilogram. One breeding cycle lasts 35 to 45 days and they can harvest around 400 to 600 kilograms from 200 to 300 basins. Net profit of THB84 000-126 000 can be obtained for each harvesting cycle.

In contrast, production cost per kilogram of palm weevil larvae bred in sago palm trunks is about THB20/kilogram (cost of the palm trunk, Table 8,9). One palm stem (length 50 centimetres) can produce 2-3 kilograms/trunk. The sale price is THB200-250/kilogram. Therefore net profit is around THB180-230/kilogram. Farmers on average use 350 to 400 palm trunks for weevil breeding. The net profit per harvesting cycle (35 to 45 days) can be around THB143 000-164 000. The higher profitability of production in palm trunks is because no extra feed costs are included with the trunks whereas in basin production feed inputs (pig feed) are required.

Apart from direct income generated from selling palm weevil larvae, by-products (palm weevil feces) can be used as an organic fertilizer and sold as both liquid (THB50/litre) and solid fertilizers (THB20/20 kilograms).

According to the Department of Agriculture Extension, Ministry of

Agriculture and Cooperatives of Thailand, production of palm weevil larvae in 2010-2011 was about 43 tonnes and the total gross income was around THB1 920 000 (Sanewong Na Ayudtaya 2011).

The market flow for palm weevil larvae is simple. The farmers usually sell their products through wholesale buyers who supply market vendors or restaurants, and sometimes directly to local consumers or to gecko breeders for feed.

Table 8. Production cost/kilogram of palm weevil larvae production by a farmer in Phattalung Province with seven years' experience since 2001 using direct breeding on sago palm trunks

Expense items	Amount/ unit	THB/unit	Total cost (THB)	Usable life (year)	Depreciation/one harvesting cycle (THB)
Fixed costs					
Nursery/shed	1	5 000	5 000	3	840
Variable costs					
Palm trunk	400	60	24 000	8-9 month (for 2 generations)	12 000
Labour	1 person	50/day (use 2hr/ day at 200/day)	2 000 (50x40 days)		2 000
Miscellaneous costs					
Electricity, water, bags	1	800	800		800
Total cost per harvesting cycle					**15 640**
One harvesting cycle can produce 800 kg; production cost = THB20/kg					

Table 9. Income and net profit per harvesting cycle by the same farmer

Sales	Total production (kg) for 400 trunks	Sale price/ kg (THB)	Cost/kg (THB)	Gross income (THB)	Total cost (THB)	Net profit per one harvesting cycle (THB)
Wholesale	700	200	20	140 000	14 000	126 000
Retail	100	250	20	25 000	2 000	23 000
Total	**800**			**165 000**	**16 000**	**149 000**

Note: One palm trunk can produce 2 kilograms of palm weevil larvae for 35-45 days.

Table 10. Production cost/kilogram of palm weevil larvae production by a farmer in Nakhon Si Thammarat Province with three years' experience since 2009 using plastic containers containing mixed ground palm stalks and pig feed

Expense items	Amount/ unit	THB/unit	Total cost (THB)	Duration use(year)	Depreciation/one harvesting cycle (THB)
Fixed costs					
Nursery/shed	1	5000	5000	2	555
Plastic container	200	90	18000	3	2000
Palm stalk grinding machine	1	5000	5000	10	160
Variable costs					
Sago trunk (1 trunk per 100 containers)	2	250	500		500
Pig feed (12 % protein)	1	335	335		335
Coconut coir	4	15	60	60	
Miscellaneous costs					
Electricity, water, bags	1	800	800		800
Labour	1 person	50/ day(use 2 hr/day at 200/day)	1 500 (50 x 30 days)		1500
Total cost per one harvesting cycle				**5 910**	
One harvesting cycle produces 400 kilograms (2 kg/container); production cost/kg = THB15.					

Note: Production capacity is around three harvesting cycles/year.

Table 11. Income and net profit per harvesting cycle by the same farmer

Sales	Total production (kg) for 200 basins	Sale price/ kg (THB)	Cost/kg (THB)	Income (THB)	Total cost(THB)	Net profit per one harvesting cycle(THB)
Wholesale	300	200	15	60 000	4 500	55 500
Retail	100	220	15	22 000	1 500	20 500
Total	**400**			**82 000**	**6 000**	**76 000**

Note: One basin can produce 2 kilograms of palm weevil larvae for 35-45 days.

Figure 9. Palm weevil farm in the south: (a) palm weevil larvae, (b) palm weevil adults, (c) plastic containers for breeding, (d) sago palm stem breeding and (e-f) solid and liquid fertilizers from larvae waste

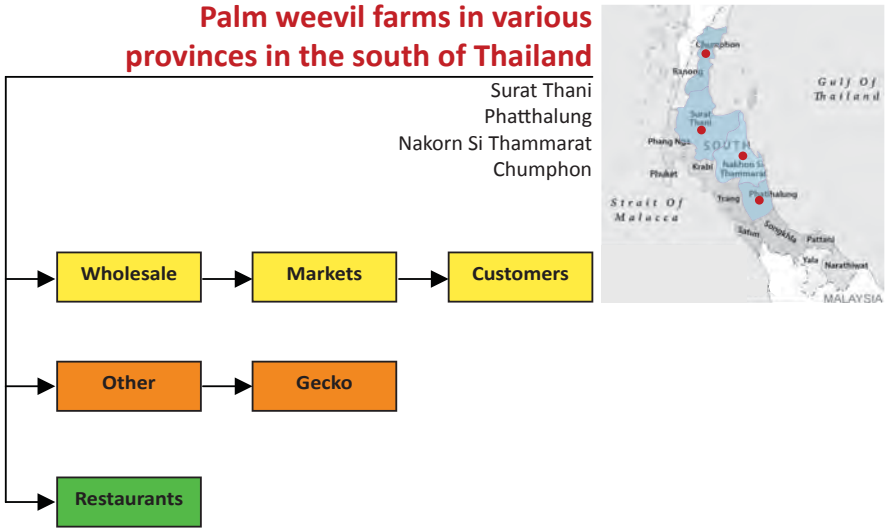

Figure 10. Product and marketing pathways for palm weevils

Constraints and threats for palm weevil larvae farming

The market demand for edible palm weevil larvae is still high, while yields are not enough to meet it. Recently, palm weevil larvae have been sold in frozen packages and distributed in the Makro wholesale supermarket chain throughout Thailand.

