

OFF-SEASON SWARMING IN THE JAPANESE HONEY BEE (*APIS CERANA JAPONICA*)

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Abstract

Several studies have reported fragmentary evidence that climate change is altering the phenology and behavior of honey bees. We compiled records of off-season swarming of the Japanese honey bee (*Apis cerana japonica*) between autumn and winter to improve our understanding of the impact of climate change on the subspecies' swarming phenology. Based on a survey of 311 beekeepers, eleven off-season swarming records were collected, with ten of them are from 2020 onward. The beekeepers who reported off-season swarming records had eight to twenty years of beekeeping experience, and they declared that they were witnessing off-season swarming for the first time, suggesting a recent increase. One possible factor contributing to the increase in off-season swarming is the temperature rise, as average autumn and winter temperatures in Japan have been increasing.

Keywords: Asian honey bee, climate change, phenology, reproductive behavior, swarming cycle

INTRODUCTION

Several studies have reported fragmentary evidence that climate change is altering the phenology and behavior of honey bees. For example, rising temperatures in the U.S. and Canada have increased the daily flight time of European honey bees, *Apis mellifera* (Rogers et al., 2022). In Poland, the first cleansing flight (spring cleaning) of European honey bees is starting earlier (Sparks et al., 2010). However, there remains a lack of understanding of the impacts of climate change on honey bees (Havard et al., 2019), especially for members of the genus *Apis* other than *A. mellifera*. The Japanese honey bee, *Apis cerana japonica* (Hymenoptera, Apidae), is a wild subspecies of the Eastern honey bee, *Apis cerana*, that is endemic to Japan. The Japanese honey bee is a moderately common bee within its distribution range. The basic life history of the Japanese honey bee is similar to that of the European honey bee, colonies of which have been imported to Japan, although *A. cerana japonica* is thought to be better adapted to the environmental characteristics of Japan's climate and natural enemies (Yoshida, 1997;

Sugahara & Sakamoto, 2009). Japanese honey bees form colonies ranging from several thousand to 20,000 individuals, which is generally less than half the size of European honey bee colonies (Okada, 1997; Yoshida, 1997). In part due to their small colony size, Japanese honey bees typically produce 2.4 to 7.2 kg of honey per colony per year, which is also considered lower than that of European honey bees in Japan (e.g., 31-68 L, as reported by Harui, 1995).

Reproductive swarming (hereafter "swarming") is the behavior of a queen bee flying off to a new nest site with some workers in tow. A swarming cycle comprises one to several swarms. Swarming is the only method by which honey bees increase their colonies under natural conditions. Unlike European honey bees, which are kept primarily in Langstroth beehives, Japanese honey bees are often kept in structures without hive frames, and swarm prevention and artificial swarming are not common. Therefore, the swarming behavior of kept Japanese honey bees is thought to be similar to that of wild populations. Successful overwintering colonies of Japanese honey bees usually increase their colony via a swarming cycle between late March and May (Okada, 1997). In

some cases, colonies that have swarmed may swarm again in July or August of the same year without experiencing overwintering (Sugahara, 2000). However, we sometimes receive beekeeper accounts of off-season swarming by *A. cerana japonica*.

In this study, we compiled records of off-season swarming in autumn and winter, previously unknown swarming seasons of Japanese honey bees. Our study is the first report of an increase in off-season swarming by *A. cerana japonica*, suggesting an impact of climate change on native Japanese honey bees.

MATERIAL AND METHODS

On 13 February 2023, we requested via email information on cases of off-season swarming between autumn and winter (September through February) from 311 beekeepers who kept Japanese honey bees. To compile information on off-season swarming, we collected data on the swarming date of each colony, the address where the hive was located, the success or failure of overwintering by the swarmed colony, the number of co-located hives prior to the swarming and years of beekeeping experience. If the exact date of the swarming was not known, we asked the beekeeper to provide the dates of hive inspection pre- and post-swarming. If beekeepers had photographs of the hive inspections, we requested that photographic data as well. Cases of such possible unproductive swarming as an escaped swarm having been captured by a bait hive were excluded from our data.

A case of swarming in December 2022 was reported in the February 2023 issue of the newsletter for beekeepers of Japanese honey bees (The Japanese Native Honey Bee Association, 2023), and this information was added to the dataset as well.

