Chapter 10
Bee Diversity and Current Status of Beekeeping in Japan

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Abstract Beekeeping in Japan is not a large industry; however, because of the role as pollinator, beekeeping is considered to be major agriculture sector. Beekeeping in Japan faces many problems as it does in European and North American counties. In this chapter, we will describe such problems focusing on bee diseases and parasites.

Keywords Pollination · *Apis cerana japonica* · *Apis mellifera* · Bee diseases Traditional beekeeping · Insecticide · History of beekeeping

10.1 Introduction

In comparison with other Asian countries, beekeeping is not a large industry in Japan (Fig. 10.1). Only about 5000 beekeepers register with local governments, and most of them keep less than 100 hives. In addition, most honey consumed in Japan is imported from China and other countries. Nonetheless, in Japan beekeeping is thought to be very important in agriculture due to the role of honey bee as pollinator in horticulture. Honey bees are used as pollinators for production of fruit such as apple and plum, and more than 200,000 bee hives have been introduced into

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P. Chantawannakul et al. (eds.), *Asian Beekeeping in the 21st Century*,
https://doi.org/10.1007/978-981-10-8222-1_10

Fig. 10.1 Typical Japanese apiary

greenhouse production of crops such as strawberry. The peak of strawberry production is in January. Even though domestic honeys are traded in the market at higher prices than imported honey, and the demand for honey bees as pollinator remains steady, beekeeping still faces many problems in Japan, e.g., damage due to insecticides, bee diseases, parasitic mites, malnutrition, and lack of flowers, as it does in European and North American counties. In this chapter, we introduce Japanese beekeeping, focusing on the problem of bee diseases, which is considered to be the most important issue.

10.2 Honey Bee Diversity in Japan

Only one indigenous *Apis* species is distributed in Japan, the Japanese honey bee, *Apis cerana japonica* (Ruttner 1988; Engels 1999). Japanese honey bees are essentially a wild species (Fig. 10.2), but some are reared by beekeepers, and most managed hives are kept by hobbyists (Sasaki 1999; Yoshida 2000). After its introduction to Japan, the European honey bee (*Apis mellifera*) has dominated in beekeeping industry in Japan (Matsuura and Yamane 1984).

Japanese honey bees are distributed throughout the three main islands (e.g., Honshu, Kyushu, and Shikoku islands), but are not found on Hokkaido and Ryukyu islands. *A. cerana japonica* exhibit little or no genetic variation in their mitochondrial DNA (Takahashi et al. 2007). Genetically, the *A. cerana japonica* is closely related to *A. cerana* in Korea (Takahashi and Yoshida 2003).

Fig. 10.2 Japanese honey bee (*A. cerana japonica*) nest is often found in a cave. (Courtesy of Dr. Jun-ichi Takahashi (Kyoto Sangyo University))

The European honey bee was introduced in the late nineteenth century, as described below. Most European honey bees kept in Japan are *A. mellifera ligustica,* although some *A. mellifera carnica* have been imported from Balkan countries. Due to quarantine limitations in recent years, queens have been imported only from Australia and Slovenia. In 2015, 2127 queens and 748 queens were imported from Australia and Slovenia, respectively (Animal Quarantine Service, Ministry of Agriculture, Forestry and Fishery 2015). Whole colony import has not been performed within recorded history. Mitochondrial DNA surveys revealed only haplotype C1 (Takahashi et al. 2014), indicating that the genetic variation of *A. mellifera* in Japan is much smaller than in American countries and Australia (Oldroyd et al. 1995; Koulianos and Crozier 1996; Franck et al. 2001; Clarke et al. 2002).

10.3 Historical Records of Beekeeping

10.3.1 History of Japanese Beekeeping

The history of beekeeping using Japanese honey bee (*A. cerana japonica*) dates back to about 1400 years ago (Bureau of Animal Husbandry, Ministry of Agriculture and Forestry 1966; Sasaki 1999; Yoshida 2000). The first literature in which the word "honey bee" is used is the *Nihon-Shoki* (the second-oldest book of classical Japanese history). According to this book, in 643 AD, Yogi, a naturalized

Korean, tried to start beekeeping, but the attempt ended in failure. In later literature, the term “honey bee” was mentioned, revealing that honey was used as an important tribute. During this period, most honey was collected from natural wild hives; however, people started to capture and keep wild bees around 1000 years ago, representing the dawn of beekeeping in Japan. In the Edo period (ca. 1600–1860 AD), beekeeping became fully developed, and books on ecology and beekeeping technology were published. Although beekeeping using *A. cerana japonica* was not highly productive, beekeeping techniques were conducted widely (Fig. 10.3).