Constraints for palm weevil larvae farming are:

• Food supply: Palm weevil feed is a natural source (palm trees). Production capacity and farm location are therefore limited to areas that can grow palm trees – mainly in southern Thailand.

• Declining palm tree numbers (cabbage palm *Corypha utan* Lam. and sago palm *Metroxylon sagu* Rolth.): Most farming techniques still use the traditional farming method of breeding directly on the palm tree stem. Modified techniques such as using only the palm leaf and breeding colonies in plastic containers are underway, but the technology is somewhat complicated and not so widespread as the traditional farming method. Therefore, there is the risk that palm trees will be threatened by overharvesting. Nevertheless, the palm weevil is also a serious pest of palm trees, including the coconut tree. Promoting consumption of this insect species is a form of biological control that can reduce numbers of this pest in the wild.

Wild-harvested edible insects

Apart from farmed edible insects like crickets and palm weevil larvae, other edible insect species such as silkworm pupae, grasshoppers, weaver ants and bamboo caterpillars are also popular food items and can be found in every market.

Grasshoppers, weaver ants, giant water bugs and bamboo caterpillars are the most popular wild edible insects consumed. Grasshoppers are collected in the wild, but mainly imported from Cambodia; weaver ants and bamboo caterpillars are harvested in the wild seasonally.

Bamboo caterpillar (*Omphisa fuscidenttalis* Hampson, Family Pyralidae)

Known in Thai as rod fai duan or 'the express train' the larvae live inside bamboo plants for around ten months. It feeds on 11 species of *Dendrocalamus* and *Thyrsostachys* bamboo. The number of larvae depends on the size of the bamboo culms (Kayikananta 2000; Leksawasdi 2001).

Collecting techniques

Bamboo caterpillars are mainly collected in the north of Thailand. Bamboo caterpillars were traditionally collected by cutting down entire bamboo clumps to harvest the caterpillars. This approach was destructive and sometimes wasteful of bamboo material. More recently a less invasive collection method has been tried. Sustainable collection without cutting bamboo trees is starting to be practised by local people. Mr.Piyachart, a collector of bamboo caterpillars from the wild, was interviewed in Chiang Rai Province to learn about his sustainable collecting method. The adult caterpillar exits, after pupa emergence, from a hole at the base of the bamboo stem. The first or second internode is examined to reveal the damage caused by the bamboo caterpillar and its location. The denseness of an internode is a clue to indicate the presence of bamboo caterpillars. The harvesting of bamboo caterpillars is conducted by slicing the specific infested internode to obtain the larvae without cutting the whole plant. Collection is carried out by cutting a rectangular hole approximately 9 x 13 square centimetres in size at specific internodes hosting the bamboo caterpillars.

The female moth lays a mass of 80 to 130 eggs on the sheaths at the base of bamboo shoots. After hatching, the young larvae bore an entrance hole mostly from the fifth to the tenth internodes. The larvae live and eat inside the bamboo shoot, usually a young shoot, on the upper part, until they are 45 to 60 days old, when they move down to congregate in the internode with the existing egress point for another eight months. The Royal Forest Department recommends that the best time for collecting bamboo caterpillars is around January to April when bamboo caterpillars can be obtained from the specific internode and the infested bamboo culm can be harvested for later utilization (Kayikananta 2000).

Generally, the infested bamboo culms are stronger than the non-infested ones because the wood cells are small and dense, making them stronger and heavier than normal bamboo. They can be utilized to make bamboo handicrafts and construction poles.

Rearing technique

The best practice for farming bamboo caterpillars has yet to be developed. Currently, the Royal Forest Department had developed management rearing techniques for bamboo caterpillars (Kayikananta 2000). Two management methods are recommended. The first is controlling mating in a nylon net cage covering the bamboo shoot and the second is releasing moths for natural mating into the bamboo plot. The latter is best because it is easy and convenient.

Economics and marketing

According to farmer groups at Tambon Waree, Chiang Rai Province, each year about 500 kilograms of bamboo caterpillars are harvested and sold at THB200-250/kilogram to buyers who come to their villages.

Mr Jaturong, an edible insect entrepreneur, is one of the biggest buyers of bamboo caterpillars. His company brand is 'Mae Urai, Edible Insect'. Each year he buys at least 20 000 kilograms of bamboo caterpillars from villages in the north of Thailand; 10-20 percent comes from neighbouring countries such as Lao PDR and Myanmar. The product is packaged in both uncooked frozen packs and ready-to-eat boxes (deep-fried beforehand). The uncooked frozen packs are distributed throughout Thailand via the Makro wholesale supermarket chain. On average, 1 000 kilograms are sold each month at THB365/kilogram. The ready-to-eat (cooked) bamboo caterpillars are packed in plastic boxes containing 100 grams and sell at THB130 in retail shops. Each month

around 3 500 to 4 000 boxes are sold. Recently, the company has developed a new product line of cooked bamboo caterpillars sealed in a container that can be heated in a microwave oven before eating.

Opportunities and constraints

Bamboo caterpillars are one of the most popular edible insects and the selling price is still quite high compared to other edible species. A rearing technique has been developed, although it is still based on semi-natural habitat and still needs bamboo as the food source. However, with proper management of semi-natural farming and harvesting, bamboo caterpillars can become a more popular edible insect and help with income generation for local people. The area of bamboo plantations could be increased for farming purposes – an indirect contribution to environmental conservation.

