Beekeeping Basics

The Greatest Generation: Winter Bees

by MEGHAN MILBRATH

"Whether a colony survives the winter in good condition is determined more by its make-up than by the kind or amount of protection." — Farrar, 1944[1]

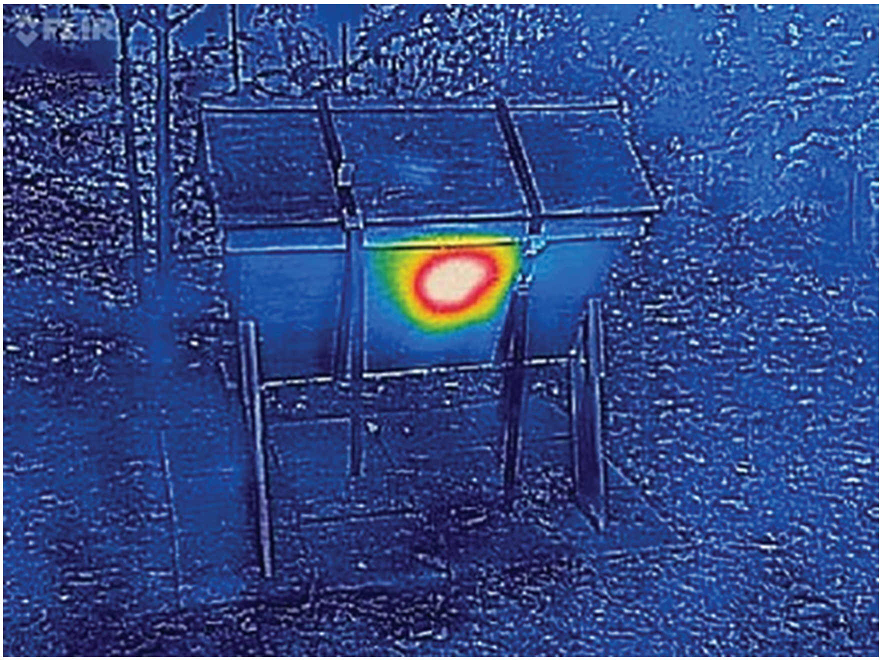
Beekeepers love to discuss winter hive protection — wrapping vs. insulation, upper entrances, quilt boxes or moisture boards, bee cozies, straw bales, and which way to turn the hole on the entrance reducer. Our hives may be the best protected hives in history! Our colonies, however, have the lowest rates of survival through winter. In the winter of 2018-2019 beekeepers in the U.S. reported losses of 38% — the highest ever reported in the Bee Informed Partnership survey, and much higher than what beekeepers consider sustainable.[2] To improve winter survival, we have to pay attention to what Farrar said, turning our conversations away from hive protection, and focusing on the make-up of the colony. Whether a colony survives winter depends very little on what we did to the structure itself, and very much on the health and size of the colony — the precious and wonderfully adapted generation of winter bees.

*An exposed honey bee hive in a northern climate. Honey bees are adapted to live in wooden cavities through seriously cold winter conditions and long periods without food. Photo by CheepShot - Exposed Bee Hive, CC BY 2.0, **https://commons.wikimedia.org/w/index.php?curid=37126773***

Winter bees are a caste. In insects, the term "caste" is used to describe a physically distinct group of individuals that is specialized to perform a function in the colony. When we think of honey bee castes, we focus on queens vs. workers — female bees with very different bodies and very different functions. However, the worker bees are not a homogenous group, and we also see specialization among workers: summer bees and winter bees. Winter bees have very differently adapted bodies and very different functions than their summer counterparts. As honey bee colonies expanded their range north, bees were forced to adapt to survive cold temperatures and periods without incoming pollen. They had to figure out how to insulate themselves, create warmth, and store energy to survive long cold winters. Honey bees adapted by developing a special bee (winter bee), and a special behavior (the winter cluster).

Plenty of other small animals are adapted to survive the cold besides honey bees — Canada geese, snowshoe hares, penguins, otters, Arctic foxes, snowy owls, etc. all do just fine in prolonged cold temperatures. The reason all these animals do fine in cold temperatures is not because someone builds them a hive and vents it just perfectly and tilts it just right. Cold adapted animals survive because they keep their bodies insulated, and they store a layer of food. Honey bees are the same. They use the cluster to insulate themselves, and winter bees store a layer of food. As long as a colony is healthy, it can survive very cold temperatures. In fact, it was shown that a cluster of bees could survive minus 112 degrees Fahrenheit (-80 Celsius for 12 hours)![3]

How do bees survive extreme cold if not in insulated hives? By acting like penguins! Emperor penguins in Antarctica don't try to heat the entire frozen continent, they heat themselves by forming a tight cluster, with the outer individuals forming an insulating layer for the penguins on the inside. Honey bees act similarly;



A thermal image of a honey bee cluster in a top bar hive. Notice how very little heat escapes the cluster, leaving the temperature in the hive roughly the same as the outside temperature. Many studies have shown that the cluster is efficient at trapping heat, and very little escapes into the hive cavity. Photo by Rusty Burlew. *Rusty's blog "Honey Bee Suite" has more great information on winter bees — **www.honeybeesuite.com**.*

bees do not heat the hive — they heat themselves in a cluster. It would be super-inefficient for penguins to heat an iceberg, or for bees to heat a hive. Instead, the bees (and penguins) act as a unified superorganism, creating a warm insulating layer around their whole "body."