In the Meiji era (1868–1912 AD), Japan opened its doors to overseas and rushed towards westernization. The new government promoted aggressive measures in multiple industrial sectors, one of which was beekeeping. In 1877, an Italian strain of *A. mellifera* was first imported from the USA and maintained in a national agriculture experimental station, marking the beginning of a new era in beekeeping. Immediately thereafter, modern beekeeping began in the private sector. The beekeeping industry gained a great attention as a new industry during the period of industrialization following the Russo-Japanese War (1904–1905). Migratory beekeeping was also initiated around 100 years ago.

After World War II, in response to the high demand for sweet foods, beekeeping developed rapidly, with honey production peaking in the 1970s. In the 1960s, the demand of bees in greenhouse crops has been increasing. Starting in the 1980s, land development occurred and led to the change of natural environment. Honey bees

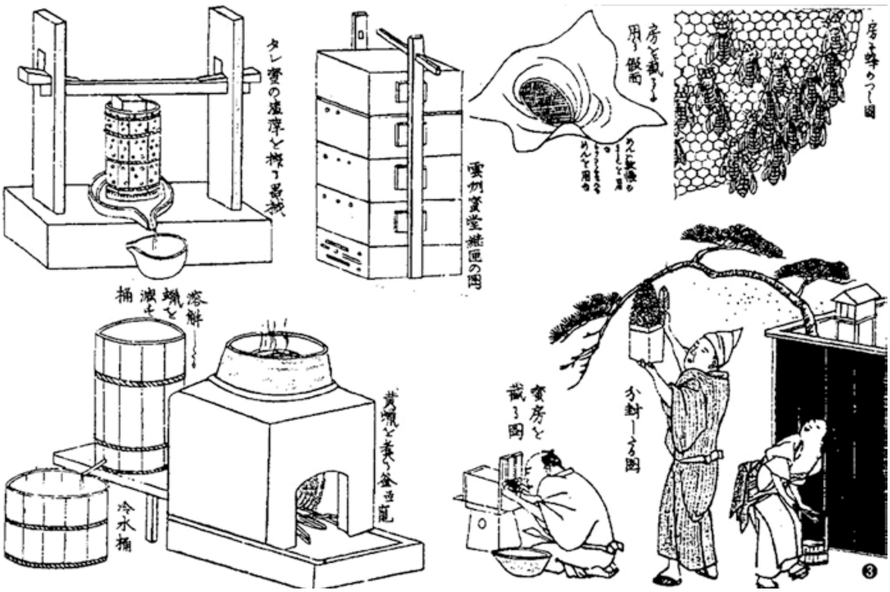

Fig. 10.3 Illustrations from *Text book of beekeeping* using Japanese honey bee before introduction of *Apis mellifera* (*Hachimitsu Ichiran* (Chart of Honey) 1872)

have higher risks to be affected by pesticides used in the farming practices. The cultivation conditions of agricultural land have also changed greatly, and the cultivation area of their former major nectar sources was reduced to about 11% for milk vetch and about 5% for rapeseeds, in comparison with that of in the year 1965. Imports of cheap honey sharply increased, prices of domestically produced honey were sluggish, and beekeepers aged. As a result of these factors, the number of beekeepers fell from 9499 in 1985 to 4790 in 2005.

10.3.2 Modern Beekeeping in Japan

Currently, some 200,000 colonies of bees are maintained in Japan, of which around 80,000 colonies are being used for pollination of greenhouse horticulture such as strawberry (MAFF 2016a). The beekeepers prepared hives (2–3 frames) for pollination before winter and introduced these small hives into the greenhouses for strawberry production (Fig. 10.4). These hives are kept in the houses until April–May.

Supply of pollination colonies is not sufficient to meet such demand, and beekeepers often need to supply bee colonies for both honey and pollination services (e.g., for melon) in the early spring. In 2009, the shortage of pollination hives has become a serious problem (Kimura 2011).

Fig. 10.4 A bee hive is installed in a greenhouse for pollination of strawberry production

On the other hand, honey produced within Japan accounts only for less than 10% of the honey consumed domestically. The price of domestically produced honey has remained high. In addition, numbers of both honey bee colonies and beekeepers started to decline in 1980. The rates of decline had leveled off since around 2000, and in the last few years, the numbers have slightly increased.

10.4 Bee Forage Resources

Due to Japan is located in a temperate zone, many flowers are available as honey and pollen sources in the spring. In Kanto (area around Tokyo), flowers start to bloom at the same time, starting at the end of March and peaking in May and June and the number of flowering species declines thereafter. Many species of flowers bloom in summer, but honey production is not high during this season due to the hot weather. Consequently, many beekeepers migrate to cooler regions in Northern Japan, e.g., Hokkaido and/or mountainous regions.

