Review: vanEngelsdorp et al. (2008). *PLoS ONE*, **3**: e4071.
Written: February 1, 2009
Posted: 02/02/09
Word count: 724

Q*uestion*: Are there any patterns in the recent bee die-offs?

A*nswer*: Some, but they are complicated, which is what makes finding the cause(s) so difficult

It is often said that there is a special place in hell reserved for three groups of dishonest people: liars, damned liars, and statisticians. While certainly true for the first two, and those who employ statistics have been known—on occasion—to fudge the numbers, it gives number crunchers and other bean counters a pretty unfair reputation. Statistics, in its most basic form, is the application of mathematics and probability theory to make sense of raw data so that we can make understand it all. Without it, much of what we do in society would be practically baseless.

Historically, it has been exceptionally difficult to get any meaningful statistics about beekeeping. Oh sure, we have very good numbers on how many acres of upland cotton is planted in Georgia, the average yield of apples per acre in upstate New York, and how many head of cattle there are in western Texas. But how many beehives are there in North Carolina? No idea. The "official" statistics, collected and reported by the National Agricultural Statistics Service (NASS), says that there are 15,000 managed honey bee colonies in the state. I can account for that many by thinking of only a few dozen large-scale beekeepers, so these numbers are *way* off (we often quote roughly 100,000 colonies in the state, but that is more a questimate than a statistic). Nationally, this huge shortcoming of understanding our industry has long been highlighted as an impediment to helping solve many of the large-scale problems that have befallen the apiculture industry.

It is for this reason that when a study compiles some new statistics, particularly those with much more realistic numbers than the NASS reports, we can really hope to identify patterns that might help answer some of the bigger questions that we are currently asking. This is what a new study, lead by Dennis vanEngelsdorp of the Pennsylvania Department of Agriculture, has recently accomplished. They surveyed beekeepers all across the country, asking them detailed questions about many things but centered around winter mortality (over the 2007-2008 season). In doing so, they got information on 324,571 (13.3%) of the 2.44 million beehives in the nation, therefore the patterns that they found are very insightful indeed.

They found several important patterns in their statistics. First, there was a total loss of 35.8% of colonies, which is an increase of 11.4% compared to year prior. This is indeed a stunning figure: could you imagine if more than a third of Holstein cattle died every year without any explanation?! Second, sixty percent of all colonies that were reported dead in their survey died without a noticeable number of dead bees in or around the hive. Since this is the hallmark symptom of Colony Collapse Disorder, this opens the possibly that many (even a majority) of these beehives suffered from CCD. Third, large-scale operations (those with over 50 colonies) were more likely to have this symptom, suggesting that a contagious condition and/or different management practices may be causal factors. Fourth, when the beekeepers were asked what they suspected for their mortality, they responded that poor queens (31%), starvation (28%), varroa mites (24%), CCD (9%), and poor weather (9%) were to blame in that ranked order. Finally, within the state of Pennsylvania (where some of the best numbers are known because of mandatory registration of beehives), losses decreased in warmer regions in the state, indicating that ambient temperature over winter may be an important factor.

Even with these important statistics, they were still not able to detect any strong pattern as to why so many colonies are dying. In essence, there are many, many different reasons for colony mortality, which makes identifying the underlying cause much more difficult. Nonetheless, this study will help serve as a baseline for future comparisons and help guide future research into more mechanistic studies of mortality. Clearly, exceptions need to be made for the heavenly fate of some statisticians.

Reference

vanEngelsdorp, D., J. Hayes, R. M. Underwood, and J. Pettis. (2008). A Survey of honey bee colony losses in the U.S., fall 2007 to spring 2008. *PLoS ONE*, **3**: e4071. doi:10.1371/journal.pone.0004071

Review: Wilson-Rich et al. (2008). *Journal of Insect Physiology*, **54**: 1392-1399.
Written: 01/14//09
Posted: January 14, 2009
Word count: 642

Q*uestion*: Does a bee's immune system change as she ages?

A*nswer*: Yes, in ways that are important for overall colony health.

Now that researchers have sequenced the honey bee genome—the genetic blueprint that codes for how bees become bees—there is an inherent promise that we will gain significant new insights into keeping bees healthy and productive. While knowing the genome is a starting point and not the end point, researchers have already learned a great deal about bees when it comes to colony health and their overall immunity. For example, it has been shown that honey bees have about one-third fewer genes for fighting off diseases and other infections compared to other insects. This has led some to speculate that the "social immunity" of honey bees is more important than bolstering individual bees' immune systems.

But we should not discount the importance of how individual bees are able to stave off infection. After all, when living in a colony of 50,000 crowded sisters, if one bee gets sick it may quite easily spread throughout the hive. Understanding how this might be done, and how bees might prevent widespread disease outbreaks, is particularly important given the different life stages of developing bees in a colony at a given time.

A recent study, led by Noah Wilson-Rich at Tufts University in Boston, followed the immune responses of bees at different ages. Specifically, they studied bees at two developmental stages (larvae and pupae) and at two adult stages (younger nurse bees and older forager bees). They measured several different immune responses that help individual bees prevent or fight infections. First, they measured total hemocyte counts, analogous to our white blood cells that target foreign pathogens and kill them. Second, they measured the encapsulation response of bees towards sterile nylon threads. This immune response is a way that the insect's body surrounds large objects with cells to "quarantine" the foreign object and keep it from doing harm. Third, they measured phenoloxidase activity, which is an enzyme in the bee's blood that recognizes then attacks foreign particles. Finally, they measured the quantity of fat bodies (in the adult workers only). Fat bodies, located in the adult abdomen, is functionally analogous to our livers since it produces antipathogenic proteins and "cleans" the blood.

Wilson-Rich and his colleagues found that a bee's immune system changes as they get older. Specifically, they found that while the encapsulation response does not significantly vary across time, developing bees (larvae and pupae) have higher hemocyte counts compared to adult bees (which makes sense since brood diseases are mostly bacterial or viral), whereas phenoloxidase activity increased directly as a function of age. Overall, they found that the immune systems of older foragers (those most likely to initially encounter a disease and bring it back to the colony) had the highest activity compared to younger bees. This suggests that by losing the foraging force from a colony—such as by moving a hive during the day or by their loss due to a pesticide, for example—it might force younger workers (who are more prone to contracting disease) to leave the nest before they are ready.

These findings show that it is very important to understand the dynamics of how bees might be able to withstand disease by using their own natural immunities. It also demonstrates that bees have a fairly well equipped disease-fighting arsenal at their disposal above and beyond behavioral mechanisms such as hygienic behavior. A greater understanding of these benefits might help us make more practical and effective management decisions.

Reference

Wilson-Rich, N, S. T. Dres, and P. T. Starks. (2008). The ontogeny of immunity: Development of innate immune strength in the honey bee (*Apis mellifera*). *Journal of Insect Physiology*, **54**: 1392-1399.

Review: Balayiannis & Balayiannis. (2008). Archives of Environmental Contamination and Toxicology, **55**: 462-470.
Written: December 9, 2008
Posted: 12/09/08
Word count: 718

Question: Can honey bees be used as sensors for the environment?

Answer: Yes, to detect pesticides in agricultural ecosystems

We all know the phrase "canary in a coalmine", and not just because of the old tune that Sting wrote before he left the *Police*. Miners used to put bird cages in the deep caverns in which they worked as a safety precaution. If toxic fumes would build up while they worked, the canary inhabitants would first succumb to them and die; a dead bird meant danger and to leave the area immediately. While antiquated and inconsiderate (from the birds' point of view), this is one of the more well-known examples of a 'bioindicator', or a living system that can detect something in the environment as to provide us with information that we might not otherwise be able to attain.

Honey bees can forage out from the hive about 4 miles, at least if they're really desperate. This means that they have access to a huge area. Going back to grade-school geometry (and you thought you'd never use it again!), the area of a circle is pr^2, with the radius (r) being 4 miles. That means a single colony can cover about 32,000 acres, which is over 50 square miles! In doing so, they often scout and locate any number of floral sources from that area. With 50,000 bees per colony, and roughly half of them actively foraging, that's a lot of interaction with the local environment.

So it has been suggested that honey bees might serve as effective bioindicators. After all, if they are literally sampling nectar and pollen from such a large area, a single colony might serve as a sink for certain substances that its foragers may inadvertently pick up. But what?

Pesticides. A honey bee colony is a very good reservoir for chemicals that they pick up from the environment. Most are benign, such as those they get from flowers (in fact, these floral odors are what bees use to recognize nestmates from non-nestmates). But human-made chemicals are just as easily incorporated into the colony, and they do so in two main ways. First, lipophilic chemicals are those that "love fat" and are easily incorporated into wax, where they can remain for long periods of time (which is why you regularly replace all of your old, darkened combs, right?!). Second, hydrophyllic chemicals are those that "love water" and are easily dissolved into honey.

It is this second approach that a research team in Greece took to use bees as bioindicators of agricultural pesticides. They took samples of honey from all across the country over two years, noting the types of agricultural crops the beehives were near (such as cotton, citrus, sunflowers, and natural vegetation). They then analyzed the chemical makeup of the honeys using gas chromatography to determine the levels of common pesticides and their derivatives (since many compounds break down over time into known and predictable secondary compounds).

Not surprisingly, the researchers found many different chemicals. In all, they found 0% of the non-agricultural samples tested positive for three main classes of agricultural pesticides, but 84%, 47%, and 44% of the honeys were positive for hives near citrus, cotton, and sunflower fields, respectively. What's more is that most (74%) of all samples were positive for coumaphos, the active chemical in Checkmite+ used to control varroa mites.

Clearly, honey bees are good bioindicators, and what they're telling us is not very welcome news. They're saying that they're picking up lots of chemicals from their environment, the cumulative effect of which is not very well known. They're also saying that the primary pollutant is something that we as beekeepers are putting into the hives ourselves. While it may be going too far to suggest that honey bees are nature's canary in a coalmine (as some have suggested in response to CCD), this approach could be used for some more systematic monitoring of agroecosystems in the future to help protect beekeepers and their bees.