The insulating layer is formed when the bees on the outer edge pack tightly together with their heads toward the center. When the bees are tightly packed, their branched hairs can interlace, trapping air and basically acting like a warm coat of fur. Even more amazingly, bees can prevent heat loss through their exposed abdomens by controlling their body heat using an internal counter-current heat exchange system. This system works by transferring the heat in the hemolymph leaving the thorax to the hemolymph entering the thorax. As hemolymph is pumped from the abdomen to the thorax it has to pass through the narrow, constricted petiole (waist) of the bee, where the aorta makes a series of hairpin turns. As the cool fluid from the abdomen winds through the twists and turns, it is warmed from the heated hemolymph returning from the thorax. The heat transfers to the incoming fluid, and stays in the thorax, so the bees lose very little heat through their exposed abdomens when in the cluster. Because of the interwoven branched hair, tightly packed bodies, and cool abdomens, the efficient outer layer of the cluster is an excellent insulator. In fact, it approaches the insulation factors of goose down or fur.[4] We can now picture our winter colony as an animal with a warm insulating layer, designed to withstand cold temperatures.

Screened research colony used to overwinter colonies through Wisconsin winters. The temperatures in the screened hives were similar to temperatures in wooden hives, demonstrating how little heat leaves the cluster. Photo from Production Research Report No. 169, Agricultural Research Service, USDA in Cooperation with the University of Wisconsin College of Agricultural and Life Sciences, 1977

So they don't get too cold, the bees in the insulating layer rotate into the warm core of the cluster. If the body temperature of an individual bee falls below 42 F (about 5.5 C), the bee will enter a "chill coma" where it can't move. Below 29 F (about -2 C), the body tissue of a bee will freeze, and it will die from cold in less than an hour.[5] The temperature at the outer edge of the cluster is usually about 46 F (8 C), so the bees in the outer layer are kept right above the chill coma temperature. This means that it is important to keep bees in the insulating layer from getting cold too quickly. If the cluster is exposed to wind, the bees on the outside of the cluster can cool rapidly, fall into a coma, drop from the cluster, and freeze to death at the bottom of the hive.

This was shown in the 1970s by researchers at the UDSA/University of Wisconsin College of Agriculture.[6] They performed an experiment where they overwintered four regular hives and four hives with walls made of screen. The temperatures in the clusters were similar in both styles of hive, even when they were brood rearing, and even during the coldest temperatures in January. The screened colonies only died after a storm with high winds. Presumably, the winds caused the outside bees to cool so quickly that they entered a chill coma and dropped from the cluster, rapidly shrinking the cluster, and exposing the next layer of bees. When the screened hives were in sheltered locations, away from piercing winds, the colonies could survive. Go ahead and open the lid to peek at the colony and check food stores — just don't do it in a blizzard when you could quickly cool the outer layer of bees. Since the bees don't let much heat out of the cluster, you won't be letting much heat out of the hive.

Clustering behavior occurs without a centralized controller coordinating behavior, and in the absence of communication; the winter cluster emerges from the collective behavior of thousands of bees that only know their immediately local condition. They enter the cluster formation whenever the temperature dips cool enough (about 60 F [15 C]). As temperatures drop further, the cluster tightens to hold in more heat. It can shrink in size five-fold until about 15 F (-10 C), at which point the cluster is the tightest. If temperatures drop even colder, the bees on the inside of the cluster shiver by flexing the large flight muscles in their thorax, creating heat. When temperatures are just below 50 F (about 10 C), the cluster is most efficient, because it can maintain warmth without expending too much energy.

Even though bees are well adapted to cold, it is stressful. When we think about winter stress, we think about metabolic expenditure — how much energy the bees need to use to survive. A larger cluster can operate much more efficiently than a smaller cluster, as a smaller proportion of the bees will have to be engaged in insulating or shivering tasks. Furthermore, the bees in a large cluster lose proportionally less heat — a larger cluster will have a smaller surface-area-to-mass ratio than a smaller cluster (think of the surface area-to-volume ratios of spheres of different radii). If the colony gets too small, it is really difficult for the bees to create enough heat and maintain the structure of the winter cluster. A large cluster of bees has a better chance of survival — this is why it is often recommended to combine smaller colonies in the fall.

Once the colony starts to raise brood in the spring, the energy needs (and the stress on the bees) increase dramatically. When the cluster is not raising brood, it can keep the core temperature of the colony fairly low, because they just have to keep adult bees from freezing. Once the bees start to raise brood, the core temperature has to be kept much warmer (86-95 F/30-35 C). This means that the bees are working much harder to keep the cluster warm, and they are using much more honey and releasing much more moist air in respiration.