The most important flowers used as nectar sources by bees in Japan are listed in Table 10.1 (Japan Beekeeping Association 2005). Sixteen of the flower species are classified as "very important" plants, and 21 are classified as "important." Sasaki (2013) listed 647 species as pollen and nectar sources, of which 56.9% are native. Nevertheless, 37 major species of native honey plants drop to 46%, indicating that honey bees also depend on introduced species of plants as their food sources.

10.5 Local Knowledge of Honey Bees

As described above, traditional beekeeping using *A. cerana japonica* has a long history, but introduction of the *A. mellifera* caused a decline in *A. cerana japonica* beekeeping. However, in some parts of Japan, the traditional type of beekeeping still exists such as Tsushima Island, located in the Japan Sea between the Korean Peninsula and Kyushu island (Sasaki 1999; Yoshida 2000). *Hatto*, traditional beehives, can be seen throughout most of the island (Fig. 10.5).

There is no European beekeeping in Tsushima Island. In addition to traditional beekeeping, over the past 10 years *A. cerana japonica* beekeeping has become popular, with the formation of beekeeping hobby groups and the publication of many introductory books on beekeeping. Some groups have tried to introduce western-style methods to *A. cerana japonica* beekeeping (e.g., using Langstroth hives), whereas others have tried to improve traditional beekeeping. Many people believe that honey from *A. cerana japonica* has special medical effects than honey from *A. mellifera*, but no concrete scientific evidence supports this claim.

Under these circumstances, bee diseases have been transmitted from European honey bees into *A. cerana japonica*. For example, European foulbrood had not been reported to *A. cerana japonica*, but infected *A. cerana japonica* hives have been reported frequently over last few years (Uemura et al. 2013). In addition, infestation

Table 10.1 Major nectar source plants in Japan

	Scientific name	Introduced species	Flowering period
Very important[a]			
Satsuma Orange, Mikan	*Citrus unshiu*	○	Early Summer
Japanese Snowbell	*Styrax japonica*		Early Summer
Amur Corktree	*Phelodendron amurense*		Summer
Round Leaf Holly	*Ilex rotunda*		Spring
Japanese Chinquapin	*Eleutherococcus sciadophylloides*		Late Summer
Japanese Lime	*Tilia japonica*		Summer
Buckwheat	*Fagopyrum esculentum*		Summer-Fall
Longstalk Holly	*Ilex pedunculosa*		Early Summer
Romerillo	*Bidens pilosa*	○	Late Spring-Fall
Horsechestnut, Japanese Marronnier	*Aesculus turbinata*	○	Early Summer
Rapeseed	*Brasica rapa*	○	Spring
Falseacacia, Locustacacia	*Robiniapseudo-acacia*	○	Early Summer
Wax tree	*Rhus sucedanea*	○	Early Summer
White Clover	*Trifolium repens*	○	Summer
Apple	*Malus pumila*	○	Spring
Chinese Vetch	*Astragalus sinicus*	○	Spring
Important[a]			
Thistle	Genus *Cirsium*		Late Summer-Fall
Bastard Indigobush	*Amorpha fruticosa*	○	Fall
Japanese Knotweed	*Fallopia japonica*		Summer
Persimmon	*Diospyros kaki*		Early Summer
Japanese Prickly-ash	*Zanthoxylum ailanthoides*		Summer
Citrus fruits	Genus *Citreae*	○	Early Summer
Amur Corktree	*Phellodendron amurense*		Summer
Japanese Chestnut	*Castanea crenata*		Early Summer
Japanese Raisin Tree	*Hovenia dulcis*		Summer
Cherry Blossom	Sub-genus *Cerasus*		Spring
Cherry (fruit)	*Prunus avium*	○	Spring
Canada Goldenrod	*Solidago canadensis*	○	Fall
Caster Aralia	*Kalopanax septemlobus*		Early Summer
Dandelion	Genus *Taraxacum*	○	Spring
Glossy Privet	*Ligustrum lucidum*	○	Early Summer
Runner Bean	*Phaseolus coccineus*	○	Summer
Bee bee Tree	*Euodia daniellii*	○	Spring-Early Summer
Hairy Vetch	*Vicia villosa*	○	Late Spring
Safflower	*Carthamus tinctorius*	○	Summer
Japanese Clethra	*Clethra barbinervis*		Summer
American Tulip Tree	*Liriodendron tulipifera*	○	Spring

[a]Very important and Important Plants listed in "The Honeybee Plants of Japan" (Japan Beekeeping Association 2005)

Fig. 10.5 Traditional beekeeping in Tsushima Island, Japan. *Hatto* (hollow logs) are used for bee hives (Courtesy of Dr. Jun-ichi Takahashi (Kyoto Sangyo University))

by tracheal mites (*Acarapis woodi*) represents a serious problem for *A. cerana japonica* beekeeping (Maeda 2016). This mite was first reported in *A. cerana japonica* in 2011 (Kojima et al. 2011). In addition, Thai sacbrood causes serious problems in *A. cerana japonica* (Kojima et al. 2011) (see also Sect. 10.6).

