Specialty Crops for Pacific Island Agroforestry (http://agroforestry.net/scps)

Farm and Forestry
Production and Marketing Profile for

Honey Bees

(*Apis mellifera*)

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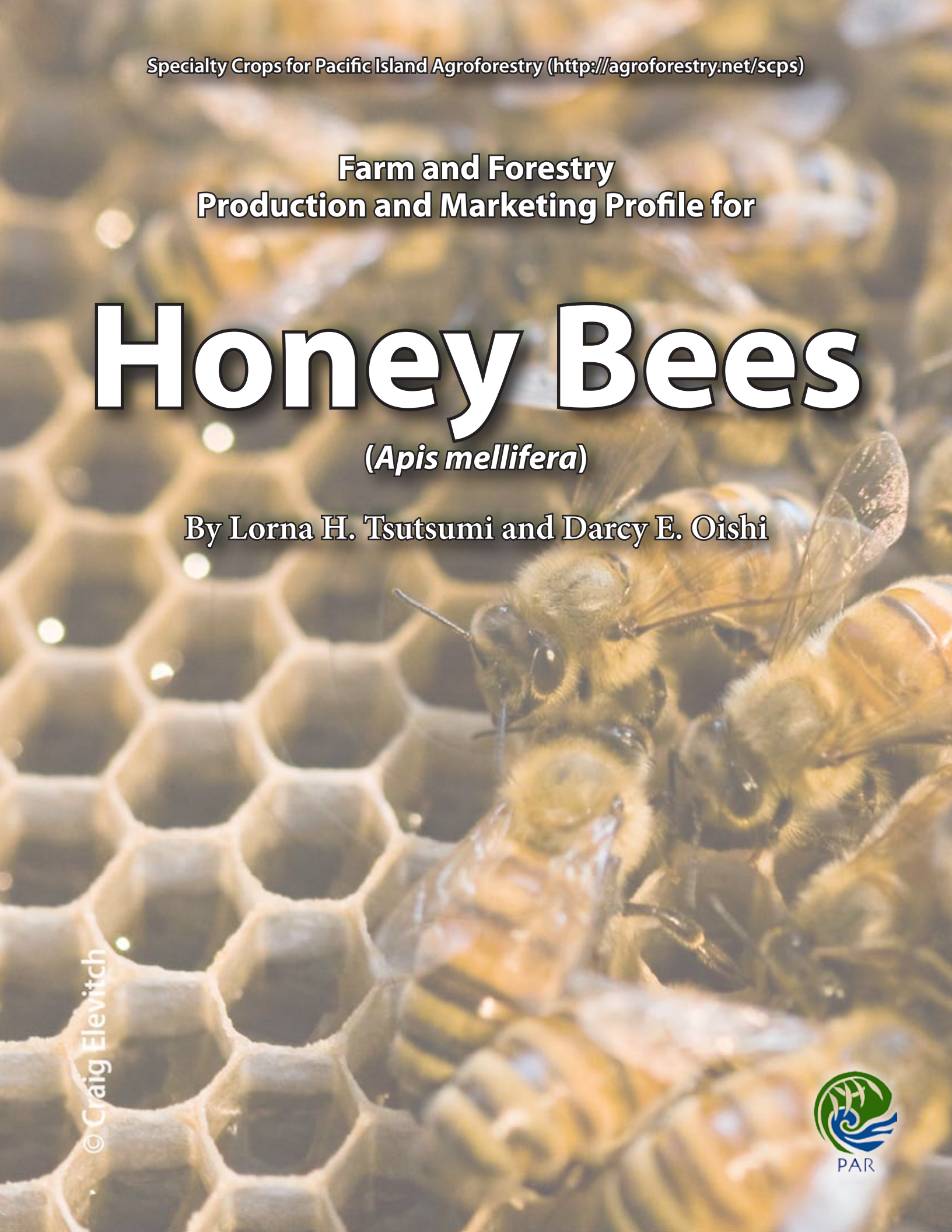

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INTRODUCTION

There are several bee species that are cultivated for their products and pollination services but the most widely used species is the honey bee, *Apis mellifera*. Honey bees are found on all land masses except for the extreme poles. In Hawai'i and in the Pacific, there is a great potential for beekeeping at all scales. Rural areas in the Pacific are ideal for supporting beekeeping activities because of the abundant year round floral sources that can provide enough honey for family and/or community needs with the possibility of additional income from the selling surplus honey. Additionally, because of geographic isolation, Pacific island beekeepers face reduced risk for new bee diseases and pests than most other beekeepers. Beekeepers can develop commercial operations to sell honey and other value-added products for export, especially if branded with localized floral sources or locations. In parts of the Pacific, beekeeping activities are becoming established initially at a small-scale with the possibility of larger commercial operations developing. In Hawai'i, honey production reached its peak in the early 1940's when it was ranked as the 8th leading export behind large agricultural crops such as sugar, pineapple (*Ananas comosus*), banana (*Musa* spp.), macadamia nut (*Macadamia integrifolia*), coffee (*Coffea arabica*), and papaya (*Carica papaya*) (Roddy and Arita-Tsutsumi, 1997). Honey as an industry has the potential for resurgence because of the trend toward agricultural diversification with crops that require insect pollination.

USES AND PRODUCTS

The most well known and utilized of the harvestable products from honey bees is honey. Honey can be consumed as soon as it is harvested from the hive (or stored for later use) or it can be used to make a variety of value-added food products such as desserts, dressings, and mead. Honey can also be used as an ingredient in other value-added products such as cosmetics and health supplements. Other harvestable products derived from honey bee cultivation include: pollen, wax, propolis, royal jelly, venom, packaged bees, and queen bees. Products such as pollen and royal jelly can be consumed in their natural state from the hive but are usually mixed with other ingredients to produce medicinal or health supplements. Other raw products such as propolis and wax need to be processed into a more stable or usable form and then used for a variety of value-added products including cosmetics, candles, and medicinal ointments or tinctures. Venom is a specialized product with a limited medicinal market. Queen bee and package bee producers are specialized beekeepers that utilize their hives for the purpose of producing bees for sale.

Pollination services are an important source of beekeeper income, especially on the U.S. mainland. This is an essential service to ensure maximum fruit yields, especially for large monocrops (e.g., almonds, oranges, apples, watermelon). In Hawai'i and in the Pacific, beekeepers often negotiate a trade for land use in exchange for pollination services. Pollination services performed by honey bees make them an essential component on agricultural lands as well as in local ecosystems that are dependent on insect pollinators.

ORIGIN OF HONEY BEE CULTIVATION

People recognized thousands of years ago that certain types of bees were associated with highly prized honey. In areas of Africa, Asia, and South America, people continue the generations-old practice of collecting honey from wild bee hives. People probably observed that bees would move into hollow cavities such as vases or clay pots and the honey from such colonies could be more easily harvested than from wild

Left: Feral hive in a tree hollow. Kurtistown, Hawai'i. Right: Langstroth bee hives with roofs for rain protection at the University of Hawai'i at Hilo Farm, Panaewa, Hawai'i.

Left: Honey bee worker gathering nectar and pollen in Panaewa, Hawai'i. Right: Gather coffee blossom nectar in North Kona, Hawai'i.

hives. Providing these spaces and encouraging bees to use them as hives were probably the earliest attempts to cultivate bees for purposes of harvesting their hive products. In 1851, Langstroth, considered the "father" of modern day beekeeping, developed the first movable hive that allowed for frames to be removed from the hive, the honey extracted from the frame, and the frame placed back into the hive resulting in little harm to the colony. The movable hive and improved beekeeping methods increased the efficiency of producing honey bee hive products and allowed the servicing of agricultural crops requiring pollination.

THE HONEY BEE AND ITS RELATIVES

Since honey bees belong to the genus *Apis,* which in Latin means "bee," the prefix "api" is often used in beekeeping terms such as, apiarist, a beekeeper or honey farmer; apiary, the location of bee hives; apiculture, the cultivation or farming of bees; and apitherapy, the use of bee products for health purposes.

The official common name (approved by the common names committee of the Entomological Society of America) for *Apis mellifera* is the honey bee. Other English names include: honeybee (without a space), Western honey bee, and Eastern honey bee. Since honey bees are global in distribution, there is a name for honey bee in most languages. In the Pacific where it is cultivated, the honey bee is known in some languages as

Fiji: *oni*
Hawai'i: *nalo mele*
Palau: *hats*
Samoa: *lago meli*
Tahiti: *miel abeille*
Tonga: *hone*
Vanuatu: *lenakel*

This social insect lives in a colony of several thousand bees and is in the order Hymenoptera, family Apidae, and subfamily Apinae. The Asiatic, Eastern, or Indian honey bee (*Apis cerana* Fabricius, also known as *Apis* (*cerana*) *indica*) is native to Asia and is also cultivated for honey and pollination. The use of this species is localized to the East in countries such as India, Japan, and China (Kapil, 1971). However because of the larger amounts of honey and other products that can be harvested from an *A. mellifera* hive, many beekeepers in these areas are converting to this species. Two other species in the genus *Apis* are native to southern Asia but cannot be cultivated. These species, *Apis dorsata* Fabricius, the Giant or rock bee and *Apis florea* Fabricius, the little or dwarf bee, build only single comb nests with minimal amounts of harvestable honey (Lindauer, 1957). Throughout the remainder of text, the common name of honey bee or bee is used in reference to *Apis mellifera* unless otherwise specified.

GEOGRAPHICAL DISTRIBUTION

The native range for the honey bee is Europe, Africa, and the Near East. Selection and adaptation to the biotic (e.g., native plant species) and abiotic (e.g., climate) factors in these different regions resulted in anatomical and behavioral changes in the honey bee leading to the development of distinct subspecies or "races" (Ruttner, 1968). There are a total of 11 subspecies that originated in Europe, three of which are used commonly in small scale or commercial bee operations or by hobbyist beekeepers. One subspecies is *Apis mellifera carnica* Pollmann, commonly known as the Carniolan bee. Its homeland is the southern part of the Austrian Alps and the North Balkan (Yugoslavia). It is considered by many as the gentlest among the different races with long tongues (6.4–6.8 mm), which make this race ideal for the pollination of floral sources that have deep nectaries. The hair cover-

age is grey to brown. Another subspecies is *Apis mellifera mellifera* L., the German bee. Its original homeland is considered to be all of Europe north and west of the Alps. This race is generally aggressive with relatively large bodies and short tongues (5.7–6.4 mm). The third species from Europe is *Apis mellifera ligustica* Spinola, the Italian bee. The original homeland is Italy except for Sicily. This race is generally smaller than the German bee with relatively long tongues (6.3–6.6 mm). This race is very calm and forms strong breeding colonies. There are six subspecies that originated in the Middle East, one of which is used commercially, *Apis mellifera caucasica* Pollmann, the Caucasian bee. The homeland for this race is the valleys of the Central Caucasus. The abdomen is dark with brown spots. The race has very long tongues (up to 7.2 mm). This race uses a lot of propolis but is known to be gentle and calm on the combs. None of the 11 subspecies or races from Africa is used commercially in the U.S. and the Pacific but one that is well known and is a problem for both homeowners and beekeepers in the U.S. and Central/South America is *Apis mellifera scutellata* Lepeletier which is commonly known as the African, Africanized, or "killer" bee.