Lack of knowledge or only basic understanding about the biology, ecology and habitat of these caterpillars by local harvesters presents a risk to the ongoing availability of the species. Therefore, proper management and harvesting techniques for sustainable use of this insect are urgently needed for local people; mainly ethnic groups in the north of Thailand.

As the bamboo caterpillar is widely consumed and in demand, a simple and efficient breeding technology for bamboo caterpillars at the farm level as well as imported product processing should be further investigated and developed.

Weaver ant (*Oecophylla smaragdina* Fabricius, Family Formicidae)

Weaver ants are known locally as 'red' ants or mod-daeng and are a popular delicacy. The ant workers construct nests by weaving together leaves using larval silk. Many ant colonies can be found on one tree.

Weaver ants are predominantly found in the northeast and have been interlinked with the way of life of people in this region for a long time. Traditional local folk songs and dances have included stories of red ant egg harvesting. Red ant eggs (the larval and pupal stage), or khai mod-daeng are popular food. Pupae and adults are also eaten. The most popular dishes, particularly in the northeast, are omelet mixed with red ant eggs and Thai red ant egg salad (yum khai mod-daeng).

Usually weaver ants are harvested from trees in the wild. However, some

farmers can breed and maintain weaver ant colonies in their own gardens on mango trees. The colonies can be maintained and expanded if their host trees are protected from predators and have good access to water. The weaver ants need water to produce acetic acid.

A method to propagate ant nests in mango orchards is the use of overhead ant highways that link the trees of the orchard. These ant highways help the ants to conserve energy by not needing to leave their trees and also protect them from ground based predators. Consequently nest multiplication is accelerated. The highways are made from any type of rope, except plastic material, but rattan canes are preferred.

Collecting techniques

In north and northeast Thailand the season for weaver ants' harvesting usually occurs once a year during the dry season between February and May. During this period the arboreal nests of the weaver ants are full of eggs, larvae and pupae. In Petchabun Province the season occurs from January to May and three crops are obtained annually.

Harvesting is undertaken using a long bamboo pole with a bag or basket attached with strings to the tip. A hole is poked into the nest with the tip of the pole and it is shaken so the larvae and pupae fall down into the bag. Then the bag is poured onto a plate or container and some rice or tapioca flour is added to prevent the ants from climbing up to bite the collector. A branch is put on the plate for adult ants to climb back up the branch and it is whipped against a tree to release the adult ants. The remaining larvae and pupae are removed for consumption (Lewvanich *et al*. 1999).

Economics and marketing

Information on production and marketing of weaver ants is limited to individual cases. Currently, the market price for weaver ant eggs is round THB250-500/kilogram depending on the period and location. When the season is nearly over, the price will be high. Usually 1-2 kilograms of weaver ants can be collected in the wild each day although some collectors can collect 5-8 kilograms/day. About 300-400 grams of larvae and pupae per nest can be harvested. On average one collector can earn THB250-500/day.

The income for weaver ant sellers at markets in the northeast and north (based on interviews) is around THB 1 200-3 000/day with around 5-10 kilograms of weaver ants sold per day (on average 5 kilograms/day).

One wholesaler at Talad Thai market in Bangkok, which is one of the biggest edible insect markets, can sell around 30-40 kilograms/day and net profit is around THB2 000-2 500/day.

Weaver ants can generate good income for both collectors and sellers but weaver ant harvesting is still a sideline occupation. Income from their collection exceeds normal farm income from rice or cassava production for example. However, there is only a short harvesting period of three to four months per year starting in February. Weaver ants are sold as fresh produce in markets everywhere, particularly in the north and northeast during the harvesting period in the dry season. Canned weaver ants in brine are also sold, a common practice which preserves the product for a long time, ideal for export to overseas markets.

Opportunities and constraints

Weaver ants are very popular and consumer demand is higher than the natural supply. According to local people, numbers of weaver ants have been decreasing and they are more difficult to find in the wild. Decreasing populations are a negative impact on ecological systems because ants are predators and perform many ecological roles that are beneficial to humans, including the suppression of pest populations. Weaver ants were first used for biological control of citrus pests in China, and are used in mango and cashew plantations in Australia (Peng *et al.* 1999; Peng and Christian 2004-2007).

Weaver ants can easily be semi-farmed in home gardens by feeding with food scraps and sufficient water; colonies can be expanded with proper management. However, biological and ecological aspects, particularly finding the queen of the colony or creating a new queen for the colony as well as preferred trees and ecological habitat need proper understanding. Weaver ant queens do not live in the large nests seen lower down in the tree host. The queen is found in a small nest at the highest point of the tree where it is difficult to reach. A colony on a tree without a queen will eventually die.

Giant water bug (*Lethocerus indicus* Lep.-Serv., Family Belostomatidae)

The giant water bug is native to Southeast Asia. It is a popular edible insect, known by locals as malaeng da na and is consumed in almost all parts of Thailand. The whole bug except the wings is eaten. It can be grilled or fried or used as an extract in sauces to make Nam Phrik Mangda, a type of chili sauce. Usually the male is preferred as the male has a scent gland that can produce a strong distinctive smell.

Collecting techniques

Giant water bugs live in still water, swamps and rice paddies. During the rainy season (May to August) they come out of the water and are attracted to lights, especially blue neon lights. One common method for catching them in a field is to set up a blue neon light with a long bamboo pole 2-3 metres high. A water container is placed on the ground to collect the bugs that fall down. Fishing nets are also used to harvest them from swamps and ponds (Lewvanich et al. 1999).

Economics and marketing

Giant water bugs are predaceous insects and usually sensitive to polluted environments. Although the giant water bug is a very popular edible insect among Thai people, these days the population of this species is declining due to environmental and habitat changes and pollution. Large numbers of giant water bugs are bought from neighbouring countries like Cambodia and Myanmar.

Due to high demand in the market, the price is high and increasing year by year. In the last few years one male would cost THB10. However the price rose to THB15 in 2011. Females are cheaper and sold at THB8-10 each.