10.6 Pests and Diseases of Honey Bees

Most of the diseases and pests affecting global apiculture are also present throughout Japan. In this section, we describe the presence of pathogens, parasites, and pests that influence the health of honey bee colonies in Japan, as well as methods for controlling these diseases and pests in Japanese apiculture. Main pests and diseases of honey bees in Japan are listed in Table 10.2.

10.6.1 Bacteria

10.6.1.1 American Foulbrood (*Paenibacillus larvae*)

American foulbrood (AFB), the most deleterious disease of honey bee broods (Bailey and Ball 1991; Genersch 2010), is a serious problem in apiculture all over the world. The causative agent is the Gram-positive, spore-forming bacterium

Table 10.2 Summary of pathogens, parasites, and pests associated with honeybees in Japan

Name of bee diseases	Disease incidence	Domestic animal infectious disease	Notifiable animal infectious disease	Listed in the OIE terrestrial Animal Health Code
Acarapisosis	○		○	○
American Foulbrood	○	○		○
European Foulbrood	○	○		○
Small hive beetle infection				○
Tropilaelaps				○
Varroasis	○		○	○
Nosemosis	○		○	
Chalkbrood disease	○		○	

Paenibacillus larvae (Genersch 2010). Young larvae become infected by ingestion of spores of *P. larvae* from contaminated food. In the larval midgut, the spores germinate, and the vegetative bacteria proliferate in the lumen, eventually breaching the midgut epithelium and invading the hemocoel (Yue et al. 2008; Ebeling et al. 2016). Spores of *P. larvae* have the ability to survive severely adverse environmental conditions and remain infective in hives for more than 35 years (Hasemann 1961). Due to this high degree of contagiousness in colonies and the high lethality in larvae, AFB is designated as a domestic animal infectious disease in Japan. AFB is subject to official control by the livestock hygiene service center. Affected colonies are subject to compulsory execution, mainly by incineration.

There are four genotypes (ERIC I–IV) of *P. larvae* strains (Genersch et al. 2006). In addition, Morrissey et al. (2015) developed a multilocus sequence typing (MLST) scheme to describe the genetic structure of *P. larvae*. Epidemiological studies showed that ERIC I and II are frequently isolated from AFB-infected hives. The two genotypes differ in virulence, with ERIC II strains more virulent against individual larvae and ERIC I strains less so (Genersch et al. 2005; Rauch et al. 2009; Genersch 2010). Recently, Hirai et al. (2016) genotyped Japanese isolates and detected the existence of ERIC I and II in Aichi prefecture in Japan. Apiten®, a formulation of the antibiotic mirosamicin, is commercially available as a prophylactic against for AFB (Kawashima 2000), and remains the only preventative drug approved by the Japanese government for control of the disease.

10.6.1.2 European Foulbrood (*Melissococcus plutonius*)

European foulbrood (EFB) is another bacterial disease of honey bee broods. In this case, the etiological agent is the Gram-positive lanceolate coccus *Melissococcus plutonius* (Forsgren 2010). *M. plutonius* is digested along with contaminated food during feeding by nurse bees. The bacteria multiply within the larval gut and kill larvae aged 4–5 days (Bailey and Ball 1991; Forsgren 2010). At present, EFB is widespread and present in most countries, with the exception of New Zealand (Ellis and Munn 2005). In recent years, the Ministry of Agriculture, Forestry and Fisheries has reported more than 100 confirmed cases of foulbrood disease annually (MAFF 2017a). However, the annual numbers of EFB cases are not known with precision because both AFB and EFB are referred to collectively as foulbrood diseases. Since the first suspected case was described in the 1950s (Azuma 1956), incidences of EFB have been sporadically reported. Recently, phenotypically and genetically atypical *M. plutonius* strains have been detected in both *A. mellifera* and *A. cerana japonica* manifesting clinical signs of EFB (Arai et al. 2012; Takamatsu et al. 2014).

