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Ukraine Is Moving Forward from "Undiscovered Honey Land" to Active Participation in International Monitoring of Honey Bee Colony Losses

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Introduction

The history of beekeeping in Ukraine has long and diverse traditions. In the times of Kievan Rus already in the ninth century honey and wax were supplied widely to the countries of the Old World, and formed the basis of the domestic economy (Jones, 2015). Ukraine is also the origin of the first dismountable frame beehive developed by Petro Prokopovych in 1814, which is considered as the beginning the era of rational beekeeping.

Ukraine has variety of natural physiographic zones with favorable climatic conditions for producing high-quality honey based on agricultural crops like sunflower (*Helianthus annuus*), rapeseed (*Brassica napus*), buckwheat (*Fagopyrum esculentum*), sainfoin (*Onobrychis viciifolia*), sweet clover (*Melilotus officinalis*); acacia (*Robinia pseudoacacia*) as an introduced and also invasive tree species and the native tree linden (*Tilia* spp.); as well as a wide range of domesticated and wild plants in traditional cultural landscape woodlands (see Levenets & Malashenko, 1959; Yasko & Yasko, 2017). Together with strong traditions of beekeeping, there are high expectations of increasing export of honey from Ukraine (Jones, 2013). During the Soviet period (1922–1991), the honey market was regulated by the state. Currently, Ukraine is the fastest-growing exporter of honey 2012–2017 see García, 2018). In 2016, Ukraine occupied the seventh highest dollar value among the countries that exported honey. This corresponds to 4.8% of the global honey export values (Workman, 2017), despite the fact that due to tough competition, Ukrainian honey producers are selling their product at very low prices (García, 2018). Small private apiaries in rural traditional cultural landscape settings (e.g., Angelstam, Yamelynets, Elbakidze, Prots, & Manton, 2017) are the base of honey production in Ukraine.

Outside Ukraine, beekeepers may derive considerable profit from the provision of pollination services to farmers (Hanley, Breeze, Ellis, & Goulson, 2015). In Ukraine, this type of business is heavily underdeveloped and there is no payment for providing bees to orchards or agricultural crops for pollination service. Moreover, due to uncontrolled use of pesticides and also high percentage of fake-labelled pesticide products (up to 25%) (Lycholat, 2018), severe summer losses of bees as a result of poisoning happen regularly (e.g., *Death of bees near Kharkov: What is known*, 2018). Cooperation of beehive owners and farmers would be mutually beneficial, and could increase the productivity of both bees and plant crops.

At the 43rd International Apicultural Congress of Apimondia with the theme "Discover the European Honeyland" in 2013 in Kyiv, as the capital of undiscovered honey land, attempts were made to involve Ukrainian researchers to participate in the international monitoring of honey bee colony losses. However, nobody embarked on this. Nevertheless, after an initiative by Mariia Fedoriak at a meeting in Graz, Austria in 2014, Ukraine now participates since 2015 in the international analysis of honey bee colony losses during winter. This survey is organized by the non-profit organization "Prevention of honey bee COlony LOSSes" (COLOSS) in more than 30 countries. To enable the comparison of loss data between participating countries, a standardized questionnaire was developed (van der Zee et al., 2013). The first large international COLOSS survey was conducted after the winter 2008/2009 involving 12 countries. After the following winter 24 countries were involved. Mean honey bee losses in Europe in these 2 years varied from 7 to 30% (van der Zee et al., 2012). Subsequent COLOSS surveys (Brodschneider et al., 2016; van der Zee et al., 2014), a pan-European harmonized active epidemiological surveillance program on honey bee colony mortality (EPILOBEE) (Chauzat et al., 2016), and analyses of the surveys conducted in certain countries (Liu et al., 2016; Nguyen et al., 2010; Pirk, Human, Crew, & van Engelsdorp, 2014; Tunca, Çimrin, Büyük, Taşkin, & Oskay, 2016), provided important data as well as information about risk factors related to the winter losses of honey bee colonies.