Recently giant water bugs have been sold in frozen 10-bug packages in wholesale chain supermarkets throughout the country (for example Makro supermarket). Male bugs cost THB130/pack while females cost THB65/pack.

One wholesaler of giant water bugs at the Kalasin edible insect market in the northeast indicated that each day at least 3 000 bugs are sold at THB10-13/bug, mainly males. The bugs are bought from Cambodia through the edible insect market near the Cambodian border.

Opportunities and constraints

Farming is quite difficult and laborious because this species is predaceous and cannibalistic when populations are crowded.

Recently a researcher at Rajamangala University of Technology Isan in Sakon Nakhon Province (Sanewong Na Ayudtaya 2011) has developed a breeding method to farm the giant water bug. If this technology can be developed for farming on a commercial scale, this will help to reduce the massive harvesting of giant water bugs from the wild which impacts ecosystems by lowering predatory populations.

Grasshoppers (Order Orthoptera)

Many species of Orthoptera or grasshoppers are edible. In Thailand, they include *Patanga succincta*, *Locusta migratoria*, *Acrida* sp., *Cyrtacanthacris tatarica* and *Oxya japonica japonica* (Thunb.) (Hanboonsong *et al.* 2001; Rattanapan 2000). All of them are pests of economic crops such as maize and rice. Grasshopper species, particularly *Patanga succincta* and *Locusta migratoria*, used to be one of the major pests of maize and rice. Today they have become one of the most popular edible insects since they were introduced for human consumption by entomologists – a campaign to eat grasshoppers had been launched because control efforts had been unsuccessful. For example, in 1983 this was launched by local officials and villagers in Prachin Buri Province collected more than 10 tonnes for use as food (Lewvanich *et al*. 1999).

Collecting method

Grasshoppers are collected in paddy or maize fields by using a net, a piece of cloth or by hand at night or in the early morning as low temperatures make them inactive. Before consumption, the intestines and wings are removed and the torso is washed in water. Deep-frying is a popular way to cook them.

Economics and marketing

Wild collection of grasshoppers is rarely witnessed in Thailand. Most edible grasshoppers sold in Thai markets come from Cambodia. Approximately 170 tonnes of grasshoppers are imported annually for retail at Rong Kluea market at the Cambodia border in Sa Kaeo Province (Ratanachan 2009). Imported grasshoppers are sold through a network of fresh markets throughout the country by traders and intermediaries. They are purchased by street food vendors for sale in night

markets and food stalls all over Thailand.

Grasshoppers are also sold in frozen packages at all 51 Makro wholesale supermarkets throughout Thailand. Each day at least 10 kilograms of grasshoppers are sold at each branch for THB354/kilogram (for Bombay locust).

Opportunities and constraints

Grasshoppers are one of the most popular edible insects eaten by Thai people. Entomologists at Khon Kaen University have successfully developed a breeding technique to mass rear them, but the technology still cannot be expanded on a commercial scale as it is not an economically viable way to farm this type of insect. It has almost a year-long life cycle and still requires its natural food for feeding.

Nowadays many new species of grasshoppers are collected from the wild. Many of them are still unknown and have not yet been identified or recorded. The diversity of grasshopper species caught for consumption is wider than in the past.

Figure 11. Wild-harvested edible insect species: (a-b) bamboo caterpillars, (c) wasps and (d) water scavenger beetles

Figure 12. Wild-harvested edible insect species: (a-c) weaver ants, (d) grasshoppers and (e) dung beetles

Business and market channels

It has been difficult to determine the extent of wild harvesting and farming in Thailand because this is conducted at two levels: subsistence (use of insects for domestic consumption or as an additional source of income, mainly harvesting wild species) and commercial producers. There is no overriding group that oversees the industry, so obtaining data at any level (provincial or national) is difficult. The situation is complicated in the case of wild-harvested insects because many are imported from adjacent countries.

Subsistence and commercial use

It is difficult to get reliable information about the extent of insects gathered as subsistence food by individual farmers or sold for income generation.

Good data are available for some commercial enterprises. The production and marketing channels, cost and income can be determined in some cases. However, it is difficult to determine how information obtained at the local level can be extrapolated to the provincial or national level because the extent of edible insect trade varies considerably across Thailand, and the nature of the operations also varies.

The trading channels for edible insects are shown in Figures 15 and 16 (wild harvested insects) and Figures 8 and 10 (farmed insects). In both cases, the villager is either the collector or a farmer who keeps insect colonies.

In the case of wild-harvested insects, the collectors may use the insects themselves, sell them directly to the public or sell to an intermediary (wholesale buyer). This can occur in Thailand, but is more likely to occur in adjacent countries. The wholesale buyer will visit individual collectors and purchase the insects or the collectors will directly bring insects to the wholesale buyer's venue. They are then sold to a wholesale market (for example at the Rong Kluea market on the Cambodian border).

Once the insects reach the wholesale buyer, the scenario is similar for both wild-harvested and farmed insects. They are stored in a cool store as frozen packages and sold to distributors, who in turn sell to the retailers (generally market stall operators). There can be variations in trading channels. An intermediary may sell stock directly to distributors or retailers.

Edible insect markets

Both fresh and cooked edible insects can be found in all types of markets at provincial or district levels. Several well-known edible insect wholesale markets are Rong Kluea in Sa Kaeo Province (the biggest edible insect market near the Cambodian border), Klong Toey market (Bangkok), Talad Thai (Bangkok) and Jatujak market (Bangkok) — this market sells mainly mealworms for pet feed). Talad Kaset in Kalasin Province is one of the largest wholesale markets for distribution of edible insects in the northeast. Mainly farmed crickets, silkworm pupae, giant water bugs and grasshoppers are sold there.

Markets can be divided into three groups based on income generated from selling insects. Large markets are Rong Kluea and Talad Thai, which have an average monthly income of approximately THB300 000. Medium-size markets are Jatujak and Klong Toey markets in Bangkok, with an average monthly income of around THB200 000 to 250 000. Small insect markets are located in a scattering of submarkets in provinces in the northeast such as Warin Chamrab market in Ubon Ratchatani near the Lao border; also Kalasin and Loei provincial markets. Average monthly income ranges from THB50 000 to 80 000.