10.6.2 Fungi

10.6.2.1 Nosemosis (*Nosema apis* and *Nosema ceranae*)

Nosemosis is one of the most prevalent worldwide diseases of honey bees caused by microsporidia. Two species of microsporidia, *Nosema apis* (Zander) and *Nosema ceranae* (Fries), are intestinal parasites in honey bee (Bailey and Ball 1991; Fries 2010). *N. apis* was first identified in the European honey bee, more than 100 years ago. This Nosema species became globally distributed, and is the primary cause of Nosemosis, whereas *N. ceranae* is a newly emerging microsporidian parasite first discovered in 1994 in the Asian honey bee *A. cerana* in a sample from China (Fries et al. 1996). Since then, *N. ceranae* has spread worldwide amongst European honey bee (Higes et al. 2006; Huang et al. 2007), and over the past two decades has become more prevalent (Klee et al. 2007; Paxton et al. 2007; Martín-Hernández et al. 2012). At the colony level, dysentery is a clinical sign of *N. apis* infection (Bailey 1967), which shortens the lifespans of both queens and adult bees (Wang and Moeller 1970), whereas no colony-level symptoms of *N. ceranae* infection have been observed (Higes et al. 2008). Sublethal doses of pesticides elevate the mortality of honey bees infected with *N. ceranae*; i.e., this pathogen may synergistically and negatively affect honey bee by increasing their susceptibility to stressors (Vidau et al. 2011; Aufauvre et al. 2012; Doublet et al. 2015). No commercial medication is made available and registered for this disease to date in Japan.

10.6.2.2 Chalkbrood (*Ascosphaera apis*)

Chalkbrood, a fungal disease of honey bee larvae caused by *Ascosphaera apis*, is currently found in honey bee colonies throughout the world (Aronstein and Murray 2010). Spores ingested by larvae germinate in the midgut lumen and penetrate the midgut epithelium. Subsequently, the fungal mycelium grows and penetrates the gut wall and breaks out of the posterior end of the larvae (Bailey and Ball 1991;

Aronstein and Murray 2010). Although Chalkbrood usually does not cause serious damages to colonies, it can cause a significant reduction in honey production (Heath 1982; Zaghloul et al. 2005). Furthermore, this disease is considered to be stress-related, and statistical evidence demonstrated that *N. ceranae* infection in spring and *Varroa* infestation in summer are associated with Chalkbrood outbreaks in the next season (Hedtke et al. 2011). The recommended approach is to have good management and sanitation in beekeeping.

10.6.3 Viruses

More than 20 different viruses have been isolated from honey bees (Chen and Siede 2007), and most of them can be transmitted by *Varroa*. The mites act as biological vectors for Kashmir bee virus (KBV), Sacbrood virus (SBV), acute bee paralysis virus (ABPV), Israeli acute paralysis virus (IAPV), and deformed wing virus (DWV) (Boecking and Genersch 2008).

10.6.3.1 Deformed Wing Virus (DWV)

DWV was initially discovered as a Japanese strain of Egyptian bee virus in adult honey bees from a *Varroa*-infested colony in Japan in 1982 (Ball 1983; Bailey and Ball 1991). DWV causes wing deformities and abdominal bloating in emerging adults, and is currently widely distributed in close relationship to *Varroa* (Allen and Ball 1996). In the absence of *Varroa destructor*, DWV is transmitted vertically via eggs and semen, as well as horizontally via larval food from nurse bees, and causes covert infection without any apparent symptoms (Yue and Genersch 2005; Chen et al. 2006; Yang and Cox-Foster 2007; Yue et al. 2007). Malformed appendages of emerging adults only arise when DWV is transmitted to pupal stages via *V. destructor* (de Miranda and Genersch 2010; Genersch and Aubert 2010). Overt DWV infection often results in death in the pupal stage, or dead and dying adult bees with shriveled wings harboring a high titer of virus particles, and is sometimes associated with bloated abdomens and discoloration (Chen et al. 2005). DWV plays an important role in colony collapse via a complex interaction between *Varroa* and honey bee population dynamics (Martin et al. 1998; Martin 2001).

10.6.3.2 Sacbrood Virus (SBV)

SBV has been first identified in the United States in 1913 (White 1913) and has been widely distributed in every continent (Ellis and Munn 2005). SBV affects both larvae and adults, but 2-day-old larvae are most susceptible to infections (Ball and Bailey 1997). Although SBV does not cause obvious signs of diseases in adult bees, affected bees may have shorter lifespans (Bailey 1969; Bailey and

Fernando 1972). Young larvae become infected through SBV-contaminated food, and the virus replicates within the larvae. SBV-infected larvae appear as water-filled sacs, giving the virus its name. SBV is more virulent in *A. cerana*, than in *A. mellifera*. The disease was first reported in *A. cerana* in Thailand in 1976. Due to differences in physiochemical and serological properties, this virus was designated as Thai Sacbrood Virus (TSBV) (Bailey et al. 1982). TSBV is widespread to Nepal and India, and more than 95% of affected colonies are killed (Rana et al. 1986; Verma et al. 1990). In Japan, infection by SBV has been reported in both *A. mellifera* and *A. cerana japonica* colonies. Several reports have described extensive brood removal from the hive, a behavior observed only in SBV-infected colonies of *A. cerana japonica* (Yamashita and Tanaka 2010; Kojima et al. 2011).