HONEY BEE IMPORTATION TO HAWAI'I

The first successful introduction of honey bees to the Hawaiian Islands occurred on October 21, 1857. Initial shipments to Hawai'i included Italian, Carniolan, and Caucasian bees in addition to the original German bees. But on September 17, 1908, the territory instituted a ban on importing packaged bees as a means to prevent the accidental introduction of bee diseases and pests. The ban remains in effect today. Thus, the only races that exist in the Hawaiian Islands today originated from these four races (Fullaway, 1909). In more recent times, honey bee semen for artificial insemination, allowed under quarantine regulations, is imported for breeding purposes.

TEMPERATURE AND CLIMATIC RANGE

In order to fly, the internal temperature of the honey bee must be at least 35°C (95°F) which is also the temperature maintained in the center of the hive. The optimal air temperature for foraging is 22–25°C (71.6–77°F). Below 7–10°C (44.6–50°F), bees become immobile due to cold and above 38°C (100.4°F) bee activity stops due to excessive heat, although honey bees can tolerate temperatures as high as 50°C (122°F) for short periods of time. Because of their large range of temperature tolerance, honey bees can be found in latitudes from the equator to the Arctic Circle (Graham, 1992) as long as there are plant sources to provide adequate pollen and nectar for food. Since honey bees usually live in enclosed spaces, rain is not a limiting factor but the lack of water for cooling the hive and for drinking can prevent establishment in arid areas.

BIOLOGY

Colony composition

A honey bee colony is made up of three classes or castes: one queen, several hundred drones, and several thousand workers. The queen is a fertile female that lays the eggs for the colony. The eggs are laid in honeycomb cells and after the larvae hatch, it is the responsibility of the workers to care for the developing young. The drones are males that are responsible for mating with the queen. The workers are sterile females that perform the remaining duties for the hive which include: feeding of the young, defense of the hive, building honey comb, maintenance of the hive, and collection and production of food needed for the survival of the colony.

Anatomy

The honey bee has three body parts, the head, thorax, and abdomen. The head has one pair of antennae, one pair of compound eyes and a set of mouthparts. The thorax has two wings and three pairs of legs. The abdomen varies in shape among the three classes. The queen can be recognized by her large size and relatively long abdomen in comparison to the worker bees. Her stinger is barbless and is used only in fights with other queens. Drones can be recognized by their large eyes and rounder body. The drone does not have a stinger. Because of the duties performed by the workers, there are many anatomical features unique to this class. Workers have a barbed stinger that is connected to the poison sac that is used in defense of the hive. Once imbedded, the stinger cannot easily be removed and continues to inject poison into

Queen bee (center of photo) being fed and groomed by workers.

the intruder. On the second pair of legs, there is a pollen pick which is used to remove the pollen pellet that is found in the pollen basket or corbiculum located on the third pair of legs. The mouthparts of the worker are designed to extract nectar from flowering plants and for softening wax used in making honeycomb.

Development

The eggs of all three classes are white and banana-shaped. The queen lays eggs into worker, drone, or queen cells. Within 3 days, the eggs of all three classes hatch into larvae. The larvae are fed and cared for by nurse worker bees. The larvae of all classes are fed royal jelly for the first three days. Royal jelly is a special protein-rich substance produced by nurse worker bees. After 3 days, the larvae in the drone and worker cells are fed a mixture of diluted honey and pollen known as "bee bread." In comparison, the larvae in the queen cells are fed royal jelly for the duration of their feeding period. After the feeding stage, the larvae develop into a non-feeding pupal stage. At this stage, the cells of all three classes are sealed, from which they emerge as adults. The developmental period for the worker from egg to emerging adult is 21 days. The queen takes 16 days and the drone develops in 24 days.

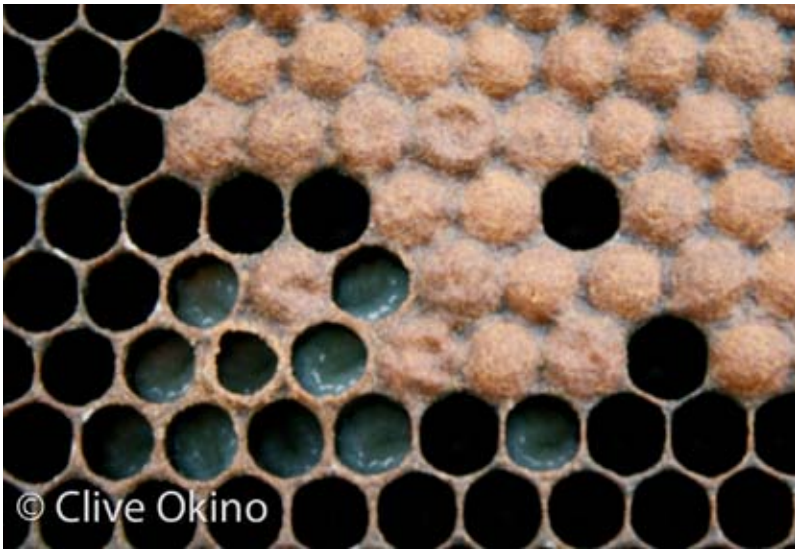
BEEKEEPING BASICS

Basic parts of a hive

In the wild, honey bees can be found in tree hollows, on the outside of well shaded trees, inside structures like houses and sheds, or other undisturbed places that provide adequate space, and are dark and well ventilated. In the past, people used wooden boxes, woven baskets, or hollowed logs to cultivate bees so that the honey and other products could be easily harvested in comparison to collecting from wild honey bee hives. People learned that colonies could be cultivated in movable hives with removable interior frames that could be replaced without disrupting the rest of the hive. The Langstroth or modern day hive is in standard use by beekeepers today.

The basic Langstroth hive consists of one to several hive bodies, a bottom board and a cover. The hive body is a four-sided box with standard inside dimensions of 373 mm x 465 mm (14-11/16 in x 18-5/16 in). The depth of the hive body is variable, but only the deep-body 243 mm (9-9/16 in) and the shallow-body 146 mm (5-3/4 in) are commonly used in Hawai'i. These hive bodies can be stacked. Frames that fit into the hive bodies come in standard dimensions.

In assembling the hive, the bottom board is placed on a stand to keep the hive off the ground. The stand can be hollow tiles, bricks, a wooden bench or specially designed moats stands where ants are a problem. The hive bodies are placed on top of the bottom board and then the cover on top. There



Top: Honeycomb cells being filled with nectar and pollen gathered from the field and stored as honey and bee bread. Middle: Larvae in royal jelly, a protein rich food, in unsealed cells. Bottom: Unsealed cells with worker larvae and wax sealed cells with worker pupae.

is a screen called the queen excluder (which can be purchased through a bee supply company) between two hive bodies that confines the queen to one part of the hive. The hive bodies that are below the queen excluder and where the queen is confined, are called the brood chamber(s) named for the developing bee eggs, larvae, and pupae (brood). Usually the hive bodies used for the brood chambers are the deep type. The hive bodies above the queen excluder are used for the storage of honey and are called supers. The use of a queen excluder ensures that the frames in the super contain only honey. Many small-scale operations and hobbyists prefer the shallow type for supers because the excessive weight of deep hive bodies containing honey-filled frames. The queen excluder is not needed if the hive is maintained primarily for pollination purposes. The entrance to the hive is at the bottom and is created by an opening in the bottom board. In most areas of Hawai'i and in other Pacific regions that have high rainfall, roofing should be added to prevent water damage to the outside and inside of the hive.

Top: Empty frame held with a frame grip and ready for placement into a hive. Bottom left: Frame with drawn out honeycomb. Bottom right: Poor hive management and neglect of bee hives.

Hive management

Hawai'i's climate is relatively mild throughout the year and there is usually some type of flowering plant at any given time. Beekeeping activity occurs all year, unlike in temperate areas where cold temperatures and the lack of flowering plants restrict honey bee activity during the winter. However, even in Hawai'i, larger nectar flows occur in the spring. Beekeepers fall into two categories: migratory beekeepers that move their hives into areas with flowering plants and non-migratory beekeepers who do not move their hives at all. Non-migratory beekeepers must pay close attention to the amount of honey removed from each hive to insure that during times of little flowering in their area, the bees have adequate food supplies until the next set of flowering plants produce nectar and pollen. In drier areas a water source may be needed. Additional hive bodies need to be added when bees are actively collecting nectar. In addition to insuring adequate space, food, and water, beekeepers should also check to make sure there are no apparent diseases or pests. Hives should be inspected at least once a month for honey readiness and for overall health. Poor hive management and neglect can result in reduced honey production and pollination.

Protective clothing

While no clothing is entirely sting proof, specialized clothing can keep beekeepers well ventilated while providing a high level of protection from bee stings. The following clothing is recommended and can be purchased from bee supply companies:

1. **Bee suit.** Usually made from a cotton/polyester blend, the bee suit covers the entire body and should be worn loose.
2. **Helmet and veil.** The helmet can be made of various materials such as plastic or straw. The veil is worn over the helmet and is made of screen material that allows maximum sight and ventilation for the beekeeper during use. The veil can be designed to be connected to the bee suit with a zipper or is attached around the body by string. Another type of headgear combines the helmet and veil in what is termed a hatless veil that can be zippered to the suit as well.

3. **Gloves.** Gloves can be of cloth or leather and have ventilation panels on the sleeve area. The gloves are worn over the hands and lower sleeve portion of the suit.
4. **Shoes and leg straps.** Covered shoes are recommended when working with bees. Leg straps are recommended for bees that are more aggressive. The leg straps are used to close the bottom of the pant leg so that the bees do not crawl up into the suit. Masking tape is an inexpensive means of closing the bottom of the legs.