Storage for edible insects

Most edible insects sold in markets are wild harvested and they are available seasonally. Therefore, the wholesalers usually keep insects in cold storage and in some cases, like giant water bugs, are preserved with salt for prolonged storage. There are two types of cold storage: (1) plastic tanks in which the products are covered with ice cubes (temporary storage for two to three days) and (2) long-term storage in cold storage rooms at -18 °C to -20 °C (products can be kept for one to two years). Some wholesalers have their own cold rooms with up to 300-tonne capacity. However, this type of storage has both positive and negative aspects. Proper cold storage will prolong the usable life of the insects and also is an important food safety factor. On the negative side, it may encourage overharvesting of insects that are very seasonal. For example weaver ants – collectors may be tempted to collect more than is ecologically sustainable in order to generate more income. The wholesaler can store the weaver ants and sell them at times when they are generally not available.

Imported insect products

Only a few species can be farmed such as house crickets, palm weevils and

mealworms. Recently, giant water bug farming technology has also been developed but it has not been very successful. Other species such as grasshoppers, bamboo caterpillars and giant water bugs are still wild harvested and imported from neighbouring countries to Rong Kluea market. Grasshoppers, black scorpions and giant water bugs are imported from Cambodia. Silkworm pupae are produced in the northeast where the silkworm industry is located. The supply of silkworm pupae consumption is still not sufficient. Approximately 270 tonnes per year are imported from China by wholesalers at Rong Kluea market. It has been reported that about 800 tonnes of edible insects are annually imported from Cambodia, Myanmar, Lao PDR and China to Rong Kluea market (Ratanachan 2009). The top five imported insects are silkworm pupae, ground crickets, leaf-eating grasshoppers, mole crickets and giant water bugs. The economic value of imported insects is estimated at around THB40 million per year.

Figure 13. Edible insects are sold in various markets

Figure 14. Edible insect markets and businesses: (a) wholesale sellers at Rong Kluea market, (b) frozen packages in a supermarket, (c) precooked bamboo caterpillars on sale at a souvenir food shop and (d) precooked bamboo caterpillars for microwaving