10.6.3.3 Chronic Bee Paralysis Virus (CBPV)

CBPV mainly affects adult honey bees (Bailey et al. 1963). The typical symptom is a trembling motion of bodies and wings, crawling on the ground due to lack of flight ability, and a hairless shiny body surface (Bailey et al. 1963, 1968). A field survey revealed that the frequency of CBPV infection was low, and no seasonal pattern appeared (Tentcheva et al. 2004). In Japan, CBPV infection is rare in *A. mellifera*, and CBPV could not be found in *A. cerana japonica* (Morimoto et al. 2012).

10.6.3.4 Kashmir Bee Virus (KBV)

KBV infection in honey bee populations is less prevalent, and was detected at low frequency in a field survey in France (Tentcheva et al. 2004). In Japan, the frequency of KBV is also considered to be low (Kojima et al. 2011). Currently, no chemotherapeutic agents are available for treating viral diseases of honey bees in Japan. Since *Varroa* can transmit viruses, prevention or control of mite infestation in the bee colonies is important for honey bee virus control strategies.

10.6.4 Mites

10.6.4.1 Varroasis (*Varroa destructor*)

The ectoparasitic mite *V. destructor* is one of the most devastating pests in worldwide apiculture (Anderson and Trueman 2000; Cornman et al. 2010). Of several haplotypes of *V. destructor*, only two (Japanese and Korean) are known to be capable of reproducing in *A. mellifera* (Anderson and Trueman 2000). In this species, the Japanese haplotype spread into Thailand and Brazil, and later into North

America (De Jong et al. 1982a; de Guzman et al. 1999). The Korean haplotype has a broader worldwide distribution than the Japanese haplotype, and is considered more pathogenic (Anderson and Trueman 2000). *V. destructor* directly causes serious damage to honey bees by feeding on the hemolymph of the larvae, pupae, and adult bees (Rosenkranz et al. 2010), decreasing body weight (De Jong et al. 1982b) and life span (Amdam et al. 2004). Furthermore, *V. destructor* can serve as a vector for several honey bee viruses, including KBV, SBV, ABPV, IAPV, and DWV (Boecking and Genersch 2008), thereby contributing to a decline in the honey bee population (Chen and Siede 2007; Wilfert et al. 2016). Without proper treatment, most bee colonies infected by *V. destructor* parasites collapse in less than 3 years (Rosenkranz et al. 2010). Only two acaricides are commercially available for controlling *Varroa* in Japan. Apistan®, made with the pyrethroid tau-fluvalinate, has been used for the past three decades. However, resistance of *V. destructor* to fluvalinate is widely documented (Thompson et al. 2002; Gracia-Salinas et al. 2006). In 2009, Apivar® Amitraz strips were approved for *Varroa* control and became available to beekeepers in Japan. However, some *Varro*a populations exhibited resistance to Amitraz (Elzen et al. 2000; Sammataro et al. 2005).

10.6.4.2 Acarapisosis (*Acarapis woodi*)

Acarapisosis is a disease of the adult honey bee *A. mellifera* and other Apis species caused by the tracheal mite *Acarapis woodi* (OIE 2008). *A. woodi* parasites reproduce in the tracheal tubes of adult honey bees, feeding on the hemolymph of hosts (Pettis and Wilson 1996). Heavy infestation by *A. woodi* causes colony death by reducing honey production (Eischen et al. 1989) and decreasing the hive's ability to thermoregulate (McMullan and Brown 2009). *A. woodi* was first discovered in the United Kingdom in 1919 (Rennie 1921). Since then, this mite has spread worldwide, except in Sweden, Norway, Denmark, New Zealand, and Australia, and the state of Hawaii (Sammataro et al. 2000). The first report of *A. woodi* in Japan was in the Japanese honey bee, *A. cerana japonica*, in 2010 (MAFF 2011). *A. woodi* is distributed widely in this species (Maeda 2015), and colonies infested by this mite exhibit elevated rates of mortality and colony demise during winter (Maeda and Sakamoto 2016). On the other hand, mite load in the European honey bee, *A. mellifera*, has been rarely observed in Japan (Kojima et al. 2011; Maeda 2015). No tracheal mite-specific chemotherapeutic agent is available for prevention of acarapisosis in Japan to date, and no commercial products have been registered for this purpose.