Reference

Balayiannis, G. and P. Balayiannis. (2008). Bee honey as an environmental bioindicator of pesticides' occurrence in six agricultural areas of Greece. Archives of Environmental Contamination and Toxicology, **55**: 462-470.

Review: Aliano and Ellis. (2008). *Apidologie*, **39**: 481-487
Written: November 14, 2008
Posted: 11/15/08
Word count: 696

Question: What is the mode of action for oxalic acid control of varroa?

Answer: Direct contact, not fumigation

Our continuing troubles with varroa mites can sometimes seem daunting, with near ubiquitous infestations, increasing virulence, and developing resistance to chemical controls. In the face of these challenges, some beekeepers have been tempted to use non-labeled alternative controls, which cannot be condoned. These issues do, however, necessitate the exploration into as many *safe* alternatives for control as possible.

Fortunately, there are several relatively new alternatives to Apistan (fluvalinate) and Checkmite+ (coumaphos), as both have mites developing resistance to them. Products such as MiteAway II (formic acid) and ApiLife VAR (thymol) have been on the market for several years and show high levels of mite control when used properly. Their mode of action is to turn the hive into a fumigation chamber; the chemicals are soaked in pads that release them into the air, and the volatiles then contact the mites and kill them.

One newer alternative, which has been used in Europe and Canada for many years, is the use of oxalic acid (OA). Like the formic acid and thymol products, OA is considered a "softer" chemical than the synthetic acaracides used more widely in this country, yet it has shown to have high efficacy (>90%) in varroa control. It can be readily introduced into a beehive by applying it in several ways, but the most popular has been to drip about a half cup full of 3.5% solution directly onto the bees. But we need to understand more about its mode of action before we can be assured that it is both effective and safe for the bees.

A recent study by Nick Aliano and Marion Ellis from the University of Nebraska tested the mode of action for OA in a simple yet elegant study. At issue was whether OA kills mites through fumigation (like formic acid and thymol), by making the bees somehow "distasteful" to the mites (by ingesting the chemical), or direct contact among the bees (and therefore to the mites). They established several experimental hives in single-story hives, which they then divided in half with one of three types of division boards. The first was a double screen, which permitted volatiles and other odors to pass from one side to the other but did not allow any interactions among workers between the two sides. The second was a single screen, which also allowed volatiles to be exchanged but also trophallaxis among workers from the two sides (but not direct contact). The third was a queen excluder, which allowed volatiles and workers to interact with each other directly.

The researchers then administered oxalic acid treatment to one side of each double-hive, measuring mite levels before and after treatment on both sides. They then treated all units with coumaphos to kill the remaining mites, which enabled them to calculate the efficacy of the OA treatment. More importantly, they were then able to compare the mite control on the non-treated halves of each hive to determine the mode of action of OA. If it kills mites through fumigation, then all three treatments should show equal levels of control; if it kills mites through ingestion, then the single screen and queen excluder treatments should show higher levels of control than the double screen;

and if it kills mites through direct bee-to-bee contact, then only the queen-excluder treatment should show effective control.

It is this latter result that they found, strongly suggesting that direct worker interaction is necessary for oxalic acid to control varroa mites. Thus OA does not turn a hive into a fumigation chamber, like some of the other newer products, but rather needs to be passed from bee to bee, and from bee to mite. This study should give us hope for yet another effect control method for varroa. But let's wait until it is registered before we start using it, which hopefully should be soon.

Reference

Aliano, N. P. and M. D. Ellis. (2008). Bee-to-bee contact drives oxalic acid distribution in honey bee colonies. *Apidologie*, **39**: 481-487.

Review: Carneiro et al. (2007). *Neotropical Entomology*, **36**: 949-952
Written: October 22, 2008
Posted: 10/23/08
Word count: 728

Q*uestion*: Are Africanized bees less prone to varroa mites?

A*nswer*: Not as much as they used to be!

It's a general biological principle that life in the tropics is more diverse and therefore a lot more competitive. This, of course, stems from the fact that temperatures are higher and there is more sunshine around the equator, which permits for more plant growth (and thus the struggle over eating them; nature, red in tooth and claw, after all). With more life comes more lifeforms that try to make a living off of other lifeforms (pests, parasites, and pathogens). Just think about it; virtually all of the really bad diseases in the world at least derived in the tropics. You don't have to get a litany of immunizations whenever you travel to Iceland!

It is not surprising, therefore, that tropical honey bees are a bit on the defensive side. If our honey bees had to put up with elephant and giraffe predation on a daily basis (and no, I'm not making that up), perhaps ours would be too. But with increased defensiveness comes certain side effects. For example, African bees are a lot more paranoid about robbing, so their guard bees are ever vigilant. This, presumably, cuts down on colony mortality and honey losses, and even reduces disease transmission.

There's yet another benefit. African bees develop more quickly than European bees, and are thus a tad smaller in adult body size (the two are not linked, however; smaller bees are not necessarily more defensive). This enables African colonies to reproduce slightly faster, to build up more quickly, and to rebound from population crashes more readily. This trait also results on perhaps the single-most important trait for honey bees today: resistance to varroa mites.

Mites enter brood cells just before they are capped, hiding out in the brood food out of sight until they are sealed in. Once securely behind closed doors, they then make a cut in the side of the pupa and start feeding on its hemolymph ("bee blood")—no wonder they're sometimes referred to as the vampire mite. The female then lays one egg at 30-hour intervals: first a daughter, then a son, then the rest daughters. The more time the mother mite has—that is, the longer the pupal development time—the more daughter mites she can raise. This is why varroa prefers drone brood; they're longer development time means a dramatic increase in their own reproductive success.

It is this same reason why Africanized honey bees are thought to bee less susceptible to varroa. If the AHB develops faster, the mite levels within their colonies won't build up to the same levels to pose a problem. In the neotropics of Latin America, beekeepers have seen this first hand.

But a new study out of Brazil gives pause to the complacency of tropical beekeepers, and casts doubt on the AHB's ability to withstand the varroa mite. A research team lead by Francisco Carneiro measure the reproductive ability of varroa in Africanized bees, comparing numbers today to those measured in the mid-1980s (when the mite was first introduced). They also measured colonies over the course of an entire year to determine seasonality. They measured mite reproduction by percent fertility, percent of mites that reproduced, and number of offspring per mite. In all of these measures, and in all of the months of the year, they found that varroa reproduction has risen since they were first recorded 20 years ago.

It is unfortunate that there was no comparison to rates of varroa reproduction in European colonies in this study, as that would indicate the relative degree to which the AHB may still be tolerant of mites. Nonetheless, it is fairly obvious that Africanized bees may not be as resistant to parasites as we once thought, and may even becoming more susceptible over time. It seems that the competitive nature of the tropics continues, and the general biological principle marches on.

Reference

Carneiro, F. E., R. R. Torres, R. Strapazzon, S. A. Ramírez, J. C.V. Guerra Jr, D. F. Koling, and G. Moretto. (2007). Changes in the reproductive ability of the mite *Varroa destructor* (Anderson and Trueman) in Africanized honey bees (*Apis mellifera* L.) (Hymenoptera: Apidae) colonies in southern Brazil. *Neotropical Entomology*, **36**: 949-952.

Review: Maistrello et al. (2008). *Apidologie*, **39**: 436-445
Written: September 5, 2008
Posted: 09/05/08
Word count: 61(2008).) [(A) 0cm BT 10Aord cud c Tf[(W) 80.2 (ord c) 0.2 (o c) 0.2 (pt) 0ycptPo(pt) 0.29.221 10R367 Tm /F3.0 1 Tf

Unlike feeding these natural compounds through sugar syrup like fumagilin, the research team fed infected bees by providing them with "laced" sugar candy (a mixture of 85% powdered sugar, 10% sterilized honey, and 5% water). This is a common means of supplementally feeding honey bee colonies during the colder months of the year, and is therefore a more efficient means of targeting infected bees right at the time that they are most contagious. Tests in the lab suggest that mortality didn't differ among bees feeding on candy with vetiver, lysozyme, resveratrol, or thymol compared to controls, suggesting that the chemicals were themselves not toxic to the bees at the levels tested. More importantly, however, is that thymol (at 0.12 mg/g of candy) and resveratrol (at 0.001mg/g of candy) both significantly lowered the nosema infection rates of the experimental bees.

These are quite encouraging results for several reasons. First, it introduces another possible delivery mechanism for products to increase colony health. Second, it suggests at least two possible alternatives to fumagilin for nosema control, which may be very helpful particularly if nosema develops resistance. So while the current thymol products on the market for varroa control may not be "two-for-one" products for nosema (since the bees do not ingest the thymol), there is hope that this essential oil may help colony health in other ways as well.

Reference

Maistrello, L. M. Lodesani, C. Costa, F. Leonardi, G. Marani, M. Caldon, F. Mutinelli, and A. Granato. (2008). Screening of natural compounds for the control of nosema disease in honeybees (*Apis mellifera*). *Apidologie*, **39**: 436-445.

Review: Baum et al. (2008). *Landscape and Urban Planning*, **85**: 123-132
Written: August 20, 2008
Posted: 08/20/08
Word count: 539

Question: Do Africanized bees like urban environments?

Answer: Yes, particularly after it rains.

Africanized bees are opportunists. They are just as likely to set up a colony in a water meter as they are in a tree cavity, and their nests have been found in everything from rock outcroppings to backyard grills. One important question, however, is whether or not there is a method to their madness.

As the AHB moved up from South America through Mexico, they entered southern Texas in October of 1990. They subsequently occupied most of TX, NM, and AZ. In 1995, they crossed into southern CA and started moving north. Their eastward progress, however, curiously seemed to stall west of the Mississippi. That is until earlier this decade when a new population of AHB was discovered in southern FL, which introduces the realistic possibility of them being introduced all up and down the eastern seaboard.