Equipment

Beekeepers use certain equipment to maintain hives and for harvesting products. The basic equipment needed is as follows:

1. The smoker produces smoke that is blown into the hive prior to opening the hive and occasionally while the beekeeper is working inside the hive. Smoke has a calming effect on bees because it masks the alarm pheromone (chemical substance emitted from bees when the hive is threatened) of worker bees so other worker bees are not alerted to the potential threat of an intruder (Visscher, 1995). To start a smoker, paper is inserted into the smoker and lit. After the fire has started, dense, dried material such as leaves, wood chips, burlap, or rolled cardboard is added. The cover of the smoker is then closed and the bellow side of the smoker is pumped to produce a "cool" smoke. Cool smoke has little associated heat and no flames.
2. The hive tool is a multifunctional metal pry bar designed for beekeeping. It is used to pry open the hive and loosen frames, to scrape off built up propolis, and to pull nails.
3. The bee brush is used to remove bees from the frames and parts of the hive during inspection. It is a light-

Left: Bee suit with hatless veil, gloves, and covered shoes. Panaewa, Hawai'i. Top right: Beekeeping equipment. From left to right, hive tool, bee brush, and frame grip. Bottom right: Lighted smoker filled with ironwood (*Casuarina* sp.) needles.

Left: Smoking hive for inspection at the University of Hawai'i at Hilo Farm, Panaewa, Hawai'i. Right: Frame of mostly wax-capped honey and some uncapped honey (right side of frame).

weight brush which should be held at a 45° angle to brush bees from frames and other hive parts with the least amount of trauma.

4. The frame grip is a metal clamp that is spring-loaded. When squeezed, the grip holds the top bar of a frame and helps to remove it from the hive for honey removal or inspection.

Inspecting a hive

With proper equipment and protective clothing, the beekeeper can comfortably and safely inspect a hive for the quantity of harvestable honey and other products and to assess the health of the colony. The basic procedure is as follows:

- Start smoker and make sure there is adequate material on hand so that it can be refilled if necessary.
- Smoke entrance to the hive. Wait several seconds. Using the hive tool, pry open the hive and smoke the tops of the frames. Close the cover and wait several seconds. Remove cover and set on the side of the hive. Scrape off excess propolis that has built up on the inside of the cover.
- When inspecting the hive for honey, frames above the queen excluder should be checked for the proportion of uncapped and capped cells. If both sides of the frame are at least 75% capped, the frame is ready to be removed for extraction.
- When inspecting a hive for health, remove a frame from below the queen excluder. The eggs within the cells should be white in color. The larvae should be a pearl color and the pupae should be sealed in dome shaped cells. The sealed cells should be clustered and uniformly sealed.

CURRENT PRODUCTION

Honey and wax production in Hawai'i

In 2007, there were 40 operations with 10,000 colonies producing an average of 41.7 kg (92 lb) per colony with an average price of $3.48/kg ($1.58/lb). Wax production in Hawai'i was 2.7 MT (6,000 lb) in 2007 and the price of wax $6.75/kg ($2.94/lb) (DOA, 2007) The honey and wax prices reflect the combined price from wholesale, retail, and cooperative markets.

The two largest beekeeping operations are located on the island of Hawai'i. These two operations follow continental U.S. practices of moving hives to follow seasonal flowering, in particular for macadamia nut, 'ōhi'a lehua (*Metrosideros polymorpha*), and Christmas berry (*Schinus terebinthifolius*). Moving of hives, mild climatic conditions, and the abundance of nectar flow from different floral sources year round, make Hawai'i an ideal location for honey production.

Table 1. Hawai'i honey production data (US$) (Hawai'i DOA, 2009)

Year	# of operations	# of colonies	yield/colony (kg)	average price/kg
2001	30	8,000	39.5	$1.92
2002	30	7,000	61.7	$2.45
2003	29	7,000	51.7	$3.20
2004	31	8,000	43.5	$3.56
2005	34	9,000	59.4	$3.15
2006	35	10,000	42.2	$2.62
2007	40	10,000	41.7	$3.48

Honey and wax production in the United States (including Hawai'i)

In 2007, there were 2,443,000 colonies in the U.S. producing an average of 27.5 kg (60.7 lb) of honey per colony. The average price of honey was $2.37/kg ($1.07/lb) for a total production value of $159,763,000. In 2008, there was as 8% increase in honey production, although the number of colonies decreased compared with 2007. There were 2,301,000 colonies producing an average of 31.7 kg (69.9 lb) of honey per colony. The average price was $3.11/kg ($1.41/lb) for a total production value of $226,814,000. The National Agricultural Statistics Service (NASS) compared prices for 2007 and 2008 (NASS, 2009). The survey reflects all producers with five or more colonies and includes retail, cooperative, and private sales combined.

Table 2. U.S. production by honey type (¢/kg) (NASS, 2009)

Category	Co-op/Private	Retail	Combined
White honeys	227 (2007)	381 (2007)	231 (2007)
	306 (2008)	424 (2008)	311 (2008)
Amber honeys	215 (2007)	414(2007)	235 (2007)
	295 (2008)	453 (2008)	307 (2008)
Specialty honeys	293 (2007)	642 (2007)	387 (2007)
	299 (2008)	668 (2008)	436 (2008)
Combined honeys	220 (2007)	451 (2007)	237 (2007)
	295 (2008)	484 (2008)	311 (2008)

In 2007, Hawai'i's honey yield per colony was the second highest to Missouri that had 47.63 kg (105 lb) per colony. The value of production for Hawai'i and Missouri were $3,967,000 and $5,253,000, respectively. North Dakota had the largest number of colonies among all states with 420,000 colonies for the production value of $28,594,000.

In 2006, the U.S. exported 3,176 MT (3,494 T) of honey, primarily to Canada, Japan, Israel, and Korea. During this same period, the U.S. imported 125,939 MT (138,533 T) of honey primarily from China, Argentina, Canada, India, and Brazil (FAS, Office of Global Analysis, Agricultural Statistics 2008).

Honey (and wax) production worldwide

World honey production was over 1 million MT (1.1 million T) in 1993 (FAO, 1993). Between the two basic market segments; table (direct consumption) and industrial (cosmetic, pharmaceutical, baking purposes), a majority of the honey was sold as table honey. In 2003, China was the largest producer of honey in the world, producing over 310,756 MT (341,831 T) and consumed 146,112 MT (160,723 T). The average customs value was $0.52/kg ($0.226/lb). The Chinese government encourages beekeeping as a means to supplement rural incomes. The U.S. was the second largest producer with 77,110 MT (84,821 T) followed by Argentina. Argentina exports over 90% of its honey and is the second largest exporter of honey behind China. On the world market, the U.S. has a difficult time competing. In order to compete against cheaper foreign honey, niche and specialty markets for honey and other products have been successfully developed in the U.S. and Hawai'i and further markets need to be developed to be competitive with lower priced honeys from China and Argentina.

Although no world wax figures are available, the FAO estimates that approximately 17,000–30,000 MT (18,700–33,000 T) of wax was produced in 2003.

Honey bee activity in the Pacific

Although honey bees were first introduced into the Pacific in the mid 19th century, bee related activities did not develop into promising industries until the 1970's. In 2001, a joint project between New Zealand and the Secretariat of the Pacific Community (SPC) was conducted, the first phase of the Feasibility of Apiculture in the Pacific program, which was designed to strengthen beekeeping activities in the island nations of Samoa, Solomon Islands, Tonga, Niue, Cook Islands (Rarotonga, Mangaia, Atiu), Fiji Islands, Tuvalu, Pitcairn island, Vanuatu, Papua New Guinea, Kiribati, and Wallis & Futuna (Driscoll, undated). The SPC identified several potential bee products that can be produced within the Pacific Islands. In addition to honey, these other products include: propolis, beeswax, beauty aids, medicinal, queen bees, packaged bees, and beekeeping tools (Driscoll, undated). In 2006, a Regional Honey Standards Development Workshop was held in Fiji to further expand on the growing honey industry in the Pacific. The specific goals of the workshop participants (from Fiji, Kiribati, Niue, Palau, Papua New Guinea, Samoa, Solomon Islands, Tonga, and Vanuatu) were to increase the production and standards of honey, tap into niche and regional markets, and elevate honey from a subsistence crop to a viable export. Agriculturally, this industry has been prioritized by many Pacific island nations. Presently, beekeeping activities are limited

on some islands but are thriving on others such as in Fiji, where the annual honey production increased by 65.8% to 494 MT (543 T) in 2007 (Fiji Times, 2008). The importance of beekeeping in Fiji is acknowledged through the issuing of Fijian stamps showing bee hives, bees, a beekeeper, and a child holding a bottle labeled Fiji honey.

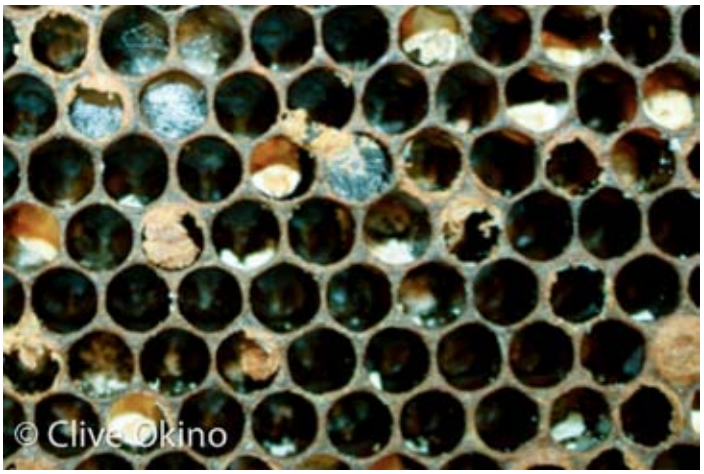
DISEASES AND CONTROL

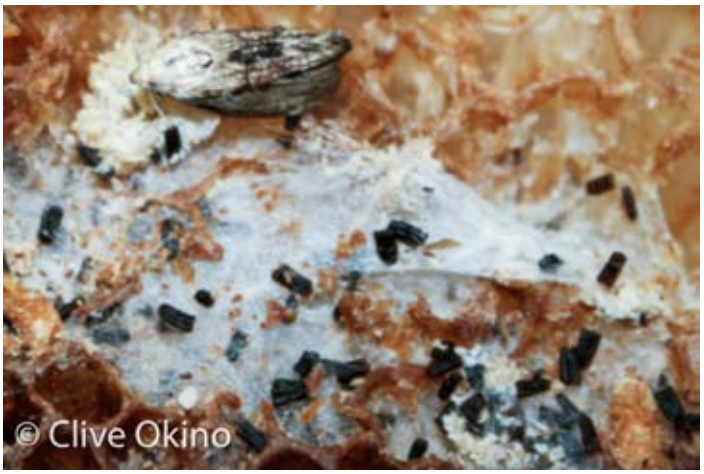
Honey bee diseases fall into two categories, brood and adult bee diseases. The primary brood diseases in Hawai'i are American and European foulbrood and Chalkbrood. The primary adult disease in Hawai'i is Nosema. As a precaution, if a beekeeper suspects a disease, equipment for inspecting a hive should be sterilized before reuse to prevent the spread of disease. Although these are the primary brood and adult diseases, there have been no recent reports of them causing substantial losses to apiaries in Hawai'i. Regular hive inspection can help prevent the occurrence of these serious diseases.