10.6.4.3 *Tropilaelaps* Mites

There is no record that *Tropilaelaps* species have been described in Japan thus far.

10.6.5 Protozoans

10.6.5.1 *Crithidia mellificae*

C*rithidia mellificae* is a trypanosomatid parasite of *A. mellifera*, first reported in Australia in 1967 (Langridge and McGhee 1967). *C. mellificae* are recognized as a contributory factor in honey bee decline, and has been found in *A. mellifera* throughout the world, including Japan (Morimoto et al. 2013; Ravoet et al. 2013; Schwarz et al. 2015). Infection by *C. mellificae* has been detected in the Asian honey bee, *Apis cerana cerana*, in China (Yang et al. 2013), but not in the Japanese honey bee *A. cerana japonica* (Morimoto et al. 2013).

10.6.5.2 *Lotmaria passim*

Lotmaria passim infection status of honey bees has not been extensively studied until recently. *L. passim*, and *L. passim* is currently the predominant trypanosomatid species in honey bee population around the world (Ravoet et al. 2015; Schwarz et al. 2015). *L. passim* was detected in an *A. mellifera* sample from Japan (Ravoet et al. 2015).

10.6.6 Pests

10.6.6.1 Small Hive Beetle

The small hive beetle (*Aethina tumida*) (SHB) is a parasite and scavenger of honey bee colonies native to sub-Saharan Africa, but is rare and therefore not especially problematic for honey bee colonies (Neumann and Ellis 2008). Since the discovery of SHB in 1996 in the southeastern United States, invasion by SHB has been reported in many other countries, including Canada, Mexico, Jamaica, Cuba, and across the east coast of Australia (Neumann et al. 2016). In 2014, an outbreak of SHB was recorded in the Philippines, where managed colonies of European honey bee spices were severely damaged, and most of them collapsed (Brion 2015). Thus, SHB poses considerable potential risks to honey bees in Japan, but to date there has been no record of SHB infestation in Japan.

10.6.6.2 Wax Moth

Two wax moth species, the greater wax moth *Galleria mellonella* and the lesser wax moth *Achroia grisella*, are ubiquitous pests of honey bee colonies worldwide (Ellis et al. 2013). The larvae of both moth species affect honey bee colonies by feeding on wax combs, pollen, stored honey and cast larval skins. In Japan, *Achroia innotata* tends to be a major pest in *A. cerana japonica*, and heavy infestation often causes the bees to abscond (Yoshida 2000). These moths can cause significant damage to stored beekeeping equipment, especially in weak or stressed colonies. Therefore, it is recommended that colonies should be kept strong and healthy by maintaining optimal sanitation, e.g., removal of wax and debris accumulated on the bottom of the hives.

10.6.6.3 Hornet

Hornets of genus *Vespa* are serious predators of honey bees in Asian countries (Matsuura 1988). In Japan, seven *Vespa* species are distributed, and among these, giant hornet (*Vespa mandarinia japonica*) causes most destructive damage on honey bee colonies. *Vespa mandarinia japonica* attack honey bee hives in groups of 10–20 workers, and often exterminate whole colonies (Matsuura and Yamane 1990). However, *A. cerana japonica* counter-attack against *V. mandarinia japonica* via a collective behavior called a "bee ball," enveloping the hornets and killing them with heat and carbon dioxide (Ono et al. 1995; Sugahara and Sakamoto 2009). On the other hand, catastrophic damage to hives is often observed in the hives of a non-native bee, *A. mellifera*. The defensive behavior of *A. mellifera* is not as well-organized, and is consequently less efficient (Ken et al. 2005; Abrol 2006). Yellow-legged hornet, *Vespa velutina* is indigenous to the Southeast Asia, but is currently expanding from its native area into southern Asia, and invaded South Korea in 2003 (Choi et al. 2012). In Japan, invasion by *V. velutina* was first recorded in 2012 on Tsushima Island (Sakai and Takahashi 2014). Commercial cardboard coated with sticky substances can be used to capture hornets. Attachment of a hornet trap device in front of the hive entrance can also decrease the damage from *Vespa* attacks.

10.6.7 Vertebrate Predators

10.6.7.1 Bears

In Japan, there are two bear species: Japanese black bear, *Ursus thibetanus japonicus*, which resides on the main Honshu island and Shikoku island; and Hokkaido brown bear, *U. arctos yesoensis*, a bigger bear, which resides in Hokkaido island (Tsuruga et al. 1994; Kurihara 2010). Statistical information about damage to bee colonies associated with bears in Japan has been reported annually. In 2011, a total of 1551 colonies were attacked by bears, resulting in estimated losses of 53,580,000 Japanese yen (Japan Beekeeping Association 2011). The use of electric fences for bear abatement is preventive to some degree, but damage to hives can still occur.