As the AHB has progressed northward (and, for that matter, southward from Brazil into Argentina), their movement didn't go according to predictions. Their migration exhibited a lot of stutters and starts, and they often zigged when they should have zagged. Understanding the factors that influence the spread and migration patterns of the AHB might provide some insights into where they might eventually go.

A recent paper by Kristen Baum and her colleagues took a novel approach to understanding the spatial dynamics of Africanized bees. Rather than study their population in wild environments, they looked at the feral population in the urban landscape of Tuscon AZ. To do so, they took the records from a pest control company that specialized in bee removals and analyzed them like scientific data. Specifically, they plotted the location of all of the swarm- and colony-removal requests from clients from 1994 to 2001. They then correlated these and other data with environmental data (such as temperature and rainfall) to see what kind of pattern they could find.

What the researchers found, quite expectedly, is that swarm removals increased dramatically from 14 in 1994 to over 1600 in 2001 as the AHB invaded the Tucson basin. When they first arrived, there didn't seem to be any pattern in where they were found, and there didn't seem to be any pattern in when they were found (that is, the time of year). After 1998, however, there seemed to be distinct clustering of colony removals in both time and space. Specifically, 1999 and 2000 were particularly dry years, and there were markedly fewer swarms during that time. 2001, however, was very wet during the monsoon season, and there was an associated spike in swarms that year.

There are many different factors that affect the spatial and temporal aggregations of colonies, but it is interesting that the AHB are particularly effected by rainfall. Moreover, if we can understand why more "mature" populations are segregated, whereas more "fledgling" populations are more random, we might uncover the methods to their madness.

Reference

Baum, K. A., M. D. Tchakerian, S. C. Thoenes, and R. N. Coulson. (2008). Africanized honey bees in urban environments: a spatio-temporal analysis. *Landscape and Urban Planning*, **85**: 123-132.

Review: Gardner et al. (2008). *Animal Behaviour*, **75:** 1291-1300.
Written: July 15, 2008
Posted: 07/15/08
Word count: 695

Question: Do honey bees have two distinct dances for recruitment?

Answer: No, the round dance is really just another type of waggle dance.

Throughout history, honey bees have intrigued us, belittled us, and even amazed us. There is no better example of this than the infamous honey bee "dance language", where certain body movements of returning foragers provide distance and direction information to novice recruit bees so that they may more easily locate the same food patch. This recruitment strategy has been termed a "language" by some since it conveys the information using an abstraction; the bees do not point to where the food is, nor do they show them the way. Rather, they translate the relative direction of the sun to the gravitational vertical inside the dark hive. This abstract form of communication has intrigued scientists of all types for centuries.

The standard view of the dance language is that returning foragers have two different forms of recruitment (see here for a full discussion and description). If the food source is <100 meters from the hive, they perform a 'round' dance. This dance is circular as viewed from above and thought to convey no directional information and only relative distance information, so that recruits merely go out from the hive and fly in ever-increasing concentric circles to find the food source. If the food source is >100 meters from the hive, they switch to a 'waggle' dance. This dance, in the shape of a figure eight, has a straight section in the middle of the circuit (the so-called waggle run) which conveys the distance and direction information. The distance is correlated with the duration of the waggle run, while the distance is given by the angle with respect to vertical; the longer the waggle run, the further the food source, and the angle away from straight up on the comb is the same angle away from the direction of the sun.

A recent study by Kathryn Gardner at Cornell University, however, has recently brought this conventional view into some question. She simply asked: "Do honey bees really have two discrete dances?" The question is posed for several good reasons. First, it is well known that there are "transitional" dances between the round and waggle dances as a food source is moved further away from the hive. This suggests a gradient rather than some abrupt change in recruitment dance. Second, bees doing the round dance still vigorously wag their tail, much like they do in the waggle dance, but only very briefly. But why should they do so if they are not conveying any directional information?

Dr. Gardner and her research colleagues investigated these questions by training foragers from observation hives to feeding stations located at 10, 30, 50, 70, 100, 150, 200, 300, 400 and 500 meters from the hive. (Remember that the supposed "transitional distance" is about 100 meters). They then videotaped the returning foragers as they performed recruitment dances and precisely measured the duration and angle of the waggle run, even for those performing classic round dances. What they found was that the duration of the waggle run correlated with distance, *even at distances under 100 meters*. Moreover, the average angle with respect to vertical was always indicating the direction of the food source, although the angle was much less accurate for a given dance when the food source was closer to the hive. So, it seems that the round dance is simply a short waggle dance with lower precision for direction.

These findings suggest that there really is only one type of recruitment dance—the waggle dance—that is highly variable depending on the distance to the food source. The authors conclude that rather than being two discrete dances, there really is only a single continuum of waggle dancing. This study helps us better understand how the bees do what they do, and it is just as fascinating.

Reference

Gardner, K. E, T. D. Seeley, and N. W. Calderone. (2008). Do honeybees have two discrete dances to advertise food sources? *Animal Behaviour*, **75:** 1291-1300.

Review: Kraus et al. (2007). *Ethology Ecology & Evolution*, **19**: 263-273.
Written: June 11, 2008
Posted: 06/11/08
Word count: 699

Q*uestion*: What are the trade-offs of drone production?

A*nswer*: The upside, more matings; the downside, more mites and lower colony survival.

Much of what we do as beekeepers involves balancing trade-offs. If we don't treat for mites in the spring, we can get a greater honey harvest at the risk of having higher mites later in the summer. If we split a colony early in the spring, we will significantly decrease their probability of swarming but drastically cut into our honey yield. If we put our hives near a cotton field, we can make some descent honey in the hot summer months but the bees might not get enough pollen to keep rearing brood.

The bees are also constantly dealing with trade-offs as well. In fact, there is pretty much an inherent balance in just about everything they do. Increase in pollen foraging means a corresponding decrease in nectar foraging. An increase in overall foraging means a corresponding drop in nursing. In increase in brood production results in less food being stored. All of these factors represent the constraints imposed on the normal functioning of a colony.

One other trade-off that has been investigated recently involves a colony's investment into drones and reproduction. Clearly, drones are a crucial aspect of the honey bee life cycle; without drones, queens wouldn't have anyone to mate with, and therefore queens would have no way to lay viable eggs to produce workers and colonies. However, how *many* drones a colony produces is a collective decision that represents a trade-off: producing too many drones may impact food storage and other important factors for colony survival, but producing too few drones reduces a colony's genes from surviving to the next generation. One other important trade-off with drones is that varroa mites reproduce at a higher rate on drone brood than they do on worker brood, so rearing more drones in a colony often means a faster population growth of the mites.

The question that Bernhard Kraus and his colleagues recently asked is whether or not these trade-offs in drone production are significant for a colony. They tested 31 drone-producing colonies housed in standard Langstroth hives and measured their investment in drones (calculated by the area of drone brood divided by the total area of worker brood), mite parasitism rate (number of 100 drones with mites), and colony survival. Moreover, the researchers provided mating nuclei in the area of the drone colonies and let their queens mate freely with local drones. They then sampled the offspring from the resultant colonies to determine the paternity of the workers, which enabled them to see which drone-source colonies were successful in siring offspring in the next generation.

They found that 17 of the 31 colonies had at least one of their drones successfully mate with at least one of the virgin queens. Compared to the “unsuccessful” colonies, these “successful” colonies had a significantly higher investment into drones (10.4% compared to 4.2%). The trade-off, however, is that the successful colonies had significantly higher levels of mites (110,158 compared to 71,419) and lower rates of survival (10 of 17 that died compared to 2 of 14 that died). So, it appears that the trade-offs in drone production for a colony are very real.

These results demonstrate that there is no free lunch in beekeeping. We need our colonies to make drones, particularly if we’re raising our own queens, but we need to accept the fact that they will have higher mite levels. We can try and reduce the number of drones that our colonies produce, but this might negatively impact the overall population (and, of course, it still won’t totally get rid of the mites). What would be ideal is to find that perfect balance for our needs, or even to develop some new management techniques that can give us the best of both worlds.

Reference

Kraus, F. B., R. Buchler, R. Siede, S. Berg, and R.F.A. Moritz. (2007). Trade-off between survival and male reproduction in *Varroa destructor* infested honeybee colonies (*Apis mellifera*). *Ethology Ecology & Evolution*, **19**: 263-273.

Review: Fries and Bommarco. (2007). *Apidologie*, **38**: 10.1051/apido:2007039
Written: May 5, 2008
Posted: 05/05/08
Word count: 583

***Q**uestion*: What happens to varroa if you let nature take its course?

***A**nswer*: According to a recent report, better-adaptive bees, not less-virulent mites.

If beekeeping were a James Bond film, and all of the honey bee diseases were like the fictional terrorist organization SPECTRE (**SP**ecial **E**xecutive for **C**ounter-intelligence, **T**errorism, **R**evenge and **E**xtortion), then varroa mites would be Ernst Blofeld, SPECTRE’s evil-genius leader and supervillain (you know, the soft-spoken bald guy who was always stroking a cat). As a result, beekeepers of the world have placed considerable effort in treating their colonies for “Number 1” using various mechanical, genetic, and (mostly) chemical approaches.

Treating your hives with acaricides (pesticides used to kill arachnids, such as mites) introduces at least four major problems. First, many of these chemicals are either hydrophyllic (they “love water”, and therefore can contaminate honey) or lipophyllic (they “love fats”, and therefore can contaminate wax). Second, there is usually a trade-off in efficacy of a product (i.e., how well it works to kill the mites) and its potential toxicity (i.e., how much it may hurt bees or beekeepers). Third, by applying the same chemical over time, mites can develop a resistance to it, making it less effective and, ultimately, useless for treating them. Finally, chemical control of varroa removes any possible selective pressure on the bees to evolve their own natural defenses.