American Foulbrood (AFB). A spore forming bacteria called *Bacillus larvae* causes AFB. The basic symptoms include punctured, sunken wax cappings of sealed brood, a scattered brood pattern, a strong foul odor, and sticky, dead remains of the larvae in open cells. Left uncontrolled, AFB can spread throughout an apiary and destroy all the hives in the area. Burning of all infected hives (to destroy the bacteria and spores) or treatment with the commercially available antibiotic oxytetracycline during early stages of infestation.

European Foulbrood (EFB). A non-spore-forming bacteria, *Streptococcus pluton*, causes EFB. EFB symptoms include punctured, sunken wax cappings of sealed brood, a "souring" odor, a scattered brood pattern, and twisted dead larvae at the base of the cell that are not sticky. Treatment for this disease is to re-queen (remove the present queen with a new queen giving the colony a reproductive 'break' and the workers time to remove the diseased larvae and pupae) or to use the antibiotic oxytetracycline. Similar to AFB, if EFB is not treated it can spread and destroy all the hives in the area.

Chalkbrood. Chalkbrood is caused by the fungus *Ascosphaera apis*. The most obvious symptom is dead larvae covered with powdery white or white-black fuzz. This occurs when there is a lot of moisture in the hive caused by poor ventilation or excessive rainfall in the area. Basic treatment is to move the hive to a drier location, place the hive in more direct sun, or widen the entrance to create better circulation within the hive. Re-queening can also minimize Chalkbrood but there is no chemotherapeutic treatment commercially available. This fungal disease is most prevalent in areas with high moisture levels such as in Hawai'i and other Pacific islands. Thus, special care must be taken in site selection to insure good hive ventilation. Hives can recover from this disease with no treatment as long as good ventilation is restored.





Top: Mummified white larvae in cells caused by Chalkbrood. Bottom: Wax moth adult and larval damage to honey comb cells with excrement and silk remains.

Nosema. Nosema is caused by the protozoans *Nosema apis* and *Nosema cerana*. It affects queen, drone, and worker adults. Symptoms include large numbers of bees crawling at the base of the hive that are unable to fly and vomiting observed as yellow liquid streaks on the bottom board. The queen, if infected with *Nosema*, has a decrease in egg-laying capacity. When dissecting a bee suspected with *Nosema*, confirmation is made by inspecting the midgut. If the midgut is swollen and white in color and bees are displaying the above-mentioned symptoms, *Nosema* is the probable cause. Control is with an antibiotic, bicyclohexylammonium fumagillin. Chen et al. (2007) indicates that *Nosema* is found in Hawai'i and in other parts of the U.S. and considered one of the most prominent adult bee diseases. Antibiotic treatment is required and should be applied as directed on the label or this disease will spread and destroy all hives.

Colony Collapse Disorder (CCD). This disorder has not been identified in Hawai'i. CCD can be recognized by the sudden decline of a large number of worker bees from a hive.

The cause is presently not known but researchers have associated this disorder with several potential causes including the varroa mite, acute paralysis virus, pesticides, genetically modified crops, and radiation. In the U.S., colony losses were approximately 29% from September 2008 to April 2009 from all causes, although CCD was reportedly responsible for 26% of all colony deaths (ScienceDaily, 2009).

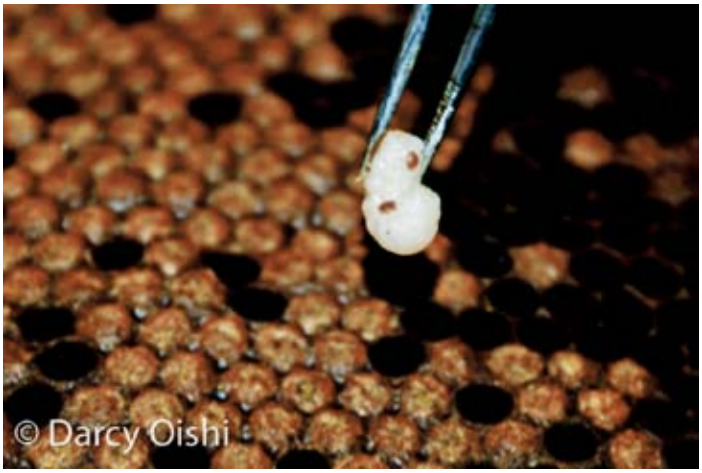
PESTS AND CONTROL

Wax moth. In Hawai'i, the greater wax moth (*Galleria mellonella*) accounts for most of the damage to honeycomb, even when the comb has been removed from the hive and stored for reuse. The wax moth larvae burrow through the honeycomb cells leaving excrement and silk-like remains which leave the honeycomb unusable for the storage of pollen, honey, or brood. The pupae can be found on the top bars of the frames in the brood chamber. Usually, the wax moth is only present in weakened hives. Several fumigants are available, but the most common includes the active ingredient paradichlrobenzene. Since the wax moth attacks only weakened hives, treatment is required or the hives will die. When wax cappings are collected during the honey extraction process, they need to be cleaned and processed so that the wax moth does not use the wax for food and development.

Little fire ant (LFA). LFA, *Wasmannia auropunctata*, is a small orange colored, slow moving ant that can inflict painful bites. These ants live in trees as well as on the ground. Similar to the red imported fire ant (RIFA, *Solenopsis invicta*), found in temperate areas, LFA invades hives for the honey and the brood resulting, if unattended, in the death of the colony. LFA was first discovered on the island of Hawai'i in 1999. At present, infestations of LFA have also been identified on Kaua'i and Maui. Moats at the base of stands and insecticide applications around the hives are the only measures that have been effective. There are commercial insecticides that are available which can be used around honey bee hives (HDOA, 2007). Care should be taken, as some of the active ingredients used for ant control are extremely toxic to bees. Insecticidal sprays should be avoided if possible.

Varroa or Asiatic bee mite. The varroa mite (*Varroa destructor*) became established in the Western world in the 1950's and was discovered in North America (Florida and Wisconsin) in 1987. By 1988, the varroa mite was detected in twelve U.S. states. Until recently, this mite was not found in Hawai'i. The absence of this mite was a valuable marketing tool for queen rearing businesses on Hawai'i Island. The mite was first discovered on O'ahu in April 2007 and then on the island of Hawai'i in August 2008 (Ramadan et al., 2008). Presently, the mite is widespread on O'ahu and limited to parts of the island of Hawai'i (from Hilo south to Kapoho and Captain Cook south to Pāhala). The mite can affect all stages by feeding on the blood (haemolymph) of the larvae, pupae, and adults. One of the most damaging effects of the varroa mite is the transmission of viruses resulting in such characteristics as wing deformation in adults. Detection of the mite at early stages can be made by visually inspecting brood with a brood comb. The mite prefers drone brood. An alternative method is to use sticky boards placed at the bottom of the hive box. A plastic screen keeps the bees from sticking to the board but any mites that naturally drop off of bees in the hive will be trapped.

Treatments can be purchased through bee supply companies. In addition to miticides, there are a variety of non-toxic controls or cultural controls that can be used. For small-scale production, powdered sugar dusted directly onto the bees can be used to reduce mite populations. Care should be taken to prevent the sugar from entering into the cells. Another cultural control method is the use of super cell frames. Super cell frames are frames that are smaller in size than normal comb cells. Larvae that develop in a super cell have a shorter developmental time, which slows mite population growth. Using drone frames is another viable control



Top: Moat stand to prevent LFA infestation to hive from ground-dwelling ants. Panaewa, Hawai'i. Instructions for this stand are available at (Tsutsumi et al., undated). Bottom: Varroa mites (dark spots) on a worker larva removed from a capped cell.

method. Varroa mite females preferentially lay their eggs in drone brood cells. After 3–4 weeks in the brood chamber, the drone frames can be removed and killed by freezing for 24 hours. This process will reduce the rate of varroa mite buildup within the hive. Commercial companies are also developing mite controls that are specific to Hawai'i and are applicable to tropical regions.

Small hive beetle. One of the most destructive of hive pests is the small hive beetle (SHB), *Aethinia tumida*. It is a small sap beetle native to Africa. Although not found in Hawai'i, the SHB is now common in the mainland U.S. and Australia. SHB larvae feed on honey, pollen, wax, and honey bee eggs and larvae. SHB feeding activity destroys the capping and comb and their waste causes the honey to become discolored and may encourage the fermentation of honey, rendering it unsellable. Heavy infestations can lead to abandoning of hives and may necessitate the destruction of hive boxes, comb, and all other material. The humid, tropical conditions of many Pacific Islands are ideal for this beetle, increasing the risk of it reaching difficult or uncontrollable levels rapidly. Detection can be made difficult as larvae could be mistaken for the wax moth larvae. Adult beetles can be mistaken for other sap beetles present in the Pacific islands.

Tropilaelaps mite. Less well known than other bee mites, the Tropilaelaps mite (*Tropilaelaps* spp.) represents the greatest threat to beekeeping in the Pacific and mainland U.S. It is widespread in Southeast Asia. Like the varroa mite, the Tropilaelaps are ectoparasites that attack honey bees and a few other species of *Apis* species. It is an obligate parasite and cannot survive for more than a week away from bee brood. Mite populations can grow rapidly all year round even in temperate climates (Camphor et al., 2005) leading to brood mortality and reduced longevity of the adult bees. Ultimately, heavy Tropilaelaps infestations can cause collapse of the hive, making it a more significant pest than the varroa mite (Laigo and Morse, 1968). Also, like the varroa mite, it can vector viruses and diseases (Forgren, 2009). Treatment options include fumigants that are available through bee supply companies. According to Culliney (2003), there were no known infestations of this mite from bee samples taken from the islands of Kaua'i, O'ahu, Maui, and Hawai'i during a survey taken in 2000 and 2001. Presently, there are no reports of this mite in Hawai'i.

Tracheal mite. The tracheal mite (*Acarapis woodi*) is already present and established on the mainland U.S. and much of the world. Unlike varroa and Tropilaelaps, the tracheal mite is an endoparasite. The tracheal mite lives within the trachea or breathing tubes of the bee. The mites live, breed, and feed within the trachea where they penetrate the tracheal walls and feed on the haemolymph (blood) of the bees. Heavily infested bees show signs of scarring of the tracheal tissue and exhibit higher than normal bacterial counts. The mites are spread through bee to bee contact and can only survive for a short period of time away from a honey bee host. Older worker and queen bees seem to develop resistance to tracheal mites. Heavily infested bees can die and collapse of the hive can occur. Chemical treatments can be purchased through bee supply companies. An alternative control method is to place vegetable oil patties on the top bars of frames between hive bodies. The vegetable oil patties are made with a ratio of two parts granulated sugar to one part vegetable shortening. The bees walk on the patties within the hive which allows the oil in the patties to spread on the bees, reducing recognition by the mite of the bee as its host. A survey for this mite taken in 2000 and 2001 showed no infestations on all the major Hawaiian Islands (Culliney, 2003). This mite has still not been reported in Hawai'i.