10.6.8 Other Problems of Beekeeping

10.6.8.1 Distribution of Beehives

As mentioned earlier, supply of honey bees in Japan is chronically insufficient. The reason that this has become such a significant issue has to do primarily with the issues related to distribution (Kimura 2011). Populations of pollinator honey bees have temporarily decreased in some areas. However, as of spring in 2009, the number of honey bee colonies throughout the nation did not markedly decrease, but the imbalances in distribution made it difficult to provide honey bees in areas that did not have enough of them. Moreover, in spring, beekeepers already start preparing for honey extraction, and cannot afford to prepare honey bees as pollinators. To address this issue, the Ministry of Agriculture, Forestry, and Fisheries has launched a system for adjusting the supply and demand of honey bees (MAFF 2016b). This system is intended "to determine the number of bees that are available for supply, as well as investigate shortages of bees, in each and every prefecture; to adjust supply and demand in each prefecture; and in the event of persistent shortage, to provide the necessary information to the parties involved, so that adjustment of supply and demand can be made beyond the borders of prefectural borders." This may have been proven effective, and we have not experienced large-scale honey bee shortages since 2010.

10.6.9 Pesticides

Agricultural damage to honey bees caused by pesticides has been an issue for many years. Recently, the effects of neonicotinoid-based pesticides on honey bees have been of concern, and some stakeholders have pointed out that these agents are the primary causes of honey bee decline. However, the effects of pesticides on honey bees have not been fully characterized (Kimura 2011). Some of the insecticide damage to bees in Japan occurs in rice paddies. The development of spotted rice grains is caused by stink bugs of sub-order Heteroptera. In summer, insecticides are widely used to control this problem. Honey bees visit paddies to collect nectar and pollen from nearby flowers, and are exposed to these chemicals while also collecting pollen from rice. Contaminated bees return to the hive, causing piles of dead bees to accumulate in front of the hive entrance (Kimura et al. 2014). In addition, many worker bees are dead before returning to the hives. In order to avoid insecticide exposure to the worker bees, the government is promoting the following measures (MAFF 2017b):

1. Active communication between farmers and beekeepers
2. Relocation of hives from spraying areas (by beekeepers)
3. Use of agricultural chemicals which are difficult for bees to be exposed (e.g., granules) (by farmers)

The government continues to promote these measures and also verifies the effectiveness of countermeasures.

10.6.10 Aging

Not only in beekeeping, but throughout agriculture, the aging of farmers is a serious problem in Japan. The average age of beekeepers was 72 years in 2009 (Kimura unpublished survey), and it is safe to assume that this population continues to age.

10.7 Other Non-*Apis* Species Found in the Region

There are 15 bumblebee species in Japan (Kinoda et al. 2013). Also, the buff-tailed bumblebee *Bombus terrestris* was introduced into Japan from Europe in 1991 for pollination of tomato plants.

B. terrestris is widely used for pollinating tomatoes grown in greenhouses in Japan. This practice risked biological invasion by this species, and indeed, *B. terrestris* has become naturalized, especially in Hokkaido (Matsumura et al. 2004; Inoue et al. 2008). Accordingly, the Ministry of Environment classified *B. terrestris* as invasive and requiring regulation by law; and, its use was permitted on the condition it be used only for agriculture and strict measures to avoid escape.

The Ministry has tried to replace *B. terrestris* with *Bombus ignitus* and other native Japanese bumblebees. However, 60,000 hives of buff-tailed bumblebees are still distributed annually to meet the farmer need for pollination service (ME and MAFF 2017).

The horned-face bee (horn-faced mason bee), *Osmia cornifrons*, is a solitary bee indigenous to Northern Asia. In Japan, this species provides up to 80% of the apple pollination (Maeta 1990, 1993).

This *Osmia* species is used for pollination in 80% of the apples in Aomori prefecture (the northernmost prefecture of Honshu island, where about half of the apples in Japan are produced). The use of *O. cornifrons* is increasing in Japan since *O. cornifrons* achieves higher pollination rates than that of honey bees. In addition, this species is stingless, making it safe to handle. Nevertheless, infestation by acrid mites has become a problem as *O. cornifrons* has expanded (Yamada 1986).

10.8 Future Perspectives

Considering the limitation of nectar sources and the aging of beekeepers, it is unlikely that honey production will expand in the future. On the other hand, the demand for honey bees for use as pollinators remains high. Thus, the most important consideration for Japanese beekeeping is maintaining a sufficient supply of bee colonies for both honey production and pollination service.

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