In the USA, the first survey on honey bee colony losses was conducted after the winter of 2006/2007, reporting 31.8% loss of colonies in 384 beekeeping operations (van Engelsdorp, Underwood, Caron, & Hayes, 2007). Of the beekeepers reporting

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hives containing few or no bees in spring, 23.8% met the definition of the poorly understood Colony Collapse Disorder (CCD), characterized by the rapid disappearance of adult bees from colonies with brood and food stores (e.g., Williams et al., 2010). After the winter 2007/2008, over 19% of the USA's estimated 2.44 million colonies were surveyed and a total loss of 35.8% of colonies was recorded being the highest loss for the USA so far (van Engelsdorp, Hayes, Underwood, & Pettis, 2008). In the following years, the winter colony loss ranged from lows of 22.3% (2014/2015) and 22.5% (2011/2012) to a high of 34.4% (2009/2010). Sufficient data from Latin America are limited. However, a survey of managed honey bee colony losses has been recently conducted in Argentina, which recorded that 13.0% of the colonies were lost after the winter of 2015/2016 (Requier, Andersson, Oddi, Garcia, & Garibaldi, 2018).

Different abiotic, biotic and anthropogenic factors have been suggested to contribute to honey bee colony losses (e.g., Goulson, Nicholls, Botías, & Rotheray, 2015; Steinmann, Corona, Neumann, & Dainat, 2015; van Engelsdorp et al., 2009; Williams et al., 2010). However, there is a growing consensus that colony mortality is the product of multiple known and unknown factors acting singly or in combination (Williams et al., 2010). The details of beekeeping, factors affecting bees and honey production, as well as the role of bee health as indicators of biodiversity and human well-being, in Ukraine remain largely unexplored. The aim of this article is to present results from the first 3 years of monitoring of bee colony loss in Ukraine. We also highlight the opportunity for innovative analyses at multiple scales, the benefits of bees, and beekeeping as social factor supporting rural development.

Methods

We collected data after the winters 2014/2015, 2015/2016, and 2016/2017. The standard COLOSS protocol, which focuses on winter losses, was translated and adopted for improved understanding of Ukrainian honey bee, beekeeper and beekeeping contexts. The core questions remained the same, while other ones were added, e.g., the question on the number of colonies lost through natural disaster after the winter 2016/2017. Beekeepers were allowed to answer anonymously. Responses with incomplete or illogical answers were excluded. To increase the number of questionnaire answers, we employed an increasing number of methods of data collection. We contacted beekeepers by email, regular mail, phone, by means of face-to-face interview, and also using an electronic survey in the last year. We also published the questionnaire and explained its essence and the importance of the survey in the *Ukrainian Beekeeper Journal*, which was fruitful. The received data were grouped according to the administrative (Oblast) and physiographic subdivisions of Ukraine (Figure 1).

Results

The number of valid answers from our respondents increased from 300 after the winter 2014/2015, 399 after the winter 2015/2016 to 536 after the winter 2016/2017. We also reached more administrative regions of Ukraine every year, and beekeepers from five of the six physiographic zones of Ukraine, except the Crimean Mountain Region (Figure 1). Respondents included hobby beekeepers, side-line beekeepers, and professionals practicing both stationary and migrating beekeeping (Figure 2).

Overall winter loss rate of honey bee colonies in Ukraine varied significantly among the 3 years and ranged from 9.9% (95% confidence interval (CI): 8.5–11.4%) to 17.9% (95% CI: 16.0–19.9%) (Figure 3). This is lower (i.e., no overlap between 95% confidence intervals) than the loss rates presented for the same winters by COLOSS, which was 12.0% (95% CI: 11.8–12.2%) and 20.9% (95% CI: 20.6–21.3%), respectively (Brodschneider et al., 2016, 2018).