RESULTS

Based on our survey, records of eleven cases of swarming between September and January were collected from six beekeepers. One swarming record was from 2012, but the remaining ten

records were from 2020 onward (Tab. 1). Of the five colonies for which the exact swarming date was not known, three were determined to have swarmed because photographs taken in routine hive inspections showed the emergence of queen cups and a drastic decline of workers. The remaining two were determined to have swarmed because inspection photographs showed the production of drones and a drastic decline of workers.

The number of swarms in a single swarming cycle ranged from one to four (Tab. 1). The swarmed colony that remained in the hive in 2012 failed to overwinter and collapsed. The swarmed colony that left this hive was not under control of the beekeeper, so the success or failure of overwintering was not recorded. In the 2020 swarming cycle, both the remaining and the swarming colony failed to overwinter and collapsed. In the 2022 and 2023 swarming cycles, two of the remaining colonies (D3 and D4) had already collapsed by the time of our survey, but six colonies had survived until February 2023. The survival status of colony E1 is unknown. The number of co-located hives at the time of pre-swarming ranged from one to nine, although no such data were available for colony E1. The beekeepers who reported off-season swarming records had eight to twenty years of beekeeping experience, and all of them declared that these reported off-season swarming cycles were the first that they had witnessed. Swarming cycles from autumn to winter were recorded in six prefectures south of 36°N (Fig. 1).

DISCUSSION

Our findings suggest that in recent years Japanese honey bees have become more likely to swarm in autumn and winter, which were not previously known as swarming seasons. This finding is supported by the fact that autumn and winter swarming has been reported in several regions since 2020 by beekeepers with eight to twenty years of experience keeping Japanese honey bees. One possible factor contributing to the increase in off-season swarming is the temperature rise, as average autumn and winter temperatures in

Table 1.

List of *Apis cerana japonica* colonies that swarmed between autumn and winter
(September through January)

Colony ID [†]	Year	Prime swarming day [‡]	After swarming day			Presumed swarming period	Over-wintering [§]	Co-located hives	Years of beekeeping experience	Location (prefecture)
			1	2	3					
A1	2012	Jan 9					Collapsed	1	13	Chiba
B1	2020	Dec 13					Collapsed	4	20	Saitama
C1	2022	Sep 9					Survived	6	8	Kanagawa
D1	2022	Oct 24	Oct 28				Survived	3		
D2	2022	-				Oct 26 to Nov 6	Survived	6		
D3	2022	-				Oct 26 to Nov 16	Collapsed	9	10	Aichi
D4	2022	-				Nov 6 to 26	Collapsed	6		
D5	2022	Dec 3	Dec 6	Dec 9	Dec 12		Survived	6		
E1 [¶]	2022	Dec 5	Dec 7	Dec 9			-	-	11	Hyogo
F1	2023	-				Jan 10 to 17	Survived	4	15	Kagoshima
F2	2023	-				Jan 17 to 25	Survived	4		

[†] The same letter in the colony ID indicates the same beekeeper.

[‡] A dash indicates unknown data.

[§] Overwintering indicates the outcome of the colonies that remained in the original hive after swarming.

^{||} Co-located hives indicate the number of sympatric hives kept together.

[¶] E1 is a colony referred to in a newsletter for beekeepers of Japanese honeybees (The Japanese Native Honey Bee Association, 2023).

Japan have been increasing (Japan Meteorological Agency: https://www.data.jma.go.jp/cpdinfo/temp/win_jpn.html). In the winter of 2022-2023, when there were relatively many reports of off-season swarming, the average temperature in November 2022 reached the highest recorded level compared to that of the same month since 1946 (Japan Meteorological Agency: <https://www.data.jma.go.jp/tcc/tcc/products/japan/climate/index.php?kikan=mon&month=11&year=2022>). One colony swarmed in January 2012, despite the temperature not being particularly warmer than usual (Tab. S1), suggesting that some Japanese honey bees have the ability to swarm in low-temperature conditions. The recent mild autumn and winter temperatures may have triggered the manifestation of this ability. Thus, temperature rise might lead to a wider range of swarming seasons for Japanese honey bees than in the past. However, further research is needed to clarify the causal relationship

between temperature rise and off-season swarming. On the other hand, there is a report that the timing of swarming is not explained by growing degree days (Gilley et al., 2018), suggesting that swarming can be affected by a variety of factors. Therefore, in addition to temperature rise, other factors would also need to be considered. The autumn and winter swarming of Japanese honey bees reported in this study might be an example of the impacts of climate change. In addition, if data on off-season drone production by Japanese honey bees can be gathered, a change in phenology of drone production may also be observed. These behaviors of Japanese honey bees may be changing, warranting continued monitoring of the swarming phenology of Japanese honey bees.