It is this last possibility that a Swedish research team, Ingemar Fries and Riccardo Bommarco, investigated in a recent study published in *Apidologie*. An isolated population on an island in the Baltic sea presented the ideal conditions for the “Bond Project”, aptly titled by following the philosophy of “Live and Let Die” (no, I’m not making this up!). For 7 years, this population survived varroa-mite parasitism without chemical treatment, letting those that succumbed die and those that live reproduce. The researchers then produced queens from these Bond colonies, placed them into standard commercial hives, and compared them with those headed by queens from

Control colonies (main-land hives regularly treated for varroa using standard chemical applications). Mite levels were then measured over the course of the season (May to September).

They found that the growth rates of Bond colonies were lower compared to those of Control colonies. In other words, there was something about the bees from the Bond colonies that caused the mite population to grow less exponentially and be three times lower than the non-selected bees by the end of the season. The authors speculate that one reason may be that the total brood area of the Bond colonies were consistently lower than the Control colonies, leaving fewer hosts for the mites to parasitize. But whatever the mechanism, the results suggest that the bees may have acquired some natural tolerance to the mites.

This is exciting news to beekeepers, particularly those who wish to minimize their reliance on chemical treatments. While a causal relationship still needs to be demonstrated between mite-tolerance and selective pressure in this Swedish population, it provides hope that our bees may be able to adapt to the mites if afforded the chance. Following the "live and let die" philosophy may not be realistic for your average beekeeper, but it might help to better understand why "James Bond" bees do better. Ian Fleming would be proud.

Reference

Fries, I. and R. Bommarco. (2007). Possible host-parasite adaptations in honey bees infested by *Varroa destructor* mites. *Apidologie*, **38**: 10.1051/apido:2007039.

Review: Thompson et al. (2007). *Journal of Experimental Zoology*, **307A**: 600-610
Written: April 8, 2008
Posted: 04/09/08
Word count: 695

Q*uestion*: What are the effects of carbon dioxide treatment on workers and queens?

A*nswer*: Differential ovary development and, more importantly, the genes that regulate reproduction

We all know that the queen is the female reproductive in a colony while the workers, that number in the tens-of-thousands, are sterile females. But the workers still retain the capacity to "reproduce"—that is, develop and lay some eggs—because they are facultatively sterile (i.e., typically behave as if they are sterile) rather than functionally sterile (i.e., do not have any reproductive organs). Some of us know all too well how workers still have ovaries and can use them if one of our colonies goes queenless for two or three weeks, as in the absence of queen pheromone about 10% of the workers develop their ovaries and start to lay eggs. Of course, since workers can't mate and therefore fertilize these eggs, all of them develop into drones. These "laying worker" colonies can be difficult to requeen and, for obvious reasons, can go downhill fast. Anarchy clearly doesn't work for bees.

Queens, on the other hand, are "supposed to" activate and develop their ovaries, typically after they mate early in life. Turning on a queen's reproductive machinery is a good thing for her and her colony, as the entire fate of the hive depends on it. Doing so, however, may not be as easy as it sounds, since ovary activation can be a complicated process with lots of moving parts. Some beekeepers may have seen problems with this process, although you may not have recognized it as such. If you bank or cage a queen for more than a few days, for example, her ovaries become deactivated since she has no place to lay. Once she is reintroduced and allowed to start laying again, sometimes she "pops the clutch" and takes a long time to start brooding, if at all.

These two issues, laying workers and queen ovary activation, may not be connected to the beekeeper, but they are closely connected physiologically. The activation of ovaries in females, and therefore the control of reproduction within them, is a complex and largely unknown process. One procedure that beekeepers have used for decades to accelerate queen ovary development is to anesthetize them with carbon dioxide, or CO_2. This begs the question, how?

An Australian research team led by Graham Thompson addressed this question in a recent study published in the *Journal of Experimental Zoology*. They subjected both workers (ages 8, 9, 10, and 12 days old) and queens (ages 8-10 days old) to CO_2 narcosis and compared them to same-aged untreated counterparts. The authors then measured the degree to which their ovaries were developed, as well as 25 individual genes that had been identified in previous studies as playing a central role in reproductive development.

What they found was interesting. As expected, CO_2-treated queens all developed their ovaries compared to controls. On the other hand, CO_2-treated workers seems to *decrease* their ovary development compared to untreated controls (at least for bees aged 8, 10, and 12 days old; the 9-day-old age group, for some reason, were no different). Moreover, of the 25 target genes that they looked at, 10 showed differences in their expression between treated and untreated bees in either workers or queens. In workers, these genes are likely tied to ovary deactivation, while in queens they are likely associated with ovary activation.

These findings are interesting, as they provide unique insights into how queens properly develop their ovaries (which is a good thing for beekeepers) and how workers develop theirs (which is a bad thing for beekeepers). Understanding the genes that regulate ovary activation or deactivation may help us control the process more effectively, which might help prevent or minimize "laying worker" colonies and even banked queens from "popping the clutch".

Reference

Thompson, G. J., H. Yockey, J. Lim, and B. P. Oldroyd. (2007). Experimental manipulation of ovary activation and gene expression in honey bee (*Apis mellifera*) queens and workers: testing hypotheses of reproductive regulation. *Journal of Experimental Zoology*, **307A**: 600-610.

Review: Le Conte et al. (2007). *Apidologie*, **38**: 1-7
Written: February 29, 2008
Posted: 03/04/08
Word count: 516

Question: How long can untreated, unbred bees survive with varroa?

Answer: Longer than you might expect.

If you keep bees, you are keenly aware that varroa mites are the primary management issue facing beekeepers. In fact, much of our beekeeping duties are centered around keeping the mites at bay. From the textbooks, we learn that left untreated, a honey bee colony will succumb to varroa-mite infestation within one or two years. As a result, the number of feral, or non-managed, bee nests living on their own in hollowed trees or other natural cavities has dropped dramatically since the mites' introduction in the mid-1980s.

The widespread problem of varroa has prompted a multitude of approaches to control their numbers. Most of us learn and employ various control strategies using chemical control methods, such as pesticide-impregnated plastic strips hung between the frames within a hive. Another main approach has been genetic, by selectively breeding certain mite-tolerant traits in our bees, such as hygienic behavior. These are just some of the ways that we can help the bees keep the mites in check.

But what about those colonies of the non-managed population that haven't succumbed to the mites? Does their persistence suggest that natural selection has caused them to adapt to the mites? Or are they simply escaped swarms from nearby managed hives that will eventually meet the same fate as everyone else? Testing so-called “survivor stock” might be helpful to determine how we, and the bees, might be able to cope with varroa mites for the long term.

A recent study by a French team of scientists, headed by Yves Le Conte in Avignon France, compared colonies of standard managed stock with some local “survivor” stock. The latter bees were collected from abandoned hives and untreated for at least three years (and probably longer), and therefore are de facto feral colonies. The researchers followed colony survival, swarming rates, honey production, and mite levels of these two populations for 7 years, a very long time indeed. They found that compared to control colonies, the VSB colonies (standing for Varroa Surviving Bees) had a similar overall survival rate (45.1% vs. 56.5%), swarming rate (41.5%), significantly lower honey production (6.9 kg vs. 18.2 kg), and significantly lower mite levels (3331 vs. 10278 as measured by weekly stickboard counts). So it seems that left on their own, honey bees can actually persist longer with varroa mites than we might have thought.

Importantly, this study does not distinguish between the VSB bees being resistant to mites or the mites being less virulent in non-managed colonies. Other similar studies suggest the latter; mites that parasitize isolated colonies too heavily kill their hosts and, consequently, themselves, selecting for “nicer” mites. Regardless of the mechanism, this study demonstrates the utility of investigating “survivor stock” in the non-managed honey bee population.

Reference

Le Conte, Y., G. de Vaublanc, D. Crauser, F. Jeanne, J-C. Rousselle, and J-M. Bécard. (2007). Honey bee colonies that have survived *Varroa destructor*. *Apidologie*, **38**: 1-7.

Review: Paxton et al. (2007). *Apidologie*, **38**
Written: February 12, 2008
Posted: 02/14/08
Word count: 676

Q*uestion*: How long has *Nosema ceranae* been a problem, and how bad a problem is it?

A*nswer*: In Europe, since at least 1998, and it might be more virulent that we would want it to be.

With all the attention on CCD in the past year, much of the discussion (and practically all of the press) has focused on that singular issue. The lack of strong empirical evidence, the complexity of the issue, and the multitude of possible causes for the disorder make it a ripe environment for speculation, conjecture, and innuendo. What this entire experience obfuscates, however, are some important discoveries that are being made across the Atlantic, many of which may very well have some bearing on our current plights.

One specific line of research has been dealing with a relatively new parasite of honey bees, *Nosema ceranae*. It isn’t new to science, and it isn’t unfamiliar to beekeepers, either. It is new in the sense that the “typical” nosema parasite that we’re used to, *Nosema apis*, coevolved with our Western honey bee (*Apis mellifera*). This “new” nosema, *N. ceranae*, coevolved with the Eastern honey bee (*A. cerana*). So, this microsporidian is a close relative of a similar parasite *in* our bees that infects a close relative *of* our bees. The problem is that recently, *N. ceranae* has started to infect our bees as well.

Nosema is a gut parasite of adult bees; that is, they live in the digestive tracts of adult bees and live off of the digested food they eat. At high levels, it can cause bees to become constipated (and therefore have distended abdomens) and have diarrhea (and therefore defecate inside the hive) at the same time. Classically, the disease tends to be the most problematic during the colder months when infected individuals have fewer opportunities to take cleansing flights.

Researchers in Europe have described and detected *Nosema ceranae* in European honey bee populations, and many have attributed their serious losses of colonies to the parasite. This has prompted researchers in the U.S. to screen for

N. ceranae in local populations, and they have found the parasite to be very widespread. The question now becomes: how problematic is it?

A research team in Europe has recently published a report that tested the relative infections of the two nosema species in Western honey bees. Their study took several approaches. First, they tested historical samples of bees infected with nosema from Finland, dating as far back as 1986. They found that *N. ceranae* has been present in Europe from as early as 1998. Perhaps more importantly, they found that the relative frequency of *N. ceranae* compared to *N. apis* has been increasing ever since. In fact, the "old" nosema is no longer found alone, it is only found in combination with the "new" nosema.