Other pests of the hive. In the Pacific, the most prominent pests of the hive are ants, toads, and termites. Because the wood used for the hive bodies is untreated, termites can feed and inhabit the bodies and wood frame pieces, making the removal of the frames from the hive body difficult at best and stacking of the hive bodies impossible. In order to prevent termite infestations, the hives and frames need to be inspected on a regular monthly basis. Once infested, the hive bodies and frames need to be replaced. In addition to LFA, other ant species can enter the hive for honey and protein (brood). Physical barriers such as stands coated with an adhesive or placed into a water moat are effective. Toads feed on adult bees as they exit or enter the hive. Stands made with bricks or tiles elevate the hive so that toads cannot reach the bees. These stands also keep the hive off the ground, preventing termite and ant infestations and reducing water damage to the hive.

Pesticides

Pesticides, chemical substances that are used to kill pests, are commonly found in agricultural settings where honey bees are active. Many of these pesticides are toxic to honey bees and beekeepers should be aware of the type of pesticides being applied in their area. To reduce the possibility of pesticide poisoning, it is prudent to locate hives at least 90 m (300 ft) from any treated fields. Beekeepers should look for high amounts of dead bees (1,000 or more per day) at the base of the hive as an indicator of severe pesticide poisoning. Additional symptoms of pesticide poisoning include: overly aggressive bees, bees that are unable to fly, dead brood in front of the hive entrance, and a poor egg-laying pattern by the queen.

Since minimal or no use of pesticides in agricultural areas with honey bees is recommended, a specialty market is quickly developing for organic honey. Organic honey must meet strict organic certification in its production, process-

ing, and packaging. At least 6.4 km radius from the hive must be pesticide-free.

HARVESTABLE PRODUCTS FROM THE HIVE

Honey

Honey bees make honey from the nectar they collect from plants. Foraging worker bees ingest nectar and store it in their honey stomach to be carried back to the hive. The nectar is then placed into a honeycomb cell to undergo the process of evaporation and sugar changes. Before the honeycomb cell is capped with wax, the liquid inside the cell that is between nectar and honey is called "green" honey. Bees cap the cell with wax when all the sugar changes have taken place and the moisture content of the liquid is below 20%. After capping, the honey within the capped cell is referred to as "ripe" honey. Whether in the cell or extracted, ripe honey can last indefinitely. In addition to water, the major components in honey are several sugars, primarily glucose and fructose and a small amount of sucrose. Less than 1% of honey is made up of acids, proteins, and ash.

There are different ways to describe or classify honey. The first is by the plant source of the nectar that was used collected. When bees gather the nectar from a primary plant source, the honey is usually labeled with the source, such as macadamia nut, coffee, kiawe (*Prosopis juliflora*), or ʻōhiʻa lehua. Honey that is from one plant source is also known as monofloral. Sometimes a combination of two plant names is included such as macadamia nut/ʻōhiʻa lehua or citrus/eucalyptus. When the plant source is unknown or there are many sources, the honey is labeled by seasons (e.g., winter, summer) or given a locality name (e.g., Volcano, Kona) or an exotic marketable label (e.g., lava gold, Hawaiian sunset). Honey that is from more than one plant source is also known as polyfloral.

Honey contains over 180 different substances, which is why it is nearly impossible to manufacture artificially. The composition and nutritional value also varies depending on the floral source used in making the honey (Krell, 1996).

Other characteristics are also used to classify honey. Extracted honey has been removed from the cells using gravity, centrifugal force, or straining. If the honey has no visible crystals, it is called extracted liquid honey. If the bottom portion of the container has visible crystals, it is called extracted partially crystallized honey and if the entire honey is crystallized in the container, it is referred to as extracted crystallized honey. Crystallization occurs when the glucose precipitates out of the honey. According to the National Honey Board, the amount of crystallization is dependent on several factors including the amount of glucose in the honey, small particles in the honey (such as pollen, propolis, wax, or air bubbles), and storage conditions (White, 1992).

Table 3. Nutritional value per Tbsp (21 g)

Water	3.6 g	**Minerals**	
Fructose	17.3 g	Calcium	1.0 mg
Glucose	8.1 g	Iron	0.05 mg
Maltose	1.5 g	Zinc	0.03 mg
Sucrose	0.3 g	Potassium	11.0 mg
Vitamins		Phosphorous	1.0 mg
Thiamin	<0.002 mg	Magnesium	0.4 mg
Riboflavin	<0.06 mg	Selenium	0.002 mg
Niacin	<0.06 mg	Copper	0.01 mg
Pantothenic Acid	<0.05 mg	Chromium	0.005 mg
Vitamin B-6	<0.005 mg	Manganese	0.04 g
Folate	<0.002 mg	Ash	0.04 g
Vitamin C	0.1 mg		

Top: Honey labeled with location (Kaʻū). Bottom: Honey labeled with location and plant source (Big Island ʻōhiʻa lehua, right).

Extracted honey is graded into four classes based on the predominance of flavor and aroma from a single floral source, the absence of defects, which refers to the degree of cleanliness, and clarity, which identifies suspended particles such as air bubbles and pollen grains in the honey. The four grades are U.S. Grade A also known as Fancy, U.S. Grade B known as Choice, U.S. Grade C also called Standard and U.S. Grade D called substandard. This grading system is important for commercial operations that can use quality standards as a marketing tool.

The color of the extracted honey is not graded but is used as a describer of the honey. The seven recognized color classes from USDA guidelines are: water white, extra white, white, extra light amber, light amber, amber, and dark amber (Crane 1980).

Honey processing

Frames that are at least 75% capped on both sides of the frame are harvested. The excess propolis is scraped off the frame and the frames sorted by honey color (if there are many frames). The cells are uncapped with a heated knife. A scratcher is used to open any remaining uncapped cells. The cappings can be cleaned and processed for beeswax.

There are different methods for extracting honey depending on the number of frames that need to be extracted. Commercial operations have electric extractors that use centrifugal force to "spin" the honey out of the cells. Small-scale electric or hand-cranked extractors (also using centrifugal force) can be purchased from bee supply companies and can accommodate 2–20 frames. For one or two frames for home use, the honey can simply be allowed to drip out of the uncapped cells onto a collecting tray or the comb can be cut into pieces and the honey strained out through a cloth. After straining, the extracted honey is allowed to settle in a holding container. The honey should be allowed to settle overnight so that the air bubbles, wax pieces and any other particles float to the top and can be removed before bottling.

Comb honey

Comb honey is sold with the honey within the wax sealed honey comb cells. Prior to the development of extracting methods, most honey was sold as comb honey. There are three types of comb honey; comb honey, chunk honey, and cut comb honey. Comb honey is made by placing specially prepared frames fitted with small wood boxes usually 10–13 cm (4–5 in) or plastic rings approximately 10 cm (4 in) into a hive with wireless wax foundation. Comb honey kits are available commercially. These frames can then be removed and packaged for sale. Comb honey is classified as U.S. Fancy, U.S. No.1, U.S. No. 2, and unclassified, based on the appearance of the wax, attachment to the frame, uniformity of the honey, and degree of cleanliness. Chunk honey is made by using a metal form to cut honeycomb filled with honey and capped with wax into smaller pieces usually less than a 10 cm (4 in) square. The pieces are then packaged in usually clear containers for sale. Cut comb honey consists of pieces of comb honey in a container as in chunk honey but with the remaining space in the container filled with extracted liquid honey. Although cut comb and chunk honey have a limited market potential, they are not subject to the conventional grading of comb honey.

Creamed (or whipped) honey is made through a process that controls the crystallization of the honey by adding a small quantity of crystallized honey (ratio 1:9) to liquid honey. The smaller the granules of crystallized honey used to start the creamed honey, the smoother the final product. The mixture should be whipped to insure even distribution of the honey granules. Once evenly stirred, the mixture is left overnight and then packaged.

In order for honey (extracted, comb, creamed) to be sold commercially, it must be processed in a certified kitchen. The certification is done by the local Department of Health. The requirements for a honey processing facility include a sink with hot and cold running water (a three compartment sink is preferred), a wash-up area, and a solid floor with drainage.

Additional processing

Honey can be processed in different ways, which should be identified on the label. Raw honey refers to honey that has been extracted from the comb or sold in the comb with no additional processing. It contains small particles including wax pieces and pollen. Filtered honey has been processed through a screen to remove small particles such as wax and pollen. The process can be done with or without heat. Heating will hastened the straining process and can simultaneously pasteurize the honey. Unpasteurized honey is honey that has not been exposed to heat. Exposure to heat changes some of the temperature sensitive sugars and many believe causes honey to lose some of its beneficial health and medicinal properties. Pasteurized honey is honey that is heat treated during processing. For processing purposes and for large commercial operations, pasteurization allows for the easier handling of the honey. One common treatment is to heat the honey to 77°C (170°F) then the honey is cooled to 54°C (130°F). Kosher honey must meet certain guidelines and be certified by a recognized rabbi. Kosher honey is minimally processed and the equipment and production of the honey must meet kosher dietary laws.

Beeswax

Beeswax is produced by workers that are about 12–15 days old and is used in the construction of honeycomb. These cells are used to store pollen and honey for food and also used for the larval development of the workers, drones, and queens. Worker bees have four pairs of wax glands on the underside of their abdomen. After consuming large quanti-

ties of honey, these wax glands secrete wax scales that are then pulled from the abdomen and chewed by the mandibles of the worker's mouth. This softened wax is then used to build hexagonal shaped honeycomb cells. Research has shown that workers consume about 8 units of honey for every one unit of wax produced. Thus, beekeepers should reuse beeswax frame foundation (after extraction) for as long as possible to reduce the amount of beeswax that is needed to build honey comb cells on new frames.

The main compounds found in pure beeswax include hydrocarbons (14%), monoesters (35%), diesters (14%), and several types of acids (12%) (Tulloch, 1980). The main source of commercial beeswax is the cappings that are collected in the uncapping stage of extracting honey. The wax in cappings is mixed with honey, pollen, and propolis residues that must be separated out so that the wax can be stored in purified form. There are several different methods for cleaning the wax cappings. The solar extraction method uses a large glass-covered wooden box with a metal bottom. The glass-covered opening is directed towards the sun to melt the cappings, which then drain into a collection tray. In the sack method, the wax cappings are placed into a porous cloth sack. The sack is submerged into a tank of hot water, which is then stirred to melt the wax in the sack. When all the cappings have melted, the sack is removed and the water/wax mixture is cooled. The wax layer will harden on the top of the water and can then be removed. Using a simple straining method, the wax cappings are added directly to hot water and the mixture strained for non-wax particles. The solution is allowed to cool and the wax layer that hardens on the top can then be removed.