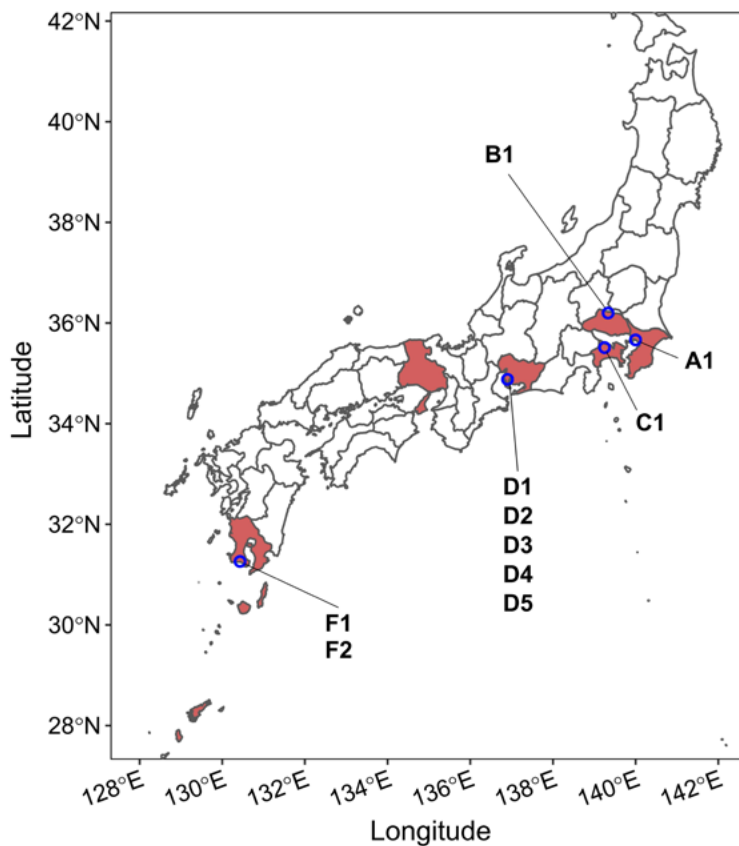


Fig. 1. Locations of the Japanese honey bee colonies that swarmed between autumn and winter (September through January). The prefectures where these swarming cycles occurred are shaded red. Circles indicate the approximate locations of the colonies. Alphanumeric codes correspond to the colony IDs in Tab. 1. Colony E1 was not plotted on the map because its exact location within Hyogo Prefecture is unknown.

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AUTHOR CONTRIBUTIONS

MK: data collection, funding acquisition, investigation, visualization, writing original draft. SY: conceptualization of the study, supervision, writing review and editing. Both authors contributed to the article and approved the submitted version.

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Table S1.

Mean temperature of the prefecture (prefectural capital) during the month of swarming in the swarming year and in 1991-2020

Colony ID	Swarming year	Month of swarming	Location (prefecture)	Mean temperature of prefecture in month and year of swarming	Mean temperature of prefecture in month of swarming, 1991-2020
A1	2012	January	Chiba	4.4°C	6.1°C
B1	2020	December	Saitama	6.3°C	6.2°C
C1	2022	September	Kanagawa	24.7°C	23.7°C
D1, D2, D3	2022	October	Aichi	18.7°C	18.6°C
D2, D3, D4	2022	November	Aichi	14.6°C	12.6°C
D5	2022	December	Aichi	6.6°C	7.2°C
E1	2022	January	Hyogo	7.9°C	8.8°C
F1, F2	2023	January	Kagoshima	9.0°C	8.7°C

This table was created with reference to the “Past weather data search” web page of the Japan Meteorological Agency (<https://www.data.jma.go.jp/stats/etrn/index.php>).