Second, they inoculated bees in controlled laboratory cages with the two nosema species to track the course of infection. Interestingly, they found that *N. apis* actually increases in number in the guts of adult workers more quickly than *N. ceranae*, but by day 10 both species have roughly the same spore population. More importantly, the number of bees that died within the experimental cages was much higher for those infected with *N. ceranae* (44%) compared to those infected with *N. apis* (8%).

While the authors are quick to point out that this trial is not replicated and therefore the data need to be interpreted with caution, such a potential increase in virulence of the "new" nosema does not bode well for beekeepers. While it is still too early to say that nosema is inextricably linked to CCD or may be another problem entirely, it seems clear that we need to keep our eye on this.

Reference

Paxton, R. J., J. Klee , S. Korpela, and I. Fries. (2007). Nosema ceranae has infected *Apis mellifera* in Europe since at least 1998 and may be more virulent than *Nosema apis*. *Apidologie*, **38**: DOI: 10.1051/apido:2007037.

Review: Ellis and Delaplane. (2007). Journal of Apicultural Research and Bee World, **46**: 256–259
Written: January 9, 2008
Posted: 01/21/08
Word count: 599

Q*uestion*: Are there any "two-for-one" treatments for varroa and small hive beetle?

A*nswer*: No, although some of miticides may be effective against SHB at different stages

As beekeepers, we have a lot on our minds when it comes to keeping our bees healthy. Indeed, much of what we do is centered around making sure our colonies are free of disease so that they can be productive. The post-modern era of beekeeping (that is, since the introduction of varroa mites) mandates that we sample, resample, and treat for numerous diseases several times each year.

Because of the huge emphasis on parasites and pathogens for today's beekeeper, it is helpful to incorporate management strategies into our craft to minimize costs (time and expense) and maximize gains (colony health and productivity). Examples abound: screened bottom boards can reduce mite levels while increasing brood (and therefore hive productivity); supering during a nectar flow can help reduce swarming tendency and increase honey production; entrance reducers in the winter reduces heat loss and prevents hive pests (mostly mice) from taking up residency within the hive. All of these "two-for-one" management options are particularly alluring for the beekeeper who wishes to maximize their time efficiency.

No wonder, therefore, that there is an interest in seeing if certain chemical treatments for one disease can also reduce the prevalence of another. This is what a recent study by Jamie Ellis and Keith Delaplane investigated for varroa mites and small hive beetles (SHB). Seeing that most beekeepers use certain chemical miticides to control mite levels within their hives, the investigators wanted to see if any of the common treatments (Apistan, Apilife VAR, and Checkmite+) had any effect on SHB control.

Their results were quite interesting. None of the mite treatments had any effect on the oviposition behavior of female beetles, as measured by the number of eggs laid within 48 hours, although numerically there was a large drop off with Checkmite+ compared to the control. Apistan (active ingredient fluvalinate) was effective in control of SHB larvae but not of the adults. Apilife VAR (active ingredients thymol, menthol, and eucalyptol) only reduced the survival of "wandering" larvae (those transitioning from the larval to pupal phases). Checkmite+ (active ingredient coumaphos) was highly toxic to beetles in the larval and adult stages. None reduced survival of the pupal stage.

What these results show is that some of the miticides that beekeepers already use can control small hive beetles. In fact, coumaphos (Checkmite+) is already the only approved in-hive chemical control for SHB. It is important to note, however that the *delivery* methods for controlling varroa and SHB are very different; for varroa, the strips are hung between the frames, whereas for SHB control a half strip is placed beneath a section of cardboard placed on the hive floor. So, even though some of these chemicals may have cross-efficacy, do not assume that you're treating for SHB if you're already treating for varroa. The different biologies of the two pests do not overlap enough to let you kill two birds with one stone.

These findings, however, are encouraging because they may help researchers pinpoint the various stages at which SHB are susceptible to different treatments. That will certainly help us keep our colonies healthy.

Reference

Ellis, J. D. and K. S. Delaplane. (2007). The effects of three acaricides on the developmental biology of small hive beetles (*Aethina tumida*). *Journal of Apicultural Research and Bee World*, **46**: 256–259.

Review: Chen and Evans (2007). *American Bee Journal*, **147**: 1027-1028.
Written: December 3, 2007
Posted: 12/11/07
Word count: 650

***Q**uestion*: Were Australian imports responsible for bringing in the IAPV virus?

***A**nswer*: No, the virus has been detected in some bee samples that predate those imports.

There has been a lot of speculation swirling around the underlying cause of Colony Collapse Disorder, or CCD. This newly describe problem for beekeepers is about a year old now, and quite a bit of headway has been made towards uncovering the factors responsible for the massive die-offs of colonies across the nation. I will forgo a detailed explanation of the phenomenon and refer you to previous descriptions of CCD.

The strongest evidence to date behind CCD is that a relatively new virus, called the Israeli Acute Paralysis Virus or IAPV, is strongly associated with collapsing colonies but not well associated with healthy colonies. The research team that discovered this potential link not only tested strong and collapsing colonies for the virus, they also tested bees recently imported from New Zealand and Australia, as well as imported royal jelly from China. They found the IAPV in all of them.

The conclusion that many instantly jumped to upon seeing this evidence was that (a) IAPV is causing CCD, and (b) the virus was recently introduced to the US by the recent imports of packaged bees from Australia. It is all logical: CCD is a very recent phenomenon, as have imports of live bees from down under. The problem with this logic, however, is that it violates some of the basal principles of the process of science. First, correlation doesn't equal causation. Just because most CCD colonies have IAPV, and just because most non-CCD colonies don't, does not necessarily mean that IAPV is the *cause* of CCD. To prove that, researchers will need to take a totally healthy hive, infect it with IAPV, and see if they can induce CCD. That experiment is currently being conducted.

The second reason the logic doesn't hold is that just because two events seem to be linked in time does not mean that they share the same root cause, or that one is directly dependent on the other. This fallacy can easily lead to the wrong conclusion, as we have a tendency to link or associate things that really aren't linked.

So, to test whether IAPV in the US is associated with recent introductions from the southern hemisphere, Chen and Evans—two imminent scientists at the USDA lab in Beltsville MD on the forefront of CCD research—went back to historic samples of bees to test for the virus. Importantly, they tested samples of bees for IAPV that were collected prior to the importation of live bees from Australia. If they found no IAPV, it would be evidence that the imports really were the original source of the virus.

Well, they found just the opposite. The historical samples screened for IAPV had plenty of virus. It appears, therefore, that the importation of Australian packages was not the precursor to CCD.

This paper is a very good example of how the scientific process works. For any finding, additional evidence is needed to support or refute the conclusions, providing additional insights into what might actually be going on. A single study is never itself wholly conclusive, but rather a compilation of evidence is needed to uncover the truth. This process takes time, effort, and is wrought with conclusions that—with hindsight—can appear to have been misleading or overreaching. But in the end, we are left with a better understanding of how things work.

We should all applaud the hard work of the CCD researchers for continuing to unpeel such a complicated onion, as in the end the process will benefit us all.

Reference

Chen, Y. and J. D. Evans. (2007). Historical presence of Israeli acute paralysis virus in the United States. *American Bee Journal*, **147**: 1027-1028.

Review: Cobey (2007). *Apidologie,* **38**: 390–410
Written: November 10, 2007
Posted: 11/10/07
Word count: 681

Q*uestion*: How well do instrumentally inseminated queens perform?

A*nswer*: If done properly, just as well as naturally mated queens, if not better.

History will judge the calendar year 2006 as a turning point in apiculture with the publication of the entire sequence of the honey bee genome. This genetic road map will provide unique insights into why bees to what they do, how they perform, and means to control various traits such as disease resistance and productivity.

Not surprisingly, hindsight permits us the opportunity to identify several other turning points in our progress of honey bee science. Perhaps most notably is the 1851 development of the Langstroth beehive, following the namesake's insights into the bee space, which revolutionized bee management. It wasn't until lateer in 19th century, however, with the advent of the bellowed smoker, the wax foundation press, and the radial extractor, that everything was brought together to usher in the modern era of beekeeping.

Another notable example comes from the world of bee genetics. Apiculturists have attempted to artificially mate queen bees for centuries. The early 20th century saw many advances in technique and design, but it wasn't until the insights of Harry Laidlaw in 1944 that the process was perfected (he described the need to circumvent a special piece of tissue in the queen, called the valve fold, that had stymied many previous attempts). The 60+ years hence has seen tremendous innovations in bee genetics and breeding.

Despite these advances, most beekeepers don't use instrumentally inseminated (II) queens but rather buy (or produce) queens that mate naturally. There are several reasons for this. First, naturally mated (NM) queens are cheaper to produce; the extra time, equipment, and training costs of II queens make II queens cost prohibitive for your everyday beekeeper. Second, most beekeepers view II as a tool for researchers ("stuffy old geneticists" as the infamous E. B. White poem refers to them, lamenting Laidlaw's perfection of the II process). Third, and perhaps most importantly, there is a prevailing view that instrumentally inseminated queens are inferior to naturally mated queens. The conventional wisdom holds that II queens don't receive enough sperm (and therefore become drone layers more quickly), aren't accepted by colonies as readily, don't produce as much brood, don't live as long, and their colonies are less productive and produce less honey.

A recent paper by Sue Cobey, now at the Harry H. Laidlaw Bee Facility at the University of California at Davis, reviews the empirical evidence behind this prevailing view. She summarizes all of the studies that have compared II queens with NM queens for several important factors, most notably honey production, brood production, and queen longevity. She found that approximately half of the studies found that II queens were roughly equivalent to NM queens in these respects. Interestingly, the other half of the studies demonstrated that II queens were in fact *superior* to NM queens for these same factors. The only study that demonstrated lower II queen performance involved queens that were relatively old when they were inseminated (2-3 weeks compared to 7 days) and with lower volumes of inseminated semen (5.4 ul compared to a full 8-12 ul).