Pollen

Pollen is produced in the male part of the plant. There are two basic types of pollen, airborne, which is carried by the wind, and non-airborne pollen that requires a carrier such as honey bees to move it to the female part of the plant. Pollen sticks to the hairy body of the foraging worker bee and the bee carries it from flower to flower, accomplishing pollination for the plant while collecting nectar and pollen. The worker bee periodically combs off the excess pollen grains from its body with rows of hairs located on the inside of the third pair of legs. The bee compresses the collected pollen grains in the "pollen press," and stores them in the corbiculum or pollen basket, which is also located on the third pair of legs. When the basket is full, the foraging worker bee returns to the hive. Once in the hive, the pollen pellets are removed and placed into cells and stored for later use by the colony as food.

Since honey bees usually collect more pollen than is required for the colony's needs, beekeepers have developed a special device known as a pollen trap which can be placed at the entrance of the hive to collect the pollen pellets from returning foraging bees. The collected pollen is processed and then sold for human consumption. The basic design of the pollen trap allows workers to enter into the hive through a mesh screen large enough to allow the bee to enter without the protruding pollen pellets, which are dislodged. The

Left: Uncapped and capped honeycomb cells made of beeswax filled with "green" honey (right) and ripe honey (left). Right: Specially made rollers for pressing recycled wax into new foundation for frames. Āhualoa, Hawai'i.

Left: Returning worker with light colored pollen pellets held within the pollen baskets located on the outer side of each hind leg. Top right: Tray from a pollen trap with collected pollen pellets. The color of the pellets can help the beekeeper determine which plant species the bees are visiting. Āhualoa, Hawai'i. Bottom right: Commercially available bee pollen in North Kona, Hawai'i.

dislodged pellets fall into a collecting drawer that is emptied daily by the beekeeper. The trap should not be used for more than a few days since pollen is a dietary requirement of developing worker and drone larvae.

Bee pollen is considered a "complete" food for people because, depending on the plant source, it usually contains all essential nutritional elements required by humans. These nutritional elements include all the essential amino acids, minerals, and B vitamins. It also contains anti-oxidants such as flavanoids, vitamins C and E, beta-carotene, and lycopene. Depending on the plant source, pollen contains proteins (20%), carbohydrates (30%), starch (3%), and a large percentage of mixed and undetermined components (Crane 1990). Presently, there is no appreciable commercial production of pollen within Hawai'i.

Royal jelly

Royal jelly is secreted by worker bees that are 5–15 days old. It is fed to queen larvae for the entire larval feeding period and to worker and drone larvae for the first 3 days of development. Royal jelly is produced in the hypopharyngeal glands in the head of the worker bee. The chemical composition is water (66%), protein (12%), lipids (5%) and other minerals including B vitamins (Lercker et al., 1992). Royal jelly is used as a human dietary supplement and in cosmetics.

The basic process to extract royal jelly from the hive requires specialized cell frames designed to rear queens. Since queen larvae require the most royal jelly, frames of queen cells are set into hives and after 3 days, the royal jelly is scooped or vacuumed out of the cells. To produce one pound of royal jelly, an average of 1,000 3-day-old cells are needed. The royal jelly is then strained and kept refrigerated for use. Presently within the state of Hawai'i, there are no known producers of royal jelly.

Propolis

Propolis is made from the sap and resins gathered by honey bees from plants. The sap and resins are gathered by the foraging worker bee in its mouth and placed directly into

the pollen basket for transport back to the hive. Generally, propolis is composed of waxes (30%), resins (55%), ethereal oil (10%), and pollen (5%) (Krell, 1996).

Bees use propolis to seal cracks, reduce openings, and strengthen the base of comb attachment. It is considered to have antimicrobial properties against bacteria and fungi, which help the bees maintain their hive. Usually considered a nuisance material in the hive by beekeepers, the request for propolis for value-added products such as tinctures and extracts has resulted in some beekeepers using special screens to collect propolis in the hive. Presently within the state of Hawai'i, there are no known commercial producers of propolis.

Brood and adults

Brood refers to the immature developmental stages of the honey bee, eggs, larvae, and pupae. The larvae, pupae, and adult bees can be harvested from the hive for several purposes. Adult bees are collected to be sold as packaged bees. The larval and pupal stages are sold for animal feed and for human consumption. They are removed from uncapped cells by shaking the frame or gently flushing the cells with water. The larvae and pupae can be consumed fresh, dried, or frozen as a protein-rich food.

Venom

Honey bee venom is produced by a pair of glands near the sting structure in worker bees. Workers that guard the entrance to the hive have the most venom stored in the venom sac, which can be released when the barbed stinger penetrates an animal. Each stinger can inject 0.15–0.3 mg of venom. In humans, the median lethal dose is 2.8 mg per kg body weight, which would require hundreds of stings for an average-size adult. Most deaths occur from allergic reactions resulting in heart failure or suffocation (Schumacher et al., 1989). The large percentage of venom is water with the remaining proportion composed of enzymes, proteins, peptides, amino acids, amines, sugars, phospholipids, and volatile compounds (Dotimas and Hider, 1987). There are many diseases or conditions that are believed to be treatable with bee venom. Many of these reports, although not based on scientific evidence, suggest that the venom is effective for conditions and diseases such as arthritis, bursitis, ulcers, ligament injuries, infections, and asthma. Bee venom can be harvested from worker bees with the use of a special trap placed into the hive. The trap is equipped with wires that generate an electrical current. The shock causes the bees to sting a collecting plate or membrane and the collected venom is then freeze-dried and stored in the refrigerator or frozen until used. Venom is a very specialized product with only one producer in the U.S. and no producers in Hawai'i. The average price is $100–200/g of dried venom.

Propolis on the inside of a hive cover at the University of Hawai'i at Hilo Farm, Panaewa, Hawai'i.

Other markets

Pollination

There are several agents that pollinate plants, including wind, water, birds, bats, and insects such as wasps, ants, flies, and moths, but the most important are bees. There are several types of bees that pollinate, including leafcutter bees (Magachilidae), stingless bees (Apidae), and the little honey bee (Apidae), but it is the honey bee that is most often employed by people, especially for commercial purposes. Honey bees are considered good pollinators because when they collect nectar and pollen for their own needs, they tend to carry pollen from plant to plant, completing the pollination process. They also tend to collect pollen from one plant species at a time, which increases their effectiveness as pollinators. Additionally, honey bees can be kept in movable hives and provide other harvestable products as a by-product of their pollination services. It is estimated that honey bees are responsible for pollinating over $34 billion worth of crops in the U.S., many of which are solely or primarily dependent on bee pollination. It is no wonder that Albert Einstein once stated that if honey bees were to disappear, people would have only 4 years to live. Some of the crops in Hawai'i that are the most dependent on honey bee pollination are lychee (*Litchi chinensis*), macadamia (*Macadamia integrifolia*), rambutan (*Nephelium lappaceum*), and all members of the Cucurbitaceae family. Crops that would be less impacted by the lack of honey bees are coffee (*Coffea* spp.), longan (*Dimocarpus longan*), avocado (*Persea americana*), and mango (*Mangifera indica*) (Nagao, pers. com.).

Pollination services are becoming an important honey-related industry. Previously in Hawai'i and the Pacific, pollination services were accomplished largely through feral bees and to a much lesser extent, native pollinators.

Queen bees

A colony will naturally replace a queen when her productivity becomes diminished. Younger queens produce more

Honey bees are important pollinators for many crops, including macadamia nut (top) and lychee (bottom). Hōlualoa, Hawai'i.

eggs than older queens, resulting in more bees and ultimately, greater honey production. Beekeepers replace existing queens (known as "re-queening") about every 2 years as part of their management practices to improve egg production. Beekeepers purchase queens from queen producers who raise queens of specific races. The price for a queen bee is currently about $20 (Bush, 2007). Producing queens can be a lucrative business. In Hawai'i, queen producers have certain advantages over continental U.S. queen producers. Hawai'i's climatic conditions allow for a steady, reliable delivery of queens. Coupled with breeding for the resistance to certain bee related diseases, the favorable climate helps Hawai'i to compete with queen producers elsewhere. Hawai'i also has the advantage of fewer pests and diseases. On the island of Hawai'i, there are several queen producers. Because of geographical isolation and favorable climatic conditions of many Pacific islands, there is potential for queen rearing ventures elsewhere in the Pacific.

Packaged bees

In many places, bee hives are started from purchased packaged bees. Live worker bees with or without a queen are sold in ventilated containers weighing usually 1–1.5 kg (2.2–3.3 lb) (container and bees). In the Pacific, New Zealand exports packaged bees on a regular basis to Canada, Korea, and Germany. Fiji supplied Tonga with some shipments of packaged bees in 2001. Although queen bees are a big business in Hawai'i, there are no known local sources of packaged bees.

Agritourism

Agritourism or agricultural tourism is an increasingly popular form of vacationing. Visitors to operational farms learn about how crops are grown, processed, and marketed, often including tasting and sampling of products. Many farms charge a visitor fee, which adds to their revenue. Because of the desirability of vacation destinations to the Pacific, agritourism for honey operations in these areas has potential for growth and development.

VALUE-ADDED PRODUCTS

There are many value-added or secondary products that can be produced from the primary bee products covered above.

Honey

Honey can be used in the making of fermented, medicinal and cosmetic products, and as a sweetener in other products. There are many recipes that include honey as an ingredient for salad dressings, desserts, main dishes, side dishes, and non-fermented beverages such as lemonade and tea. One part honey can be substituted for 1.25 parts granulated sugar. For substitution of corn syrup, the conversion ratio is one to one. Lower temperatures may be required for baking with

honey because of the quicker browning process, depending on the quantity of honey used.

Honey can also be used in brewing beverages such as beer and mead. Mead is an alcoholic drink fermented from diluted honey. To make mead, honey is diluted with water, pasteurized, and then cultured yeast cells are added. The mixture is allowed to ferment at a temperature optimal for the yeast cells.

Honey is naturally resistant to microbial contamination. It is therefore used for wound treatment by placing it directly on a cut or burn. Honey is also mixed with alcohol or herbal extracts for throat and mouth infections (Armon, 1980; Dumronglert, 1983). A simple common remedy for a sore throat is to mix two teaspoons of honey and a squeeze of lemon in a cup of tea.