We grouped beekeeping operations into small (1–50 colonies), medium (51–150 colonies) and large (>151 colonies) operations using the data collected after the winter 2016/2017. Beekeepers with small operations had higher loss rate (24.3% (95% CI: 21.9–26.9%)) than those with medium and large operations (13.7% (95% CI: 10.6–17.6%) and 14.9% (95% CI: 6.5–30.8%)).

The mortality rate reached 14.0% (95% CI: 12.3–15.9%) after the winter 2016/2017, being the highest in the 3 years (Figure 3). The rate of colony loss due to queen problems was highest after the winter 2015/2016 and made up 3.6% (95% CI: 2.89–4.49%) (Fedoriak, Tymochko, Kulmanov, Volkov, & Rudenko, 2017). After the other two winters it was much lower, and did not exceed 1.8% (95% CI: 1.4–2.2%). The question on the colonies lost due to natural disaster was asked in the 2016/2017 survey only. This kind of loss was higher in Ukraine (2.1%, 95% CI: 1.7–2.7%) compared to other countries (Brodschneider et al., 2018), and was caused by storm, fire, flooding, pine martens (*Martes martes*), birds and mice. A total 15.4% (95% CI: 12.8–16.7%) of colonies were weak after the winter, but with productive queens.

We also analyzed the differences in the loss rates of honey bee colonies among the physiographic zones of Ukraine for the winters of 2015/2016 and 2016/2017 (Figure 4). The winter of 2014/2015 was excluded due to the small amount of valid answers which mostly were obtained from the Ukrainian Carpathians.

We found a significant difference (i.e., no overlap between CIs in Figure 4) in the loss rates of honey bee colonies among the physiographic zones of Ukraine after the winter of 2015/2016, but not for 2016/2017. The highest lost rate in 2015/2016 was recorded in the mixed forest zone (29.1%) and it was significantly

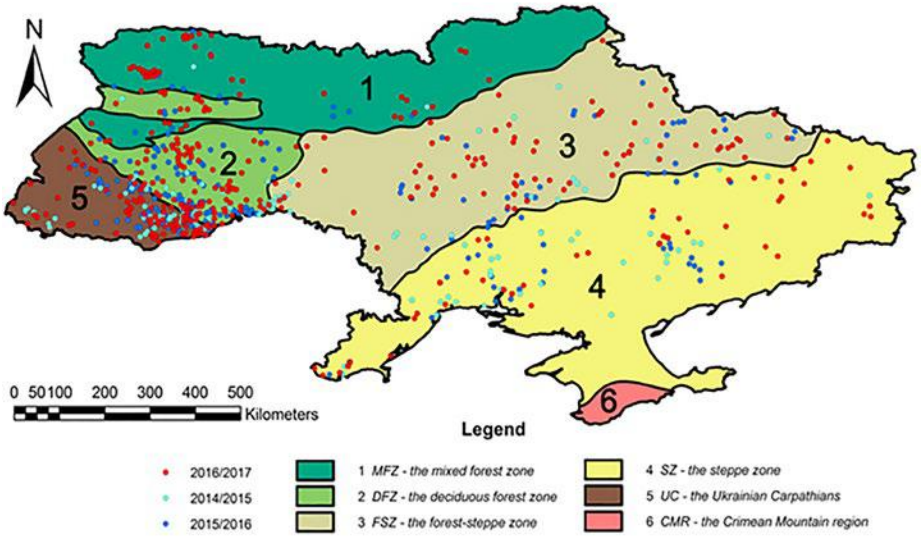

Figure 1. Geographical distribution of COLOSS survey respondents in Ukraine and Ukrainian physiographic zones.