These findings demonstrate that one of the arguments against using II queens is not really supported by the preponderance of scientific evidence. This is very encouraging, as it may prompt beekeepers to start using more II queens in their operations. With the Africanized honey bee encompassing more and more of the traditional queen-producing regions of the country, and a higher emphasis on quality control of genetic stock, perhaps the technique of instrumental insemination will become more commonplace and II queens will be more affordable and commercially available. Just like with most turning points in history, it may take some time for things to change, but if they do it almost certainly would be for the better.

Reference

Cobey, S. W. (2007). Comparison studies of instrumentally inseminated and naturally mated honey bee queens and factors affecting their performance. *Apidologie,* **38**: 390–410.

Review: Cox-Foster et al. (2007). *Science*, 10.1126/science.1146498
Written: October 1, 2007
Posted: 10/1/07
Word count: 901

Q*uestion*: What's behind the most recent CCD headlines?

A*nswer*: A new virus, but it's a lot more complicated than that

By now, most of us have heard about colony collapse disorder, or CCD. In fact, it's been hard *not* to hear about it. Since this past February, the media has covered this latest and mysterious calamity to befall the apiculture industry with ferocious intensity. With little empirical evidence to go on, such an environment has been ripe for speculation and rumor to take hold; everything from the Russian government to cell phones have been blamed as the cause of CCD.

The symptoms of this newest, and largely unknown, problem that beekeepers face are (1) a rapidly declining adult worker population without evidence of dead bees in and around the hive, (2) ample food stores that suggests starvation or absconding is not at issue, and (3) a temporary reprieve from hive pests such as robber bees, small hive beetles, and wax moths.

Government conspiracy theories aside, researchers working on the CCD problem are concentrating on three main areas: (1) nutritional stress, (2) environmental contaminates, and (3) disease. While work is ongoing with the first two issues, the first research to be published dealt with disease. Specifically, a recent report in *Science* magazine sheds some light on the potential role of virus pathogens in the onset of colony collapse.

A team of no less than 22 scientists, led by Diana Cox-Foster (Penn State), Jeff Pettis (USDA Bee Lab in Belsville), and Ian Lipkin (Columbia University), conducted a large-scale genetic screening of honey bee samples. The team collected bees from 51 colonies, 30 that were collapsing from CCD-like symptoms and 21 from "healthy" colonies from the same apiaries to serve as positive controls. Interestingly, some of these samples were collected from bees in Australia, as well as royal jelly imported from China. They then screened the samples for an incredibly wide array of bee pathogens using microarray technology, a new genetic approach to high-throughput screening for disease. In essence, the approach looks for little snippets of DNA from thousands of known microorganisms (bacteria, fungi, and viruses) in the samples to positively identify their presence.

The researchers found all sorts of bacteria in the samples, but most of them you've probably never heard of before: *Gammaproteobacteria*, *Betaproteobacteria*, *Alphaproteobacteria*, *Fimicutes*, and *Actinobateria*. These organisms have been found in honey bees before in other parts of the world, suggesting (a) that the pattern of these microbes are global and (b) they are largely benign, probably internal gut flora that may even be helpful for their digestion (much like *E. coli* is for humans). Interestingly, the bacteria that cause American and European foulbrood, *Paenibacillus larvae* and *Streptococcus pulton* respectively, were not detected in any of the samples. They did find the notable microsporidian gut parasite *Nosema apis*, as well as a newly introduced cousin *N. ceranae*. While *Nosema ceranae* was detected in all CCD colonies (as well as the Australian and royal jelly samples), it was also detected in 81% of the non-CCD samples, suggesting that it cannot alone explain the disorder.

What's been making most of the headlines, though, is the presence of certain viruses. They found many of the know viruses, such as sacbrood virus (SBV), deformed wing virus (DWV), black queen cell virus (BQCV), and acute bee paralysis virus (ABPV), all of which are known to be transmitted by varroa mites to create the "Parasitic Mite Syndrome" that we've been dealing with for years. Most interestingly, however, is that they found Kashmir bee virus (KBV) in 100% of the CCD colonies and 76% of the non-CCD colonies. Moreover, they found a highly related and new virus, known as Israeli acute paralysis virus (IAPV), in 83% of the CCD samples but only 5% (one out of 21) of the non-CCD samples. In fact, of all of the microbes the researchers found, this IAPV virus was the best predictor of a colony having CCD.

As the authors are very quick to point out, this strong correlation does not equal causation; just because it is found in most of the CCD colonies and hardly any of the non-CCD colonies does not mean that IAPV is the reason for the collapse. Perhaps it is a very opportunistic virus, infecting bees that are stressed or their immune systems compromised for another reason that *is* the ultimate cause of CCD. Therefore, research is underway to infect healthy bees with IAPV to see if the colony collapses—that will definitively show whether or not the virus is the cause of CCD.

Importantly, these data demonstrate the complexity of the problem. For example, why did five of 30 CCD colonies *not* have the virus, and why did one of 21 non-CCD colonies test *positive* for it? In other words, what are the *other* necessary factors for a colony to collapse? In the end, the finding of this new virus is incredibly important and encouraging, but it not itself the sole "smoking gun" for CCD. With further information, we may be able to determine the exact conditions required for colonies to collapse, at which point we can start implementing measures to prevent or even reverse it.

Reference

Cox-Foster, D. L. et al. (2007). A metagenomic survey of microbes in honey bee colony collapse disorder. *Science*, 10.1126/science.1146498.

Review: Mattila & Seeley (2007). *Science*, **317**: 62-64

Written: September 5, 2007
Posted: 09/05/07
Word count: 702

***Q**uestion*: What are the benefits of a well-mated queen?

***A**nswer*: A stronger, more productive colony

A lot of what beekeepers talk about is the queen: when to replace her, how to find her, whether or not to mark her, and how well she is laying. This is of no surprise, of course, since the queen is the most important individual in the colony. Not only is she the mother of all nestmates within the colony, she keeps them happy and productive by producing a chemical pheromone (which prevents workers from developing their ovaries and rearing new queens). Clearly, without the queen, the colony will either die or, at best, be thrown into social anarchy.

Because of her prominent role in the hive, attention to queen "quality" has been of interest to beekeepers and scientists alike. But what constitutes a good queen from a non-so-good queen? Some beekeepers place a high premium on a light-colored queen. While this may make things a bit easier to find the queen, it doesn't really impact her overall quality. Many beekeepers like to select larger queens, as some studies have shown that big queens produce more brood and therefore productive colonies. But most of us simply look for the general evidence of the queen: a solid laying pattern with no spotty brood, the absence of supersedure cells (which would suggest the workers want to replace her), and a good temperament and productivity of the workers. In short, when it comes to assessing queen quality, the proof, as they say, is in the pudding.

One aspect of a queen's quality, however, can be very difficult to assess because there is no direct evidence of it: how well she is mated. A queen mates early in her lifetime and stores all of the sperm she will need to fertilize the eggs that she lays. A queen mates with 12 drones, on average, on one, two, or even three mating flights when she is about a week old. Queens that mate fewer times tend to have fewer stored sperm, meaning that she won't be able to be as productive as a queen that mates more times.

A recent study suggests that a well-mated queen confers even further benefits to her colony beyond simply having more sperm. A queen that mates with many drones has worker offspring that differ genetically, which creates a cosmopolitan worker population. This increased genetic diversity, while impossible to measure without sophisticated genetic tests, can have indirect benefits that may be quite profound. In the top-tier journal *Science*, Heather Matilla and Thomas Seeley at Cornell University published a report showing that colonies headed by single-drone inseminated queens significantly outperformed colonies headed by multiple-drone inseminated queens.

Twenty-one colonies were established using queens instrumentally inseminated with known numbers of drones (9 queens mated with one drone and 12 queens mated with twelve drones). Then, they introduced swarms into standard beehives and measured how quickly and how well they became established. It became readily apparent—after only about a month—that the colonies headed by multiple-drone inseminated queens build significantly more comb, had a more foragers (both total foragers and the number of pollen foragers returning to the hive), had greater worker populations, and gained significantly more weight than the colonies headed by single-drone inseminated queens. Importantly, none of the weaker colonies headed by single-drone inseminated queens survived the winter, whereas all but one of the 12 colonies headed by multiple-drone inseminated queens survived.

These striking results demonstrate the importance of having a well-mated queen, but perhaps not for the obvious reasons. Making sure your queens have enough sperm to fertilize eggs is of course important, but making sure they have *genetically diverse* sperm to fertilize their eggs is also important for the proper growth and development of your colonies. So, while the proof is still in the pudding, we should attribute a queen's quality not only to her own physical attributes, but to her mates' as well.

Reference

Mattila, H. R. and T. D. Seeley. (2007). Productivity and fitness genetic diversity in honey bee colonies enhances productivity and fitness. *Science*, **317**: 62-64.

Review: Rüppell et al. (2007). *Current Biology*, **17**: 274-275.
Written: August 6, 2007
Posted: 08/11/07
Word count: 690

Q*uestion*: Do honey bee workers age “normally”?

A*nswer*: No, because mortality and performance are decoupled

Aging and senescence are important aspects of biology, and their very existence has puzzled scientists since the beginning of human thought. Why do all living things eventually decline in performance and die? Why do some organisms live for very short periods of time, while others can live for centuries?

Leaving the “why” question to the metaphysical (at least for now), another more proximate question is “how”. In what manner do individuals age? The conventional wisdom defines senescence as an age-dependent increase in mortality. Moreover, this increased risk of dying is associated with a corresponding decline in performance. It is generally believed that these two phenomena (increased mortality and decreased performance) are causally linked; aging causes a decline in important body functions, leading to a decrease in performance, which in turn leads an increase in mortality. As a result, the coupling of mortality and performance has been shown in most organisms, including humans.

