# REFERENCES

## 1.2. Cold snaps in autumn trigger wintering

The timing of colonies to start wintering matters for overwintering success. It is assumed that the process of wintering is indirectly triggered i.e. by decreasing temperatures in autumn [[1]](#footnote-1)[[**30**](https://royalsocietypublishing.org/doi/full/10.1098/rsos.210618#RSOS210618C30)]. If warm periods stretch into late autumn or early winter, sudden cold spells could hit underprepared colonies. Cold spells with adequate duration and intensity during late autumn trigger colony wintering at the right time, reducing the likelihood of colony loss over winter. We assume a negative correlation of cold snaps in autumn with honey bee colony winter mortality.

## 1.3. Hive hygiene in early winter

During the winter months, food stores are consumed by long-lived winter bees. Since bees do not defecate inside the hive to reduce pathogen dispersion, their faeces accumulate in their rectum. Regular snaps of warm weather during the coldest months help bees to leave the hive and defecate. The more regular these mild winter weather conditions occur, the better the hygiene of the hive can be maintained, increasing the bees' vitality [[2]](#footnote-2)[[**26**](https://royalsocietypublishing.org/doi/full/10.1098/rsos.210618#RSOS210618C26)]. Such snaps of warm weather also facilitate the movement of the winter cluster to the food stores (see below). We therefore assume a negative correlation of regular warm weather conditions during winter with colony mortality.

## VARROA

<https://beeaware.org.au/archive-pest/varroa-mites/#ad-image-0>

<https://www.sciencedirect.com/science/article/pii/S147149222030101X>

<https://www.apidologie.org/articles/apido/full_html/2010/04/m09037/m09037.html>

In temperate regions, the number of bees and brood in a colony increase between April and July and decrease between August and October [[9]](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3338694/#pone.0036285-Martin1). However, the main peak of the number of bees and brood occur earlier in the season than the peak of mite abundance [[10]](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3338694/#pone.0036285-Boot1), [[11]](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3338694/#pone.0036285-Martin2). Hence, mite infestation strongly increases during the period in which the number of bees and brood decrease [[9]](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3338694/#pone.0036285-Martin1) ([Figure 1](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3338694/figure/pone-0036285-g001/)), resulting in an increasing number of brood cells infested with V. destructor over time. It is exactly during these months of reduction in the number of brood and rapid increase in mite infestation, that bees hatching from this highly infested brood will become winter bees [[9]](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3338694/#pone.0036285-Martin1), [[12]](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3338694/#pone.0036285-Mattila1).

Adult bees, which are infested by V. destructor as pupae, do not fully develop physiological features typical of long-lived winter bees compared with non-infested workers [[6]](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3338694/#pone.0036285-Jong1)–[[8]](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3338694/#pone.0036285-Amdam1), making it unlikely for them to survive until spring and contribute to the build-up of the colony in early spring [[2]](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3338694/#pone.0036285-LeConte1). To date, however, the relation between the lifespan of individual bees and colony losses for different levels of V. destructor infestation has not been tested.

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3338694/

Therefore, the effect of temperature on biological processes is often investigated for an a priori designated time window[26](https://www.nature.com/articles/s41598-021-01369-1#ref-CR26). For example, in a previous investigation of *V. destructor* population dynamics, a two-month time lag was assumed

<https://www.nature.com/articles/s41598-021-01369-1>

raised spring (March–May) and autumn (October) temperatures reinforce autumn *V. destructor* infestation in honey bee colonies. These effects were potentially associated with the increased bee reproduction in the specific periods of the year and not, as previously hypothesized, with the extended period of activity or accelerated spring onset

1. Mattila HR, Otis GW. 2007 Dwindling pollen resources trigger the transition to broodless populations of long-lived honey bees each autumn. Ecol. Entomol. 32, 496-505. (doi:10.1111/j.1365-2311.2007.00904.x) [↑](#footnote-ref-1)
2. Sparks TH, Langowska A, Głazaczow A, Wilkaniec Z, Bieńkowska M, Tryjanowski P. 2010 Advances in the timing of spring cleaning by the honey bee Apis mellifera in Poland. Ecol. Entomol. 35, 788-791. (doi:10.1111/j.1365-2311.2010.01226.x) [↑](#footnote-ref-2)