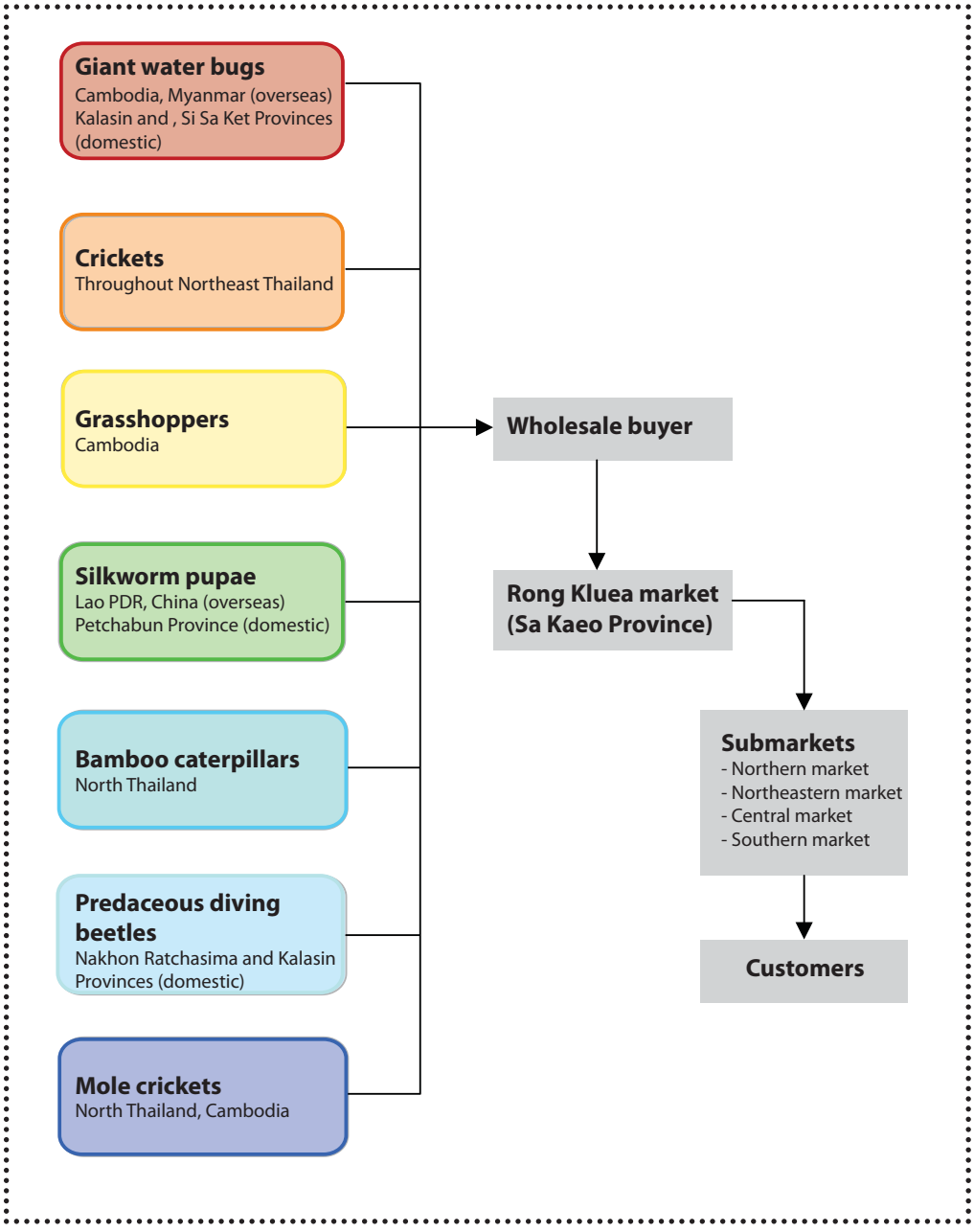

Figure 15. Collection and distribution market chains for edible insects

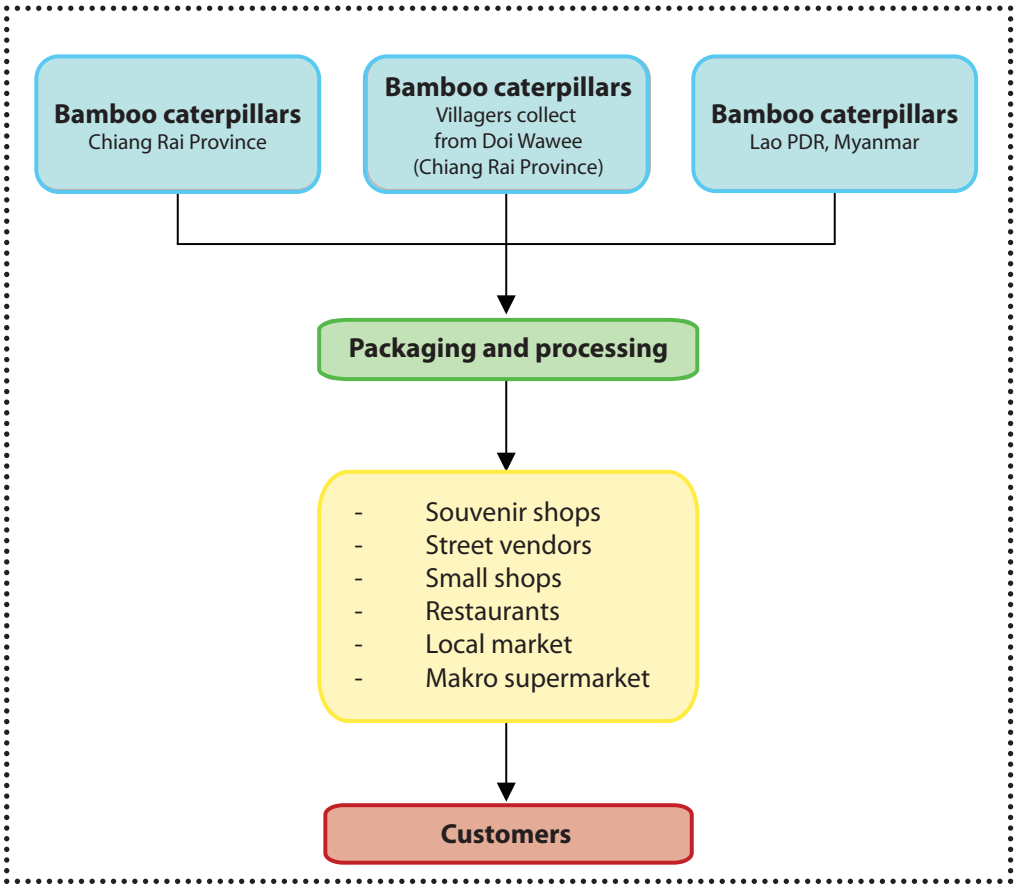

Figure 16. Bamboo caterpillar collection and distribution chain

Recommendations

The eating and trade of edible insect species in Thailand are very common and developing rapidly. Edible insect species are obtained from both wild harvesting and the farming of a few species. But while the sector has developed rapidly in the last 15 years, it is still informal and ad hoc in structure and practice. This is an industry where commercialization has outpaced academic research for species suitable for farming and best farm practices. Consequently, many questions remain unanswered on such matters as management, breeding, hygiene and marketing issues.

However, the edible insect industry has much potential for providing protein sources in the future and for income generation among Thai farmers. Development and creation of intensive insect farms on small and large scales could take the pressure off wild populations of insects in forest areas.

Wild harvesting and insect farming

The edible insect industry was founded on the wild collection of various species from forest areas around villages. Today several species are very popular with consumers and some wild species are becoming increasingly scarce. This has resulted in the need to import some species such as giant water bugs, bamboo caterpillars and grasshoppers. For species such as grasshoppers, as long as the food crops they consume are planted, wild harvesting is unlikely to reduce populations significantly so wild collection can still be considered sustainable.

There is concern that the loss of other species from local environments could occur from collection pressure, which could have undesirable effects *vis-à-vis* pest species they may control.

In the future if the focus of the sector moves away from wild collection to farm-based industry, this will take pressure off wild populations. It is also important to note that insects collected from the wild come with the associated hazard of no quality control and risks such as insecticide contamination. Therefore, farmed insect sources are preferable from a food safety perspective.

To date, farming technology and practices have only been developed for a few species such as crickets, palm weevils and mealworms so there is an urgent need to invest in research and development on farming techniques for other species that are consumed. The Thai Government

currently injects little research funding into insects as a food source compared with other agricultural industries.

Knowledge gaps

One of the problems facing the sector is that it has developed ahead of academic research. As a result farmers encounter problems for which academic and extension workers may have no solutions.

Universities should be aware of this emerging sector as a future career path for students. In the future, entomology courses will not only focus on plant protection but also on commercial insect production.

Further research is urgently needed in all stages of the production of edible insects and particularly postharvest processing. Currently, harvested insects are sold with little processing. There is potential to develop processes for preservation but as yet little work has been done. Proteins extracted from edible insects are likely to be of interest to food technologists and possibly the pharmaceutical industry.

Moreover, information about wild harvesting of insects is limited and incomplete. Consequently, for many species we cannot be sure if collection pressure is at sustainable or unsustainable levels. In addition, little work has been done on best practices or improved methods of wild collection.

Another knowledge gap concerns the scope and span of the edible insect market in Thailand as many production and consumption data are not recorded. Why this information is not available is because the notion of 'insects as food' is not included in national food data surveys conducted by various government agencies.