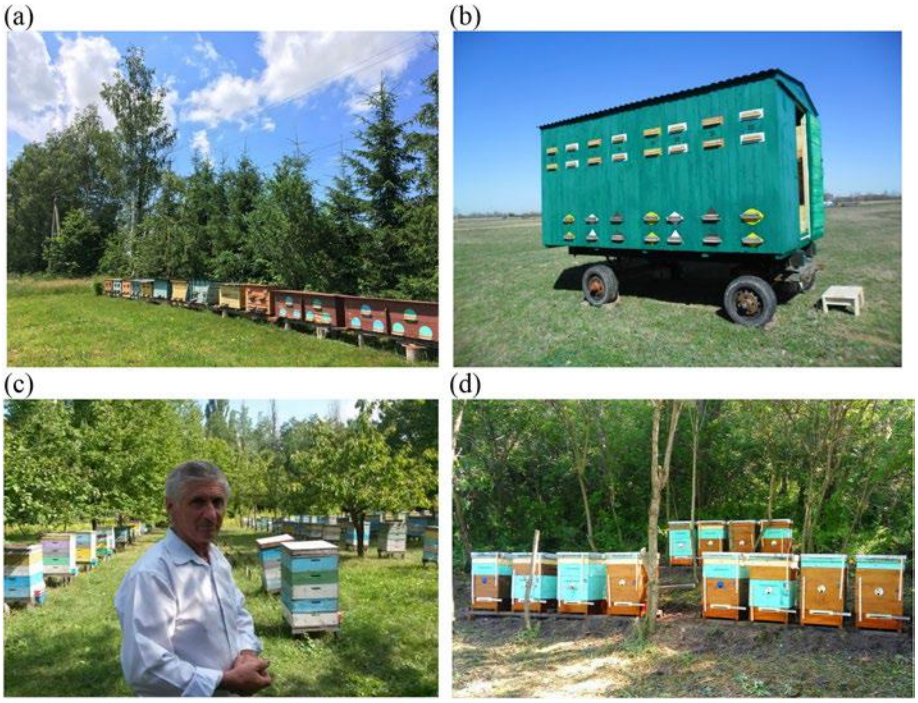

Figure 2. Different types of Ukrainian apiaries belonging to respondents from the Chernivtsi region; (a) stationary apiary, (b) mobile apiary of sideline beekeeper, (c) commercial apiary in an orchard, (d) part of the commercial apiary placed for the harvesting. Photos by Mariia Fedoriak.

higher than in all the other physiographic zones. The lowest total losses were found in the deciduous forest zone (7.1%), which was significantly lower not only than in mixed forest zone, but also than in the forest-steppe zone.

The larger sample size of 2016/2017 allowed for more detailed analyses, such as the number of colonies per beekeeper. More than a half (52.8%) of the colonies going into winter of 2016/2017 belonged to small operations with no more than 20 colonies (Figure 5). Medium-sized (101–150 colonies) operations occurred rarely and only 18 cases (3.3%) with more than 151 colonies per operation were found among our respondents. On average the respondents wintered 38.9 colonies per operation in the winter of 2016/2017, 34.7 in 2015/2016 and 36.1 in 2014/2015. The average number of colonies per operation in Poland was similar (36.2), whereas it was lower in Slovakia (24.6) and Czech Republic (17.9) (Brodschneider et al., 2016).

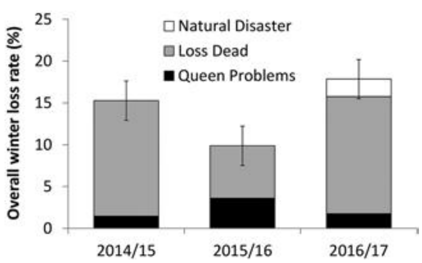

Figure 3. The overall winter loss rate of honey bee colonies in Ukraine.

A total of 43.5% of the beekeepers monitored, and 86.9% treated their colonies against *Varroa destructor* during the period of April 2016–April 2017. Various methods and products are used and they are often applied several times per season. In contrast to West European beekeepers, who mostly apply *Varroa* treatment in autumn, many Ukrainian beekeepers treat the colonies both in spring (April) and in autumn (August to October). We do not provide these details on when which application is applied, but what are the most used treatments only. Biotechnical methods are popular in Ukraine with drone brood removal being the most often used (Table 1). Among the chemical products to treat against the *Varroa* mite the ones containing Amitraz are the most popular. Products containing Flumetrin and Fluvalinat are also often used.

