Journal of Invertebrate Pathology 103 (2010) S80–S95

Contents lists available at ScienceDirect

Journal of Invertebrate Pathology

journal homepage: www.elsevier.com/locate/jip

A historical review of managed honey bee populations in Europe and the United States and the factors that may affect them

Dennis vanEngelsdorp [a,*], Marina Doris Meixner [b]

[a] Department of Entomology, The Pennsylvania State University, 501 ASI Bldg., University Park, PA 16802, USA
[b] LLH Bieneninstitut, Erlenstrasse 9, 35274 Kirchhain, Germany

ARTICLE INFO

Article history:
Received 8 June 2009
Accepted 30 June 2009
Available online 11 November 2009

Keywords:
Honey bee
Colony
Population dynamics
Abiotic
Biotic

ABSTRACT

Honey bees are a highly valued resource around the world. They are prized for their honey and wax production and depended upon for pollination of many important crops. While globally honey bee populations have been increasing, the rate of increase is not keeping pace with demand. Further, honey bee populations have not been increasing in all parts of the world, and have declined in many nations in Europe and in North America. Managed honey bee populations are influenced by many factors including diseases, parasites, pesticides, the environment, and socio-economic factors. These factors can act alone or in combination with each other. This review highlights the present day value of honey bees, followed by a detailed description of some of the historical and present day factors that influence honey bee populations, with particular emphasis on colony populations in Europe and the United States.

1. Introduction – the value of honey bees

The European honey bee, *Apis mellifera* L., is the most commonly managed bee in the world. A highly adaptable species, it has a native range that stretched from the southern parts of Scandinavia to Central Asia and throughout Africa (Seeley, 1985; Ruttner, 1988; Sheppard and Meixner, 2003). Since the 1600s, however, *A. mellifera's* range has expanded to nearly all habitable corners of the globe. Most of the European honey bee's range expansion has been the result of deliberate human transport (Crane, 1999). "Like the dog, the honeybee (*sic*) had accompanied man on most of his major migrations, and some of the early settlers in each part of the New World took hives of bees with them" (Crane, 1975). Unlike dogs however, honey bees were imported by settlers for their ability to make honey and bees wax. Honey was the only sweetener available to early African, Middle Eastern and European civilizations, and demand for the product no doubt lead to the domestication of bees by the Ancient Egyptians sometime before 2600 BCE. The practice of keeping bees was passed to the ancient Greeks by 650 BCE, who in turn passed the art to the Romans (by 150 BCE) who spread the art throughout what would become medieval Europe. It was the descendants of medieval European beekeepers who eventually spread both the practice of beekeeping and the bees themselves around the world (Ransome, 1937).

1.1. Honey

Honey was the only readily available sweetener to the peoples of Europe until methods were developed for refinement of sugar from sugar beets and sugar cane (Voorhies et al., 1933). Honey remains an important international commodity with global production estimated at 1.07 million metric ton in 2007, a 58% increase in production since 1961 (FAO, 2009). Using the average 2006 US price for honey, $1168 metric ton, the global value of honey production in 2007 had an estimated worth of US$1.25 billion.

1.2. Pollination

By far the most important contribution honey bees make to modern agriculture is the pollination services that they provide. Fifty-two of the 115 leading global food commodities depend on honey bee pollination for either fruit or seed set (Klein et al., 2007). Some (five) honey bee-dependant commodities would have $\geqslant$90% yield reduction without honey bees (Klein et al., 2007). In addition, yields in terms of fruit size, quality, or quantity would be greatly reduced (90–40%) in 16 commodities, modestly reduced (10–40%) in a further 19 commodities, and slightly reduced (<10%) in a further 13 commodities (Klein et al., 2007). In total, 22.6% of all agricultural production in the developing world, and 14.7% of agricultural production in the developed world is directly reliant on animal pollination to some extent (Aizen et al., 2008). However, when foods that indirectly benefit from pollination are included, 35% of the human diet is thought to benefit from pollination (Klein et al., 2007). Globally, the value of insect pollination has been esti-

* Corresponding author. Fax: +1 717 705 6518.
E-mail addresses: dennis.vanengelsdorp@gmail.com (D. vanEngelsdorp), marina.meixner@llh.hessen.de (M.D. Meixner).

0022-2011/$ - see front matter © 2009 Elsevier Inc. All rights reserved.
doi:10.1016/j.jip.2009.06.011

mated at US$ 212 billion (€153 billion), which represents about 9.5% of the total value of agricultural production. The value of insect pollination to agriculture is approximately the same for EU25 €14.2 billion (US$19.8 billion) and North American (excluding Mexico) nations (€14.4 billion; US$20.1 billion; (Gallai et al., 2009)).

Not all animal-dependent pollination is provided by honey bees, nor are honey bees the most efficient pollinators of most crops (NRC, 2006). However, they remain the most important pollinator for most crop monocultures worldwide (McGregor, 1976; Delaplane and Mayer, 2000). Managed honey bees are ideally suited for the pollination of large monocrop plantings for several reasons. Colonies of bees have a relatively large year round work force of 10,000–40,000 individuals, approximately one-third of which are foragers (Seeley, 1985). Beekeepers can stimulate the growth of these populations in preparation of a pollination event by feeding artificial diets of sucrose or high fructose corn syrup and artificial protein diets. Further, managed colonies are maintained in standardized equipment which facilitates the transport of colonies over large distances to pollination sites.