Capital and investment issues

The capital cost of setting up an insect farm is not great, but may still be a constraint for some otherwise motivated farmers. At present, it is difficult to borrow funds at a reasonable rate for setting up an enterprise. Some finance institutions are disinterested in lending as they are unaware of the economics involved. Cricket farming has been encouraged in Thailand through the SMCE scheme under the Ministry of Agriculture and Co-operatives. However, villages involved in this scheme have minimal involvement in other edible insect species such as palm weevils and the operation of the SMCE is not truly representative of a cooperative in terms of profit distribution.

Ideally, the lead should be taken by government agricultural lenders, as they can influence the development and location of insect farms based on their lending policy. But to date, the agriculture banks are mainly unaware of the insect-farming industry and its potential.

To raise the profile of insect farming, ideally an external organization such as FAO needs to raise the issue with regional governments and potential leaders. Once awareness and understanding of the industry's potential as a new or alternative supplier of food protein are generated, funding is likely to flow into research, processing and banking agencies associated with the new industry.

The other possible boost to the industry could come from venture capital from a commercial operator to fund research into processing and other aspects of insect production.

Public education and marketing

There is a need to raise the profile of edible insects among the public and for farmers who may wish to become involved. Some promotion has been done already by the government for cricket farming in the SMCE, but more widespread marketing and promotion of this new sector would be beneficial to create demand and raise interest among potential farmers and consumers.

Although many people in Thailand consume insect products, the market is still relatively small. There is great potential to increase consumption demand through marketing campaigns aimed at segments of the population who are currently unaware of edible insect products. Some processing and product development may be needed, but if undertaken along with clever advertising, both demand and prices could rise for the producers. Instant products, new foods and microwavable items will all appeal to young and middle class consumers.

Policy-maker awareness

As mentioned earlier, scant data on the edible insect industry are gathered by Thai Government agencies. Consequently, the extent and potential of the insect food industry is largely overlooked by policy-makers. There is a need to raise awareness of the growth and potential of the edible insect sector amongst policy-makers to promote and guide future development and channel funding into research into key areas such as best management practices, food safety issues, promotion and international trade.

Conclusion

The collection of edible insects in Thailand is an historic practice, but their farming is relatively new. Incomplete information nationwide indicates a growing and healthy market. However, knowledge gaps regarding sustainable wild collection and best management practices for farmed insects are a major risk for the industry. The current lack of government involvement in the promotion of the industry is seen as a major weakness. Edible insects have huge potential as a protein source with significance both domestically and internationally in helping to feed the burgeoning global population.

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Appendix 1. Insect species eaten in Northeast Thailand (source: Rattanapan 2000)

Order/Family/common name	Scientific name
COLEOPTERA	
Buprestidae	
Metallic wood-boring beetles	*Sternocera aequisignata* Saunders
	S. ruficornis Saunders
Cerambycidae	
Long-horned beetles	*Aeolesthus* sp.
	Apriona germai Hope
	Aristobia approximator Thomson
	Dorysthenes buqueti Guérin-Méneville
	Plocaederus obesus Gahan
	P. ruficornis Newman
Curculionidae	
Snout beetles	*Arrhines hiruts* Faust
	Arrhines spp.
	Astycus gestvoi Marshall
	Cnaphoscapus decoratus Faust
	Episomus sp.
	Genus near *Deiradorrhinus*
	Hypomeces squamosus F.
	Pollendera atomaria Motschulsky
	Sepiomus aurivilliusi Faust
	Tanymeces sp.
	Rhynchophorus ferrugineus Olivier
Hydrophilidae	
Water scavenger beetles	*Hydrobiomorpha spinicollis* Eschscholtz
	Hydrophilus bilineatus Redtenbacher
	Sternolophus rufipes F.
Dytiscidae	
Predaceous diving beetles	*Erectes stiticus* L.
	Cybister tripunctatus asiaticus Sharp
	C. limbatus F.
	C. rugosus MacLeay
	Hydaticus rhantoides Sharp
	Laccophilus pulicarius Sharp

	Copelatus sp.
	Rhantaticus congestus Klug
Scarabaeidae	
Rhinoceros beetles, elephant beetles	*Xylotrupes gideon* L.
	Oryctes rhinoceros L.
June beetles	*Adoretus* spp.
	Agestrata orichalca L.
	Anomala anguliceps Arrow
	A. antique Gyllenhal
	A. chalcites Sharp
	A. cupripes Hope
	A. pallida F.
	Apogonia sp.
	Chaetadoretus cribratus White
	Holotrichia spp.
	Maladera sp.
	Pachnessa sp.
	Protaetia sp.
	Sophrops absceussus Brenske
	S. bituberculatus Moser
	S. rotundicollis T. Ihto
	Sophrops spp.
	Sophrops species mean *abscessus* Brenske
	Tribe Sericini 7 spp.
Dung beetles	*Aphodius (Pharaphodius) crenatus* Harold
	A. (Pharaphodius) marginellus F.
	A. (Pharaphodius) putearius Reitter
	A. (Pharaphodius) sp.
	Cathasius birmanicus Lansberge
	C. molossus L.
	Copris (s.str.) *carinicus* Gillet
	C. (s.str.) *nevinsoni* Waterhouse
	C. (Paracopris) punctulatus Gillet
	C. (Microcopris) reflexus F.
	C. (Paracopris) sp.
	Gymnopleurus melanarius Harold
	Heliocopris bucephalus F.
	Heteronychus lioderes Redtenbacher
	Liatongus (Paraliatongus) rhadamitus F.