Discussion

Bees are important for the pollination of both wild and agricultural plants (Klein et al., 2007), and contribute to the economy and livelihoods of people in rural landscapes (Silviu, Oana, Stefania, & Victor, 2011). The global problem of bee mortality is caused by multiple factors, including pesticide use, foraging on monocultural crops rather than diverse flower nectar sources, parasites and diseases, and climate change (e.g., Goulson et al., 2015; Potts et al., 2011; Steinmann et al., 2015). The contact between researchers and beekeepers established through the monitoring of colony losses, and other aspects of beekeeping, is an asset for developing citizen science aimed at understanding the factors that affect bees, beekeeping and the role of bees in landscapes. Potential research topics range from honey production as a provisioning ecosystem service and the role of bees for pollination as a regulating ecosystem service, to beekeeping as means of empowering citizens. The factors affecting ecosystem services range from beekeepers' skills to maintain healthy bee colonies, to external factors linked to particular seasonal weather conditions as well as land cover and land use patterns and dynamics.

This merits comparisons of beekeeping systems in gradients of land use and land cover (Potts et al., 2010), such as from traditional cultural landscapes (Solymosi, 2011) to intensive agriculture (Odoux et al., 2014), both of which are found in Ukraine (Angelstam et al., 2017). For example, the abundance of floral resources at the landscape scale has been shown to be a critical determinant of honey bee colony success (Sponsler & Johnson, 2015). Such landscapes are also favorable for development of agrotourism and non-agricultural activities as the main solutions for socio-economic problems in rural landscapes (Silviu et al., 2011; Solymosi, 2011; Stryamets, Elbakidze, & Angelstam, 2012). In a geographically diverse country like Ukraine, this offers opportunity to stratify data based on land cover and land use and other key variables, as shown in this article with physiographic zones.

Beginning in the winter season 2014/2015, the COLOSS survey in Ukraine has to date reached more than 500 beekeepers. There is, however, opportunity and need for considerable increase of the sample size in Ukraine. First, covering 604,000 km^2, Ukraine is the largest country entirely located in the European continent. Second, Ukraine has a wide range of land cover types that host agricultural, introduced and native plants of importance for honey production. Third, the rural population is large (ca. 14 million) and beekeeping is an important part of rural livelihoods and culture. Yasko and Yasko (2017) estimated the number of beekeepers to 400,000, having a total of 3 million bee colonies. The official statistics says 2.64 million colonies for 2018 (State Statistic Service of Ukraine, 2017), which is regarded an underestimation (Anna Burka, FAO, pers. comm.).

Ukraine has a strong tradition of beekeeping and is the major supplier of

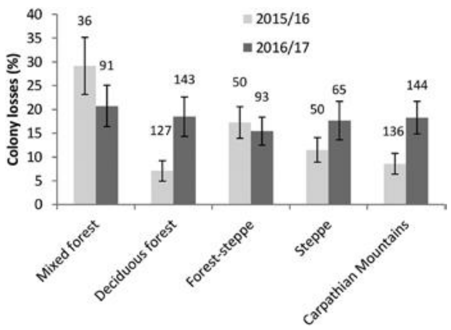

Figure 4. Overall winter loss rate after the winters of 2015/2016 and 2016/2017 among physiographic subdivisions of Ukraine; see also Figure 1. Sample size (number of operations) is presented above each bar.