Honey bees, however, are notorious for defying all sorts of rules when it comes to aging. The classic, and perhaps most obvious, example is the difference in lifespan between workers and queens. Workers, at least during the active season, live for an average of 6-8 weeks. Queens, however, live an average of 2-3 years (at least as long as they are properly mated and fully viable). The genetic difference between workers and queens is zero; any young female larva can develop either into a worker or queen. Rather, the difference in their development is how the female is fed during the larval stage: fed a “bread and water” diet of honey and pollen, it develops into a worker; fed the sugar- and protein-rich diet of royal jelly, it develops into a queen. No wonder people have been eating royal jelly for centuries in the hopes that it is the fountain of youth!

A recent paper by UNC-Greensboro researchers, lead by Olav Rüppell, tested whether or not mortality and performance are coupled in honey bee workers. Specifically, they followed numerous cohorts of foragers (aged between 26 and 52 days old) and recorded their mortality rates as well as their performance. Mortality was measured quite easily, by calculating the percentage of foragers in each age cohort that lived to the end of the experiment. Performance, however, was measured using several bioassays. First, they looked at their responsiveness to light (with the idea that a decreased in performance would show older workers not able to see as well—sound familiar to anyone?). Second, they measured their responsiveness to sucrose, the major sugar in most nectars (such that a decrease in performance would show that older workers would have a less effective sweet tooth). Third, they quantified the ability of the workers to learn—their ability to associate a stimulus (usually an odor) with a reward (usually sucrose) by sticking out their tongues (probosces) just like Pavlov’s dogs salivating at the ring of a bell.

What they found was very interesting. They showed a clear increase in mortality of workers as they aged; the older forager cohorts had a much higher probability of dying than foragers in the younger cohorts. Not all that surprising. However, they didn’t find any corresponding decrease in worker performance among the different age groups: light sensitivity actually increased with age, their sweet tooth never wavered, and their ability to learn remained constant. This clearly shows that honey bees have decoupled the “normal” relationship between performance and mortality.

These findings are very interesting to the social structure and dynamics of honey bee colonies. To the beekeeper, it means that older foragers are just as effective as younger foragers (even though they may die sooner). This line of research may help also even help us learn more about the process of aging in general, which could benefit all of us in our golden years.

Reference

Rüppell, O., S. Christine, C. Mulcrone, and L. Groves. (2007). Aging without functional senescence in honey bee workers. *Current Biology*, **17**: 274-275.

Review: Oldroyd (2007). *PLoS Biology*, **5**: 1195-1199
Written: July 2, 2007
Posted: 07/02/07
Word count: 920

Question: What's killing American honey bees?

Answer: Still no clear answers, but add one more hypothesis to the list

It has been about six months now since the initial media blitz about Colony Collapse Disorder, or CCD, hit the nation's headlines. There has been lots of discussion, congressional testimony, and endless speculation about the potential causes and consequences of the dying honey bees, but unfortunately we are no closer to the definitive answer than we were half a year ago.

For those of you who may not have heard about CCD, it is largely unknown problem that honey bee colonies have been experiencing where the entire adult population seemingly disappears. What is left behind in the hive is sometimes a small fist-sized cluster of young bees with the queen (but not always), a large area of brood (suggesting that the colony collapse occurs in a short time interval; how can a few hundred bees raise eight frames of brood?), and ample food stores of honey and pollen. Curiously, robbing bees from neighboring colonies, wax moths, and small hive beetles all seem to keep their distance from empty hives from these collapsed colonies, at least for a period of several weeks. For a single colony, this collection of symptoms may be curious but not all that alarming. But when it happens to hundreds of colonies in the same area all at the same time, it is quite obvious something strange is going on. Indeed, hundreds beekeepers across the nation have reported anywhere from 30% - 80% of their colonies collapsing in this way.

A recent review paper by Ben Oldroyd, one of Australia's eminent honey bee researchers, does a very nice job at summarizing a lot of the main issues that have been circling around Colony Collapse Disorder. Here are some of the main points he concludes in his review as to the possible causes.

Diseases and parasites: honey bees, as most beekeepers are keenly aware, are hosts to a litany of nasty bugs and parasites. Much emphasis by CCD researchers has been placed on finding something new about an existing pathology (for example, a novel interaction between a virus and varroa mites) or possibly a yet-unknown new disease that may be associated with the disorder. As yet, there is no current "front runner" that seems to be associated with CCD.

Environmental contaminants: Oldroyd briefly reviews both in-hive chemicals, mainly those used to control varroa mites, as well as agricultural insecticides that bees may pick up from their external environment. There is much concern about potential poisoning of the bees, since there are many different and varied sources of such chemicals. CCD researchers are currently testing comb samples from colonies afflicted by CCD, as well as healthy colonies in the same apiary as a control group. If they can find certain pesticide residues in the CCD colonies that are absent in the non-CCD colonies, that will provide strong circumstantial evidence toward a particular contaminant. Currently, however, there is no such smoking gun.

Nutritional stress: the changing face of modern-day beekeeping has caused a significant shift in management practices. In particular, placing hives in or near certain agricultural crops may deplete them of foraging resources that the bees need for healthy and proper development. Transporting colonies thousands of miles and into multiple, nutritionally poor crops per year may therefore be taking its toll. This, too, is a research priority for CCD researchers.

Genetically modified crops: there has been some concern about genetically modified organisms (GMOs) being used in agriculture, particularly those of staple crops like corn, cotton, canola, and soybeans whose genomes have been artificially modified to express protein insecticides from bacteria to keep damaging herbivorous insects at bay. The question arises, however, as to the secondary effects that these novel properties may have on beneficial insects such as honey bees. Several researchers, prior to the headlines of colony collapse disorder, tested the potential effects of GMO pollen on bees and found little if any negative effects, but we would all benefit from additional studies.

Lack of genetic diversity: there is emerging evidence that the overall genetic pool for honey bees in the United States is not as deep as it once was. This is probably not surprising, as much of the feral population has been decimated by varroa mites and other diseases. Oldroyd makes a strong argument that because commercial queens do not have as many unrelated drones to mate with as they did in the past, the decreased genetic diversity within the colonies may make them more vulnerable to disease. CCD researchers are involved in several experiments investigating this possibility as well.

Cool brood: Several researchers, including Oldroyd and his collaborators, have previously shown that bees which develop at sub-optimal temperatures have difficulty learning and foraging. As such, chilled colonies may produce workers that fly from the hive and not return, a symptom that is similar to what happens with CCD. This is a new hypothesis that has yet to be considered, but should be readily testable.

The take-home message: CCD is likely a combination of several of these factors, which will make it difficult to really pin down. Hopefully, honey bee researchers will be able to do so sooner rather than later.

Reference

Oldroyd, B. P. (2007). What's killing American honey bees? *PLoS Biology*, **5**: 1195-1199.

Review: Torto et al. (2007). Proceedings of the National Academy of Sciences, **104**: 8374-8378
Written: May 31, 2007
Posted: 06/05/07
Word count: 689

Q*uestion*: What attracts small hives beetles?

A*nswer*: Honey bee alarm pheromone, and not just from the bees!

The small hive beetle (SHB), *Aethina tumida,* was first discovered in South Carolina in 1996. In the spring of 1998 in Fort Pierce, Florida, this beetle was determined to be a destructive pest in beehives, at which point it was positively identified as the small hive beetle (SHB). Prior to its discovery in the U.S., the only record of this insect was in the southern regions of Africa.

During the summer of 1998, the beetle was blamed for the loss of over 20,000 colonies in Florida. The beetles spread quickly, and that same year beetles were also reported in Georgia, South Carolina, and North Carolina. Since that time, the beetle has become established in most counties in North Carolina as well as across much of the United States. This demonstrates the beetle's remarkable ability to disperse by flight and human transport.

There are several means for control and prevention of SHB. The only approved treatment <u>inside</u> the beehive is a coumophos plastic strip (CheckMite+^{TM}) cut in half and attached to a small piece of cardboard placed on the bottom board. The adult beetles will hide beneath the cardboard and contact the pesticide, which kills them. The only approved treatment outside the hive is a pemethrin soil drench (GuardStar®), a liquid treatment that is mixed with water and applied to the ground around the hive to kill the beetles pupating in the soil. There are several in-hive traps on the market, which can assist in prevention of SHB outbreaks. However, these traps are passive; they work by filling a resevoir with vegetable or mineral oil, so as the adult beetles enter and look for a hiding spot, they fall into the oil and drown. As such, it would be very helpful to find an effective chemical lure that will attract large numbers of beetles to these traps and therefore greatly minimize SHB damage.

A recent report in the prestigious *Proceedings of the National Academy of Sciences* provides some information that may help develop a chemical lure for small hive beetles. The researchers investigated what chemicals within a hive is attractive to beetles. To test this, they used gas chromatography (GC), a chemical analysis machine, and electroantenograms (EAG) of SHB adults, which measures the electrical stimulation of antennae to various smells. Based on previous work, they found that SHB adults are attracted to isopentyl acetate, 2-heptanone, and methyl benzoate. These three chemicals comprise about 75% of the honey bee alarm pheromone, strongly suggesting that the beetles are "homing in" on colonies that are disturbed in some way. Moreover, based on their EAG findings, they found that adult SHB are even more sensitive to honey bee alarm pheromone than the honey bees are!

Perhaps what is even more intriguing is that they found that the adult bees are not the only source of these chemicals in the hive. They discovered that SHB adults carry with them certain species of yeast. One in particular, *Kodamaea ohmeri*, produces the same blend of chemical compounds as honey bee alarm pheromone when it grows on pollen within the hive. This is a very interesting find, as it suggests that beetles can enter a hive, inadvertently inoculate it with this yeast, and cause a positive feedback loop where more adult beetles are attracted to the hive.

This is a very exciting finding, and one that could potentially lead to the development of an active—rather than passive—in-hive, or even external, trap for SHB. It also suggests that minimizing colony disturbance may help reduce the likelihood of SHB invasion. We will have to see in the coming months and years if this technology will benefit beekeepers.