	Onitis niger Lansberge
	O. subopagus Arrow
	Onthophagus orientalis Harold
	O. avocetta Arrow
	O. bonasus F.
	O. khonmiinitnoi Masumoto
	O. papulatus Boucomont
	O. sagittarius F.
	O. seniculus F.
	O. ragoides Boucomont
	O. tragus F.
	O. tricornis Weidemannn
	O. trituber Weidemannn
	Onthophagus sp.
HEMIPTERA	
Belostomatidae	
Water bug	*Diplonychus* sp.
Giant water bug	*Lethocerus indicus* Lepeletier & Sepville
Coriedae	
Leaf-footed bug	*Anoplocnemis phasiana* F.
Stink bug	*Homoeocerus* sp.
Gerridae	
Water strider	*Cylindrostethus scrutator* Kirkaldy
Nepidae	
Water scorpions	*Laccotrephes rubber* L.
	Ranatra longipes thai Lansbury
	R. varripes Stal.
Notonectidae	
Backswimmers	*Anisops barbutus* Brooks
	A. bouvieri Kirkaldy
Tessaratomidae	
Stink bugs	*Pygopaltys* sp.
	Tessaratoma papillosa Drury
	T. javanica Thunberg
ODONATA	
Aeshnidae	
Darner (nymph)	*Aeshna* sp.
Coenagrionidae	
Narrow-winged damselfly (nymph)	*Ceriagrion* sp.

Corduliidae	
Green-eyed skimmer (nymph)	*Epophtalmia vittigera bellicose* Lieftinck
Libellulidae	
Common skimmer	*Rhyothemis* sp.
HYMENOPTERA	
Apidae	
Bees	*Apis dorsata* F.
	A. florea F.
Formicidae	
Weaver ants	*Oecophylla smaragdina* F.
	Carebara castanea Smith
Vespidae	
Wasps	*Vespa affinis indosinensis* Perez
ORTHOPTERA	
Acrididae	
Short-horned grasshoppers	*Acrida cinerea* Thunberg
	Acrida sp.
	Chondacris rosea DeGeer
	Chortippus sp.
	Cyrtacanthacris tatarica L.
	Ducetia japonica Thunberg
	Locusta migratoria L.
	Mecopoda elongate L.
	Oxya sp.
	Parapleurus sp.
	Patanga japonica Bolivar
	P. succincta L.
	Shirakiacris shirakii
	Trilophidia annulata Thunberg
Atractomorphidae	
Short-horned grasshopper	*Atractomorpha* sp.
Catantopidae	
Short-horned grasshopper	*Ratanga avis* Rehn et Rehn
Gryllidae	
Crickets	*Teleogryllus testaceus* Walker
	T. mitratrus Burmeister
	Teleogryllus sp.
	Modicogryllus confirmatus Walker
	Brachytrupes portentosus Lichtenstein

	Gryllus bimaculatus DeGeer
	Gryllus sp.
	Gymnogryllus spp.
	Pteronemobius sp.
	Velarifictorus sp.
Gryllotalpidae	
Mole cricket	*Gryllotalpa africana microphtalma* Chopard
Mantidae	
Mantids	*Tenodera ariddifolia sinensis* Saussure
	Mantis religiosa L.
Tettrigidae	
Pygmy grasshopper	*Euparatettix* sp.
Tettigoniidae	
Long-horned grasshoppers	*Euconocephalus incertus* Walker
	Conocephalus maculatus LeGuillou
	Conocephalus sp.
	Onomachus sp.
	Pseudophyllus titan White
	Homeoxipha sp.
ISOPTERA	
Termestidae	
Termite	*Macrotermes gilvus* Hagen
LEPIDOPTERA	
Bombycidae	
Silkworm moth	*Bombyx mori* L.
Hesperidae	
Skipper	*Erionata thrax thrax* L.
Pyralidae	
Bamboo caterpillar	*Omphisa fuscidentalis* Hampson
HOMOPTERA	
Cicadidae	
Cicadas	*Chremistica* sp.
	Dundubia sp.
	Orientopsaltria sp.
	Platylomia sp.

Appendix 2. Insect species eaten in upper Southern Thailand (source: Lumsa-ad 2001)

Order/Family/common name	Scientific name
COLEOPTERA	
Curculionidae	
Snout beetles	*Hypomesus squamosus* F.
	Rhynchophorus ferrugineus Olivier
Hydrophilidae	
Water scavenger beetles	*Hydrophilus* sp.
Dytiscidae	*Cybister* sp.
Predaceous diving beetles	
Scarabaeidae	*Apogonia* sp
June beetles	*Lepidiota stigma* F.
HEMIPTERA	
Belostomatidae	
Giant water bug	*Lethocerus indicus* Lepeletier & Sepville
Cicadidae	*Dundubia intermerata* Walker
ODONATA	
Libellulidae	
Common skimmer	*Rhyothemis* sp.
HYMENOPTERA	
Apidae	
Bees	*Apis florae* F.
Formicidae	
Weaver ants	*Oecophylla smaragdina* F.
Ants	*Carebara lignata*
Vespidae	
Wasps	*Vespa affinis indosinensis* Perez
ORTHOPTERA	
Acrididae	
Short-horned grasshoppers	*Chondacris rosea burnneri* Uv.
Gryllidae	
Crickets	*Teleogryllus testaceus* Walker
	Gryllus bimaculatus Degeer
Gryllotalpidae	
Mole cricket	*Gryllotalpa africana* Pal
LEPIDOPTERA	
Bombycidae	*Bombyx mori* L.
Hesperiidae	*Erionota thrax thrax* L.

Six-legged livestock:

edible insect farming, collecting and marketing in Thailand

"How to feed a growing world population expected to reach 9 billion people by 2050?"

The traditional answer would be to develop higher yielding grain cultivars and intensify production and inputs.

But for those looking "outside the box" some of the world's under-utilized foods potentially offer even greater opportunities.

Edible insect species offer significant potential to contribute to feeding the world's expanding population. Insects offer several advantages: they are highly nutritious, rich in protein, vitamins and minerals; they are highly efficient at feed conversion; and they taste great!

This publication provides unique insights into the edible insect industry in Thailand – one of the few countries in the world where commercial production of food insects is already a reality. This detailed review offers planners, development workers, researchers, students and wannabe farmers valuable information on the Thai experience, and just maybe…. your future food.

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