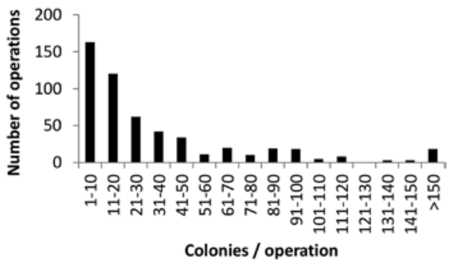

Figure 5. Size of the beekeeping operations belonging to our respondents expressed as the number of colonies going into winter 2016/2017.

honey within Europe, and globally ranks third after China and Argentina (García, 2018). This is linked to a rapid increase of honey export 2008–2017 from 3300 tons to 67800 ton (Anna Burka, FAO, pers. comm.). With its diversity of ecoregions and socio-economic legacies, Ukraine is a unique landscape laboratory where past trajectories of land use has led to large contrast between abundant remnants of traditional village system in remote locations and emergence of intensive agriculture. Adding also comparative studies that include other countries on the European continent's gradients in both ecological and social systems (e.g., Angelstam et al., 2013) offer unique opportunities to explore factors that beekeepers perceive are affecting the viability of bees, bee products and other ecosystem services. These can be linked to landscapes that are beneficial for honey bees as well as for human well-being and rural development (Ahmad, Joshi, & Gurung, 2007). However, there are also topics that cannot be understood based on questionnaire data only. Are there differences in the efficacy of different *Varroa* treatments that are applied in Ukraine? What is the role of the genetic diversity of bees? How does the regulation of pesticide use translate to the praxis, and how can beekeepers raise their voice if they are impacted by pesticides? Such questions

Table 1. Proportion of COLOSS survey respondents in Ukraine stating particular measures against the *Varroa* mite, which may or may not be combined, during the period of April 2016–April 2017.

Measures to combat the *Varroa* mite	% of respondents ($n = 536$)
Drone brood removal	42.3
Amitraz (in strips, e.g., Apivar)	34.9
Amitraz (fumigation)	28.5
Oxalic acid – trickling	11.6
Flumetrin (e.g., Bayvarol)	10.6
Oxalic acid – evaporation	10.4
Thymol (e.g., Apiguard, Api Life Var)	10.3
Formic acid – long term	4.9

require particular research designs, and both natural and social science methods. A complement to the COLOSS survey would be to carry out horizon scanning (Sutherland & Woodroof, 2009) of beekeepers' perceived barriers and bridges by strategic selection of regions with different levels of bee colony losses, both in Ukraine and internationally.

Conclusions

Ukraine is producing large quantities of honey, wax, and other bee products. Since Ukraine gained its independence in 1991 the honey volume export increased significantly. However, the details of beekeeping and underlying factors in Ukraine remain largely unexplored. Neither information on the number of honey bee colonies, the situation with varroosis, colony mortality and other problems of beekeeping in Ukraine, nor the role of beekeeping for human well-being, have been analyzed comprehensively. Ukraine joined the international COLOSS study of honey bee colony losses in the winter 2014/2015, and have now completed 3 years of monitoring. In these 3 years, we could increase both the number of responses, and the territory covered. The overall loss rates in Ukraine during the three first year of this monitoring were lower (9.9–17.9%) than the loss rates for other countries on the European continent participating in the COLOSS survey. The loss rates of honey bee colonies among the physiographic zones were significantly different during the winter of 2015/2016 but not 2016/2017. Beekeepers with small operations had higher loss rates (24.1%) than those with medium (13.7%) and large operations (14.9%). A total of 43.5% of the respondents monitored, and 86.9% treated their colonies against *Varroa* mites during the period of April 2016–April 2017. The majority of Ukrainian beekeepers use biotechnical methods, among which drone brood removal is the most popular. Chemical products containing Amitraz were the most popular. The presence of Ukraine in the COLOSS initiative offers opportunity for innovative comparative studies of the factors affecting bee colony survival, of the benefits of bees, and also the role of beekeeping as a social factor that strengthens the opportunity to highlight bees as producers of multiple ecosystem services in particular and rural development in general.

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