Honey is also added in small quantities to cosmetics products such as lotion, shampoo, soap, facial cream, and lip balm for its moisturizing properties and aroma.

Pollen

Bee pollen has many uses. It is used in medicine to help desensitize allergic patients with specially prepared pollen extracts that are subcutaneously injected (Science Daily, 2007). Pollen is included in cosmetic products for its nourishing properties for the skin, although its rejuvenating effects have not been scientifically proven. Pollen is also used as a food and dietary supplement or as an ingredient in food recipes (Krell, 1996). An easy drink recipe is a teaspoon each of honey and pollen mixed into a cup of fruit juice.

Wax

Much of the beeswax produced in the U.S. is sold to bee supply companies to recycle into foundation sheets used in bee hive frames. It is also used for making candles that burn clean with a pleasant fragrance. Beeswax has certain unique properties such as plasticity, formation of stable emulsions, and water holding capacity that make it desirable in the formulation of many cosmetic products such as lipsticks, conditioners, and facial creams. A simple lip balm can be made with equal parts of beeswax and coconut oil. Beeswax is included in polishes, varnishes, wood preservatives, and textile waterproofing. A simple wood polish can be made with 450 g (1 lb) of beeswax and 473 ml (16 oz) each of turpentine and linseed oil. Beeswax is also used to coat pills and as an ingredient in medicinal ointments (Adjare, 1984).

Propolis

Propolis is believed to improve circulation, help in tissue regeneration, improve digestion, and heal wounds (Krell, 1996). Propolis is used in cosmetics in the making of creams, facial masks, toothpaste, and shampoos. Two tablespoons (30 ml) of propolis in 473 ml (16 oz) of 100 proof alcohol makes a simple wood finish. In medicine, propolis is an ingredient in oral and nasal sprays, and ointments (Krell, 1996). A simple tincture for cuts and scratches can be made with equal parts of 100 proof alcohol and propolis heated to 93°C (200°F) and stirred until most of the propolis has melted, then strained and bottled in a dark glass container. Additionally, propolis is being studied for the treatment of certain types of cancers, tumors, and HIV.

Left: Special frame and cells used for queen rearing. Right: Queen bee in cage for shipping.

Royal jelly

Royal jelly is believed to improve external skin problems and improve general health including treating viral infection, blood pressure, and cholesterol levels (Gimbel et al., 1962). It is used internally primarily as a dietary supplement, an additive to honey or juice products, medicinal products, and cosmetics. A facial cream can be made by combining blended oil commonly used in cosmetics (80 g), coconut oil (45 g), and beeswax (15 g). Heat the ingredients until melted then cool. Once cooled to room temperature, add the fresh royal jelly and store the cream in a dark glass container.

PRODUCT STORAGE

Honey

Storage containers for liquid or crystallized honey are usually of glass or food-approved plastic with an airtight lid. All products should be kept away from heat. Storage rooms should have a temperature of about 20°C (68°F) and a relative humidity of no more than 65% (Krell, 1996).

Top: UH Hilo farm manager demonstrates mead making to beekeeping students. Panaewa, Hawai'i. Bottom: Lip balm made from local beeswax and other ingredients, North Kona, Hawai'i.

Pollen

Fresh pollen will lose its nutritional value within a few days unless it is frozen. However even when frozen, pollen will lose most of its nutritional value within a year. When dried to less than 10% (preferably 5%) moisture content and kept out of direct sunlight, pollen can be kept for several months. The same dried pollen, if refrigerated, can last a year and if frozen can last several years. Storing pollen in dark glass containers in cool places is recommended.

Propolis

Propolis is fairly stable but should be stored in airtight dark containers at less than 10°C (50°F). Properly stored, propolis can retain its properties for over a year (Krell, 1996).

Royal jelly

Royal jelly is not a very stable substance and is subject to rapid breakdown. The minimum temperature for storage is 0–5°C (32–41°F), but storage life can be improved if the temperature is -17°C (1.4°F) or lower. Freeze drying is recommended. Freeze-dried royal jelly and royal jelly-based products can be stored at room temperature for several months or years depending on the product (Krell, 1996).

Wax

Wax should be cleaned of impurities prior to storage, or it will be subject to attack by wax moths. Wax should be stored in cool, dry places and never near materials that can impart odor. Wax will crystallize over time and become harder, but melting can reverse crystallization.

ADVANTAGES AND DISADVANTAGES OF HONEY BEE CULTIVATION

Honey bees are cultivated for two main reasons, harvestable products and pollination services. The products that can be harvested from a single bee hive can sustain a family's need for honey and other products such as wax and pollen can be used in secondary products. Beekeeping can be a viable industry in the Pacific because it has relatively low technological requirements, can be learned quickly, has a relatively low start up cost, can be done by people of all ages (families or communities), has minimal land requirements, is environmentally stable, and yields products have a long shelf life with little or no refrigeration (Driscoll, undated).

Agriculturally, honey bees are the primary pollinators of many crops. Without their pollination services, the fruit set and harvest of many of these crops would decrease (Benedek et al., 2006). Klein et al. (2003) showed a 10–20% reduction in coffee fruit set without bee pollination.

However, depending on the location of operation, honey bees can be a potential threat to humans and animals because of potential allergic reactions to bee stings, which can cause severe symptoms such as dizziness, swelling, and shock. Honey bees will attack in defense of their hive. In rural settings where the possibility of disturbing a hive or walking too close would not occur very often, cultivating bees for products and pollination presents minimal risk. In urban areas, fencing and borders should be used to ensure unprovoked bee attacks are avoided. The entrances to the hives should be placed where flight paths of the bees to and from the hives do not cross human activity. Another concern about raising honey bees in new areas is that it may adversely affect native ecosystems in unknown ways.

HIVE DENSITY PER UNIT AREA

Recommendations for the number of hives per unit area for adequate pollination vary with the plant species and the number of existing pollinators in the area. The UH Cooperative Extension Service can provide pollination recommendations for some major crops. Examples of recommendations for a few crops are: seven to 14 hives per ha (2.5 acre) for maximum fruit set for mango, one to two hives per 4 ha (10 ac) for pumpkin or squash, and five to eight hives per ha (2.5 ac) for avocado (McGregor, 1976).

Urban restrictions

The State of Hawai'i does not permit the keeping of apiaries on land that is zoned residential. On agricultural lands, apiaries are permitted but no closer than 305 m (1,000 ft) from any major public street. Beekeepers need to check state and local regulations for the keeping of bees in other urban areas.

COMMERCIAL TO HOME GARDEN SCALE

Beekeeping can be done on a small to large scale depending on land availability, finances, and market. Beekeepers are generally classified as hobby beekeepers (hobbyists), sideline beekeepers (sideliners), and commercial beekeepers. Hobby beekeepers enjoy working with honey bees and collect hive products for their own use. Sideline beekeepers have more than a few hives and collect the hive products, primarily honey, for profit. However, their main source of income is not based on beekeeping. Commercial beekeepers operate their business with several hundred to thousands of bee hives for profit and livelihood. The initial investment for a commercial operation is substantial, including ensuring that there are adequate floral sources for the bees. Since the average quantity of harvestable honey per hive in Hawai'i is about 45 kg (100 lb) per year, a family of four can be supplied with a sustainable sugar source with four hives (based on an average annual sugar consumption of 45 kg per person). For the home gardener, a 0.8 ha (2 ac) parcel with a

Top: A diverse 0.8-ha (2-ac) home garden with many different plants flowering at different seasons can support two to four hives. Middle: A small number of hives can produce enough honey for a few families. Pāhoa, Hawai'i. Bottom: Commercial operation with many hives set up at a macadamia nut orchard. Wailuku, Hawai'i.

variety of plants such as avocados, tangerines, mango, cucumbers, eggplant, and pumpkin can support two to four colonies.

LABELING AND PACKAGING

According to the National Honey Board, honey labels must include: 1) the word 'honey" and the name of the floral source (if there is a primary floral source), 2) the net weight, and 3) the name of the manufacturer, packer or distributor. Additional information explaining the uses of the product, nutritional value, color, and USDA grade may increase sales. Packaging in small portions for gift baskets, hotels, and airlines can also expand markets. Specialty containers, colors, or shapes may also increase consumer interest.

INVASIVENESS

The honey bee has been imported to practically every place where it can be cultivated. Once introduced, managed bees can swarm and become established as feral colonies or abandoned hives can similarly move into nearby forested areas. Moritz et al. (2005) cautions that the honey bee establishes in native ecosystems, which is a potential threat to native bee species. Honey bees could either facilitate pollination of native plants or exclude more efficient native pollinators. The potential threat to endemic/native bee species by the honey bee is very important, especially to Pacific islands because of the limited land area. Where the honey bee has not yet been introduced in the Pacific, an assessment of its impact on the native ecosystem should be considered prior to implementation of beekeeping activities.

MARKETS

Local markets

In Hawai'i, honey is the primary product that is sold at farmer's markets and craft fairs. Grocery stores also sell locally produced honey and even market honey from contracted beekeepers under the store's name.

Export markets

There is a large market for Hawaiian honeys that are associated with specific plant sources and/or locations. One of the more successful apiaries, sells a white kiawe honey which is harvested from a localized area of Puakō, Hawai'i. These locally produced honey products are available to consumers worldwide via the Internet. Since honey does not require refrigeration or special handling, it is readily shipped for export.

Branding possibilities

Honey has been a commodity that is branded by many producers who buy honey from beekeepers and then process and bottle the honey to be sold under the producer's name. In Hawai'i, honey is purchased by at least one grocery store and sold under the store's brand name. The University of Hawai'i is similarly branding a value-added bee product for sale under the university's name. Similar branding potential exists for honey and other products not only in Hawai'i but elsewhere in the Pacific.

Honey products can be produced and sold at local farmer's markets at retail, improving the profit margin for the beekeeper. Hanalei, Hawai'i (left) and Keauhou, Hawai'i (right). Packaging and labeling can also impact customers' perception of value and affect marketability.

Potential for Internet sales

In Hawai'i, there is already an established Internet market for the sale of honey and queen bees. Honey from other regions such as New Zealand, Samoa, and Fiji are also marketed on the Internet. The potential for other Pacific islands to produce honey and stable value-added products to be marketed on the Internet allows remote areas to be competitive especially in specialty markets.

Specialty markets

Organic

Organic honey is gaining in popularity and consumers are willing to pay a higher price. In Hawai'i, there are several organic honey producers who can compete against lower priced honey because of their organic certification. The USDA is currently working on a set of national standards that honey has to meet to be certified and labeled organic. Meanwhile, certifying agencies accredited by the USDA have their own standards for honey and can inspect and certify a beekeeping operation as meeting organic standards. Certification of organic honey covers production and packaging, including the foraging area within a 6.4 km (4 mi) radius of the hives, hive management, extracting, processing, transporting, and packaging of the honey.