The biology of honey bees also makes them well suited as commercial pollinators. Honey bees are generalists, visiting a wide range of flower types, even those they are not well suited to pollinate, such as blueberries and alfalfa. Traveling an average of 4.5 km to forage (Seeley, 1985), honey bees are able to pollinate crops over an area of 6360 ha, allowing colonies to be placed in groups in the center of large orchards without affecting pollination in the orchards' periphery. Further, a bee's ability to communicate the location of floral resources to her nest mates makes honey bees particularly efficient pollinators (Seeley, 1985).

Crops not-dependent on animals for pollination represent the majority of caloric intake in human diets (Klein et al., 2007). While the total land area under cultivation has increased globally over the last 46 years, the proportion of land dedicated to the production of non-pollinator-dependent crops has shrunk when compared to land used to cultivate pollinator-dependent crops (Aizen et al., 2008). In part, this shift in land use is motivated by the fact that pollinator-dependent crops tend to have higher value than non-pollinator-dependent crops (Gallai et al., 2009). Between 1961 and 2006, agriculture industry's dependence on pollinators has increased by 50% and 62% in the developed and developing world, respectively (Aizen et al., 2009). This rate of increase surpasses that of global increases in the number of managed honey bee colonies, suggesting that pollinators may limit production of pollinator-dependent crops in the future (Aizen and Harder, in press).

The loss of all pollinators would reduce agricultural production by an estimated 8%. However, because many crops are not 100% reliant on insect pollination, some reduced production could be compensated for by increasing cultivated acreages. The loss of animal pollinators would require the developed and developing world to increase land cultivated in pollinator-dependent crops by 15% and 42%, respectively, to make up production deficits (Aizen et al., 2009). Pollinator declines and/or failure of pollinator populations to increase at the rate of pollinator-dependent crop expansion could have serious effects on world food security, just as the recent increased demand for corn for ethanol production has had significant effects on food prices (Elobeid, 2007).

2. Populations of managed honey bees

2.1. Worldwide

The total number of managed honey bee colonies worldwide was estimated at 72.6 million in 2007 (FAO, 2009). This represents a 64% increase in the total number of colonies managed since 1961 (Fig. 1). This crude approximation overestimates the change in managed bee populations because it does not account for changes in the number of nation states reporting colony numbers over the period. Aizen and Harder (in press) estimated that global stocks have increased by ~45%, after excluding all states that did not report colony numbers for the entire time series between 1961 and 2007.

While it is clear that global stocks of honey bees have increased over the last five decades, not all regions have experienced gains. Notably, in the period between 1961 and 2007, managed colonies decreased in both Europe (−26.5%) and North America (−49.5%), while large increases were recorded for Asia (426%), Africa (130%), South America (86%), and Oceania (39%) (FAO, 2009). Even within regions there was considerable variability in the honey bee colony population trends. For example, in North America, both the US and Mexico saw declines over the 46 year period, while Canada saw increases in colony numbers. In Europe, similar discrepancies in trends were apparent (Fig. 2: FAO, 2009).

2.2. United States

The number of honey-producing colonies in the US dropped 61% from their high of 5.9 million managed in 1947 to the low of 2.3 million reported in 2008 (Fig. 3). The number of honey-producing colonies has been tabulated by the USDA National Agricultural Statistics Service (NASS) for almost all years since 1943. Between 1982 and 1985 NASS discontinued its survey and colony numbers for those years were estimated by the Agricultural Stabilization and Conservation Service (Rodenberg, 1992) (Fig. 3). The annual census was designed to capture the number of honey-producing colonies in each state. As a result, the survey counts colonies that produce honey in more than one state multiple times, potentially inflating national figures (NRC, 2006). In addition, after 1985, NASS no longer counted beekeepers with five or fewer hives, potentially explaining some of the steep decline in colony numbers recorded between 1985 and 1986 (Fig. 3) (Rodenberg, 1992).

NASS also counts honey bee colonies as part of its agricultural census, an effort it conducted once every 5 years since 1982 (Fig. 3). The agricultural census (Ag Census) effort is meant to provide comprehensive information about US farms, including those with apicultural enterprises. It specifically inventories the number of honey bee colonies owned on farms on December 31 of survey years. This may underestimate the number of "production" colonies in the country as beekeepers may reduce colony numbers going into winter to avoid overwintering costs (Daberkow et al., 2009). The census survey also excludes beekeepers who do not produce or sell $1000 worth of produce per year (Hoppe et al., 2007). Total colonies inventoried by the Ag Census show a period of decline in managed colonies similar to that recorded by the Honey report between 1987 and 2002 (17% vs. 22% respectively), however, between 2002 and 2007 the number of colonies recorded by AG Census dramatically increased.

Standardized periodic surveys that quantify colony numbers provide a measure of total losses and/or gains over a period, but do not necessarily capture actual losses over that period. Beekeepers can quickly replace large losses (i.e. winter losses) by splitting surviving colonies and/or by purchasing and installing packages of bees (vanEngelsdorp et al., 2007). It is, therefore, possible for inventories of colonies reported by a given periodic survey to remain stable or even increase when substantial losses occurred between survey dates (Daberkow et al., 2009). This appears to have been the case in 2007 and 2008. After an estimated overwintering loss of 32% and 36% in the winters of 2006–2007 and 2007–2008, respectively (vanEngelsdorp et al., 2007, 2008), the total number of colonies recorded by the Honey report increased by 5% between