Not only does the brood need to be warm, but they also need to be fed. Summer bees perform the high energy task of creating royal jelly from their hypopharyngeal glands when they are young and have lots of energy. Winter bees, however, are put on nursing duty near the *end* of their lives. Spring and summer bees live a mere 25-40 days, while winter bees can live 100-200 days.[7] Near the end of their lives winter bees have to create a high fat and high protein diet for the brood from their own bodies. The only way that winter bees can live through a harsh winter and have the reserves to create royal jelly in the spring is because they are physically different from summer bees. In order to have the ability to secrete brood food in the absence of fresh pollen, bees had to adapt to store energy in their bodies. The main difference between a summer bee and a winter bee is that winter bees have enlarged fat bodies in their abdomens. These fat bodies break down fats, proteins, and carbohydrates, and they produce vitellogenin, which is linked to honey bee immunity and longevity. When we think about our bees having enough energy for winter, we usually just focus on honey stores. Most of the energy needed for winter survival (and spring growth), however, is *inside the bees!*

Winter survival depends on having a large amount of healthy winter bees. Many beekeepers feel confident when they have huge, booming colonies in the late summer. They see all the bees, and can't imagine that they won't make it through the winter. Don't count your winter bees before they hatch — a huge colony in late summer does not mean that you will have a large amount of winter bees. The bees you see in the hive in late summer are generally all summer bees. They are supposed to die before winter sets in. The bees that will be alive in December will be produced from eggs laid after early August.[8] Since only a small proportion of bees are involved in raising young, the size of the colony in fall isn't directly proportional to the number of winter bees that you will have. A small (not tiny) colony can produce enough winter bees to make an efficient winter cluster, while a huge booming colony may not have any.

The number of winter bees raised by a colony is determined by the health of the hive in late summer. The development of winter bees is triggered by a lack of incoming pollen and other environmental signals in late summer/early fall. In the best scenario, the entire generation of eggs laid at this time will be raised to healthy adults, and the colony will have enough bees for an efficient winter cluster. Unfortunately, in many hives across the U.S., by the time the winter bees are going to be raised, parasite and disease levels are so high in the hive that only a few winter bees reach adulthood, and those that survive to adulthood often have viruses or depleted fat stores that prevent them from surviving the stress of winter. By the time winter sets in, the summer bees will die off naturally, and the few healthy winter bees that remain won't be able to maintain the structure of the winter cluster.

The reason we have such high winter losses is not because we aren't good at wrapping our hives or propping the lid at just the right angle. It is because we do not put enough attention into making sure that we have enough healthy winter bees. We know that varroa mite populations peak right when winter bees are getting formed. They physically damage the developing pupae, so many don't survive to adulthood. They transmit a host of viruses that kill off the adult bees, so there aren't enough to cluster. Finally, they feed on the fat bodies — the same precious energy stores that our bees need to survive winter. It is no surprise that we lose so many colonies to this pest — our whole winter survival is dependent on having a large healthy generation of winter bees, and varroa populations peak right when this generation is formed. You can put all the care in the world

A colony that died from viruses associated with varroa mites. The mite population peaks just as the winter bees are forming, damaging the bees as they develop and infecting them with viruses. This colony likely was large in the fall — with a hive full of summer bees. When the summer bees naturally died off, there were not enough healthy winter bees to sustain a winter cluster. Many of the viruses transmitted by varroa can persist after varroa are gone. Many beekeepers make the mistake of treating only after mites have taken over the hive — the winter bees are already damaged, and the viruses have taken hold in the colony. It is much more important to always keep mite populations low.

into your bees over the summer, but if you don't protect your winter bees from varroa, your colony will have no chance of survival.

In a pre-varroa version of the book the Hive and the Honey Bee (1975), Furgula states that most of the problems associated with winter mortality/weak colonies can be avoided if beekeepers satisfy these four fundamental principles in beekeeping management:

1. Have a young queen of superior genetic stock,
2. Properly protected from extreme climatic conditions and established in a well-constructed hive,
3. An adequate supply of honey and pollen,
4. Maintained in a "disease-free" condition.

These should be fulfilled throughout the year, but particularly in late summer.[9]

These principles have not changed. If we have a healthy colony that has enough food and is sufficiently sheltered, it has the adaptations to survive long, cold winters. Yes, it is important to protect bees from the prolonged extreme cold of the Canadian prairies, and yes it is important to ensure that the moisture from the respiring bees does not condense and drip onto the cluster. In some parts of North America, you may have to take extra steps to make sure that your winter bees don't experience too much stress from the environment. However, if you are experiencing high winter losses (>30%), it is time to put more energy into the make-up of the hive than into its protection. It may make you feel better emotionally to insulate and add quilt boxes and vent and wrap, but if you really want to improve your bees' survival, make sure you are also out there all summer preventing parasites from taking over your hives so that you can raise a strong, healthy generation of winter bees.

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