Plant source

Monofloral honeys are produced from one plant source. There are many plant species that are associated with tropical regions and consumers search for these plant-specific honeys. Examples include kiawe, macadamia, and 'ōhi'a lehua honeys.

Hawaiian, other Pacific island

Similar to plant source, there is a market appeal for honeys from specific locations such as Hawai'i or even from a region within Hawai'i (e.g., Kona, Volcano). When traveling to these places, locally produced and labeled honeys are desirable as souvenirs because when packaged well, it is stable under most traveling conditions. Because of honey's liquid nature, honey products are currently subject to quantity limitations in carry-on baggage for air travelers.

Medicinal

Certain honeys have been documented to have outstanding medicinal value. An example is New Zealand's manuka honey (from the manuka bush, also known as tea tree, *Melaleuca alternifolia*). Manuka honey has been shown to be extremely high in methylglyoxal, which is associated with cancer treatments and wound healing (Waikato Honey Research Unit, undated). Although all honeys contain methylglyoxal, the amount in manuka honey can be as high as 100 times higher compared with others. The marketing of the medicinal value of honey can potentially increase sales.

Mostly wax capped kiawe honey cells ready for extraction. This honey is processed and sold as a white kiawe honey, specific to the area. Puakō, Hawai'i.

Nutraceutical

A nutraceutical is a food (or part of a food) that provides medical or health benefits, including the prevention and/or treatment of a disease (Kalra, 2003). The harvestable products from a bee hive that would be considered nutraceutical are honey, pollen, and royal jelly. Some of the medicinal and/or health benefits associated with these products are described in "Value-added products" above.

EXAMPLE SUCCESSES

Volcano Island Honey Company

Volcano Island Honey Company owned by Richard Spiegel, produces single-floral source honeys at its facility in Āhualoa, Hawai'i. Production is based on 150 colonies located in four yards around Hawai'i Island.

Richard developed a passion for beekeeping while working with a beekeeper in the state of Washington who taught him the craft in the 1970's. He now runs a vertically integrated

small business that builds its own equipment, manages bees for production, harvests and extracts honey, bottles, labels, and ships honey both to wholesale and retail customers. The company also produces small quantities of bee pollen and wax. By carrying out all aspects of production, processing, and marketing from bee to bottle, Richard meticulously controls product quality and consumer experience. All products come with a guarantee, "If for any reason this product doesn't meet your expectations, we will refund your money or replace the product, no questions asked." This commitment to customer satisfaction has led to an international reputation for quality.

Richard's honeys are carefully processed without added heat or filtration, which he believes yields a superior product both in flavor and healthful qualities. In addition to three single-floral source honeys (macadamia nut, ʻōhiʻa lehua, and kiawe), Volcano Island Honey Company is continually developing new value-added products, such as new blends of honey with wildcrafted lilikoi (passion fruit, *Passiflora* sp.) and ginger (*Zingiber officinale*). Another new product is a specially handled and processed honey with a uniquely silky texture. All of the products are certified organic. The company also offers educational opportunities including farm tours and workshops.

The quality of Richard's products has not only drawn in customers from around the world through word-of-mouth, but also media attention. His company has been highlighted in numerous major magazine articles as well as five television programs. This free coverage has meant that Volcano Island Honey Company spends little on marketing.

Richard's biggest challenge is "not to be seduced by demand and money to get big, but to stay small and high quality." Every year, Richard receives about two dozen commercial account requests that he turns down. His second biggest challenge is "to become increasingly sustainable and socially and environmentally responsible." Richard considers these values to be the foundation of his business and is constantly striving toward them.

Volcano Winery

In addition to a range of grape-based wines, Volcano Winery in Volcano, Hawaiʻi makes honey wines from locally produced macadamia nut honey. In contrast to mead, honey wine is produced without the use of heat. After fermentation is complete, the honey wines undergo a special proprietary filtration to remove particulates and produce a clear product.

The original owner of the winery chose honey wine in order to differentiate the product line and to use as many local raw materials as possible. Including the honey wines, Volcano Winery produces six wines, five of them award winning, including tropical fruit blends and other non-traditional

Top: Richard Spiegel teaching in his on-farm classroom. Bottom: Richard introduces a group of college students to beekeeping in an afternoon tour.

wines. In a further diversification of their product line, they now offer a honey wine with an infusion of black tea grown in the Volcano area. This product combines two important local products to create a wine that is unique.

All production is done on site. A retail store at the winery sells the wines, along with other local products such as honey and tea. In Hawaiʻi, their wines are widely distributed to stores that sell alcoholic beverages. Their products are also sold through their Internet site and through phone orders. Volcano Winery advertises in Hawaiʻi in several print venues for visitors, such as some drive and hotel guides and rack cards. They have also received television coverage by networks such as CNN, Food Network, Travel Channel, and Honey Kingdom (Japan). Small tour buses are accommodated for winery tours and their visitor center.

Top: Honey wines and honey on display at Volcano Winery. Bottom: A new value-added product, a honey wine infused with locally grown black tea.

Top: Michael Krones inspects his breeder queen hives. Bottom: A breeder queen at Hawaiian Queen Company labelled with an identification number.

Hawaiian Queen Company

Michael Krones and Janice Horton, owner-operators of Hawaiian Queen Company, manage 1,500 honey bee colonies in Kaʻū, Hawaiʻi. The colonies provide support for queen bee rearing, honey, and pollinization services for large macadamia nut growers and other agricultural crops. Their operations are USDA certified organic.

Their primary product is queen bees, which are exported to Canada and the U.S. mainland. To continually improve their genetic lines, Michael hires a honey bee breeder from the U.S. mainland to produce new breeder queens through artificial insemination on a yearly program. Michael provides the virgin queens from his best colonies, and the bee breeder supplies semen from his best stock. The offspring of artificial insemination inherit characteristics from both parents, incrementally improving desirable characteristics.

Michael has bee breeding for characteristics such as varroa mite resistance for several years and sees his breeding program as ongoing. His intensive selection and breeding program is geared toward producing queens that serve the needs of his customers.

The 1,500 colonies that support the queen bee operation produce an abundance of honey, which is sold through large retailers. In Hawaiʻi, the warehouse store Costco sells their honey due to its appeal as a certified organic product that is produced and packaged locally.

ECONOMIC ANALYSIS

The Kentucky Department of Agriculture calculated that the startup cost for hive materials and beekeeping equipment is approximately $270 per hive. Hive materials needed include covers, bottom boards, hive bodies, frames parts (including eyelets and wire), foundation, paint, glue, and staple gun or

hammer and nails. Beekeeping equipment needed includes the hive tool, bee brush, smoker, and frame grip. Bee suits with gloves are also needed. Equipment needed if extracting honey include an uncapper or uncapping knife, extractor, and storage barrels or containers. Other needs would be the land and transportation costs (Mussen 1994). Shipping costs to Hawai'i and other areas add substantially to the estimated start-up costs. The estimated start-up cost in Hawai'i is approximately double that on the continental U.S.

Simple hives can be constructed with local materials to reduce the initial investment, especially in remote rural areas (e.g., Sammataro, 1978; Chandler, 2009).

In order to recoup the cost of purchasing extracting equipment, it is estimated that a beekeeper needs to have at least 40 producing hives. Penn State University estimates that an initial investment of over $3,500 is needed for a ten-hive operation and about $5,500 for a 50-hive operation based on a wholesale price of $4.40/kg ($2.00/lb) (Penn State University, 2001). Again, shipping costs to Hawai'i would approximately double equipment costs.

FURTHER RESEARCH

Potential for crop improvement

The importation of honey bees is prohibited by Hawai'i State law. To improve the behavioral, disease/pest resistance and breeding qualities of the present races, queen breeders in the state have focused on introducing semen from other races. For other Pacific areas that allow the importation of bees, the purchase of queens and packaged bees are the quickest way to improve bee characteristics for productivity, gentleness, and disease and pest resistance.

Similarly, improving the resistance of honey bees in Hawai'i to varroa mite and other ectoparasites and even some internal parasites includes the introduction of genes into honey bees. These genes are most often expressed in terms of hygienic behavior. By introducing rearing stock with improved hygiene genetics and selecting for hygienic traits, bee lines (strains of a race) can be established that are more resistant to the varroa mite and therefore will require less hive management using chemicals or other cultural methods. Resistant strains include the so-called Minnesota Hygienic and VHS lines available in the U.S. Hawai'i does not restrict the importing of drone semen which can be purchased and bred into bee lines that have these mite resistant qualities. It should be noted that introduction of hygienic genes can adversely affect the gentleness of bees and their productivity, or have other negative effects. It is up to the beekeeper to decide if using these resistant strains of bees that may be more aggressive and less productive is economically advantageous.

Improving potential for family or community farming

A joint project between New Zealand and the Secretariat of the Pacific Community assessed the feasibility of apiculture in the Pacific. The project concluded that beekeeping was well suited for the Pacific region because it fit well into the agricultural philosophy of diversification, created the potential for sustainability in small farming areas, and increased the opportunity for greater income and employment. The project highlighted the need for more government agents trained in beekeeping and bee related activities including disease diagnosis and treatment.

Genetic resources where collections exist

Races of bees evolved as a result of adaptation to regional areas. The genes from these races form the genetic pool for bee breeders to improve the characteristics of their bees. There have been several mutations that have been described in bees that are the basis for bee stock improvement such as pollination activity, resistance to diseases, and colony management (Harbor and Rinderer, 1995). Importing stocks from other countries has been questioned because combination with local stocks may produce less than desired hybrids and susceptibility to other diseases. It is believed that there is already ample genetic material in the U.S. for improved selection and breeding.

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INTERNET RESOURCES

Current activity on the efforts for varroa mite control at the University of Hawai'i at Mānoa: http://www.ctahr.hawaii.edu/wrightm/Honey_Bee_Varroa/Honey_Bee_Home.html.

Feasibility of apiculture in the Pacific: http://www.spc.int/rahs/Projects/Apiculture1E.htm

Beekeeping in the tropics (Agrodok 32): http://journeytoforever.org/farm_library/AD32.pdf

Beekeeping links: http://www.badbeekeeping.com/weblinks.htm

The American Apitherapy Society promotes the use of apitherapy, which is health care using bee venom, honey, pollen, royal jelly, propolis, bee bread, and beeswax: http://apitherapy.blogspot.com/2009/08/video-bee-venom-therapy-used-to-treat.html.

USDA organic standards: http://www.ams.usda.gov/nop/NOP/standards/LabelReg.html.

Farm and Forestry Production and Marketing Profile for Honey Bees (*Apis mellifera*)

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