Reference

Torto, B., D. G. Boucias, R. T. Arbogast, J. H. Tumlinson, and P. E. A. Teal. (2007). Multitrophic interaction facilitates parasite–host relationship between an invasive beetle and the honey bee. *Proceedings of the National Academy of Sciences*, **104**: 8374-8378.

Review: Pankiw and Garza (2007). *Apidologie*, **38**: 156–163
Written: May 9, 2007
Posted: 05/09/07
Word count: 673

Question: Is the higher reproduction rate in AHB intrinsic or environmental?

Answer: While partially controlled by the environment, it is also an intrinsic trait

There are many different reasons why the Africanized honey bee has been so ecologically dominant over the last half century. One reason is that some of their more notable characteristics, such as defensive behavior, are genetically dominant. Studies have isolated several regions of the genome, known as quantitative trait loci or QTL, that explain a large percentage of how honey bees respond to intruders and pursue them for long distances from the hive. Using backcrossing techniques, the same studies have shown that bees hybrid bees—those with both African and European parents—tend to be more defensive like their African parent. Another reason is that AHB has outcompeted EHB is that they produce small, parasitic swarms that can invade and take over a European nest. This causes an immediate genetic turnover of the colony from European to African.

But perhaps the largest reason the AHB have been so successful is because of their increased reproduction. It has long been estimated that a standard European honey bee colony issues 1-2 swarms per year. On the other hand, African colonies issue as many as 16 swarms per year. The shear numerical advantage of African colonies in a given area had lead to the complete displacement of the European population by African bees. The conventional wisdom holds that this increased reproduction rate is because African bees are adapted to the tropics and therefore need not store large amounts of honey and pollen for periods of dearth, since there is almost always nectar and pollen available in the tropics. If so, then what controls what: does the environment dictate the reproductive rate of AHB, or are the AHB intrinsically more reproductive?

A recent paper by Texas A&M researchers investigated the mechanisms that govern reproduction in honey bees to answer this question. They used an important signal in the regulation of colony reproduction, brood pheromone. Created by developing larvae, brood pheromone is a complex mix of certain chemicals that create a certain bouquet that, among other things, inhibits queen rearing and worker ovary development. The researchers used worker ovary development as a proxy for how responsive they are to colony reproductive cues, such as brood pheromone. They tested several hypotheses to get to the bottom of this question. First, does brood pheromone from EHB have the same effect as brood pheromone from AHB? Second, is the effect of brood pheromone dose-dependent? (That is, does increasing the amount of brood pheromone decrease the amount of worker ovary development?) And third, does the genetic composition of bees (mixtures of AHB and EHB) affect the influence of brood pheromone on ovary development?

The researchers found that the different racial extracts of brood pheromone did not differentially affect worker ovary development, suggesting that the signal of AHB is effectively the same as EHB. However, the effective concentration of brood pheromone that caused worker ovary development was 16 times higher in AHB workers compared to EHB workers. In other words, AHB workers needed much more brood pheromone to inhibit their ovary development, suggesting that they are intrinsically "more reproductive" than EHB workers. Finally, this difference in worker ovary development was not influenced by whether the workers were all AHB, all EHB, or a mixture of both types.

The results suggest that the increased reproductive rate of AHB colonies is also reflected in an increased reproductive rate of AHB workers. In other words, while the environment obviously affects reproduction in honey bees, Africanized honey bees are "turned up" for reproduction. These findings are further evidence at why the AHB has been such a successful invasive pest, and it may even help researchers find ways to minimize their unwanted behaviors.

Reference

Pankiw, T. and C. Garza. (2007). Africanized and European honey bee worker ovarian follicle development response to racial brood pheromone extracts. *Apidologie*, **38**: 156–163.

Review: Meikle et al. (2007). *Journal of Economic Entomology*, **100**: 1-10.
Written: April 1, 2007
Posted: 04/02/07
Word count: 772

Question: Is there a potential for biocontrol of varroa mites?

Answer: Possibly, by using entomopathogenic fungi, but unfortunately not with overwhelming results

Biocontrol for pest organisms is a means of controlling one organism with another. Examples abound in agriculture. Lady beetles are beneficial in home gardens because they eat the eggs of many pest insects, reducing their number and therefore the damage they cause to flowers and shrubs. Parasitic wasps lay their eggs in (or on) caterpillars that feast on various crops, eventually killing them so they do far less damage. Phoretic flies have been released in the US to try and control the invasive red imported fire ant.

One main benefit of using biocontrol to reduce pest numbers is that the pest has a much harder time coming up with ways to survive, at least compared to other means of control. For example, pesticides usually contain only one active ingredient that kills or otherwise controls the pest. That single mechanism of control can eventually be overcome by the pest; that is, the pest can eventually develop a resistance to the chemical (through behavioral means such as avoidance, or physiological means such as detoxification enzymes). For pests to develop resistances to other species, they must simultaneously develop a wide variety of resistance mechanisms, something that is much less likely to happen.

Another important benefit of biocontrol is the persistence and sustainability of many such systems. Releasing predatory mites into a field to control an insect pest needs to be done only once, since the mites will increase their numbers and continue to reproduce on the very pest species that you are trying to control. Needless to say, that can be very beneficial not only for control of the pest population, but because repeated applications are not always necessary.

Given the many benefits of biocontrol as a means to keep pest numbers in check, several researchers have been searching for a biological agent that will kill varroa mites but have no averse effect on honey bees. Unfortunately, there is no parasitic wasp or predatory mite that preferentially attacks varroa mites. However, there are several different species of fungus that have been shown to infect varroa but are completely harmless to bees. Consequently, there has been much speculation and optimism that perhaps one of these entomopathogenic fungi may be used to control varroa in beehives.

A recent study by a French scientific team isolated one such strain of fungus to see how well it controls varroa in field colonies. Their earlier tests, performed in the laboratory, demonstrated that the fungus *Beauveria bassiana* significantly decreased the lifespan of an adult varroa mite by about 70-80%. They then used this fungal isolate in the field and measured both treated and untreated (control) colonies for mite drop (using sticky boards), adult bee population, and brood area. They also measured whether or not the dead mites developed the fungal infection, suggesting that they died from the fungus rather than another means.

The good news is that they found significantly more dead mites dying from fungal infections in the treatment colonies compared to control colonies. This suggests that the mites were indeed dying from the biocontrol agent, demonstrating its potential for use as a means of controlling varroa mites. The bad news is that the effect was neither pronounced or prolonged. They found significantly higher mite drop in treatment colonies 6 and 8 days after applying the fungal spores, but not at levels that would reduce the mite populations below an acceptable level. Moreover, the persistence of the fungus was not very pronounced, as they estimate the amount of fungi within the hives dropped below the level needed to cause infection within about one week after application.

This study differs from previous studies performed in the US, since it tested an entirely different fungus. However, the two lines of research are similar to each other in that they both demonstrate only modest control of varroa mites in field colonies. While efforts towards a biological control of varroa should certainly continue, as the current findings are very tantalizing for the possibility of using fungi for mite control, researchers have yet to demonstrate that biocontrol is a viable option for beekeepers to keep their pests under control.

Reference

Meikle, W. G., G. Mercadier, N. Holst, C. Nansen, and V. Girod. (2007). Duration and spread of an entomopathogenic fungus, *Beauveria bassiana* (Deuteromycota: Hyphomycetes), used to treat varroa mites (Acari: Varroidae) in honey bee (Hymenoptera: Apidae) hives. *Journal of Economic Entomology*, **100**: 1-10.

Review: Seeley (2007). *Apidologie,* **38**: 19–29.
Written: March 8, 2007

Posted: 03/12/07
Word count: 740

Q*uestion*: How are feral bees able to cope with varroa mites?

A*nswer*: Because the mites are less virulent, not because the bees are resistant

Parasites are among the most successful life forms on the planet. Why? Because they don't have to work as hard for their food and other resources. Rather, they tap into the resources they need from other life forms (their hosts). But there are limits to how much they can take from their host—if they take too little, they might not be able to survive and reproduce themselves; if they take too much, they run the risk of killing their host and, oftentimes, themselves. Consequently, natural selection tends to balance the degree to which parasites steal from their hosts.

The same holds true for the parasite-host relationship between the varroa mite (*Varroa destructor*) and honey bees (*Apis mellifera*). The mites run the risk of killing themselves, by killing the bee colony, if they reproduce more than the colony can handle. In a feral or "wild" setting, this would select for avirulent mites since the best way they

Review: Higes et al. (2006). Journal of Invertebrate Pathology, **92**: 93-95.
Written: February 4, 2007
Posted: 02/06/07
Word count: 729

Question: What are the new disease threats to honey bees?

Answer: There are two: a new, more virulent nosema and an unknown condition known as "colony collapse disorder"

Honey bees are hosts to more parasites and pathogens than any other social insect, with a record of 72 documented so far. Many of the most economically important ones, including varroa mites, have resulted from introductions of foreign exotic pests. In biology, this is known as a "host shift", where a parasite from one species jumps ship and starts to parasitize another species. In the case of varroa, the mites shifted hosts from the Eastern honey bee (*Apis cerana*) to our Western honey bee (*Apis mellifera*). Because our bees had not evolved any natural defenses against varroa, the mites are highly virulent; that is, our bees succumb very quickly to them (at least compared to their original hosts).

Well, it looks as if history is repeating itself, as another parasite seems to have shifted hosts from *A. cerana* to *A. mellifera*. This time, it is not an ectoparasitic mite but rather an internal microsporidian that infests the hind gut of adult bees. We are already familiar with such a parasite, *Nosema apis*, which causes nosema disease. The typical symptoms of nosema include unusually high defecation rates in and around the hive, lethargic bees, and swollen abdomens. While the disease can cause problems for colony productivity, our bees usually don't succumb to nosema and can be easily and readily treated with antibiotics (fumigilin) fed through sugar syrup. However, *A. cerana* has its own version of nosema, *N. ceranae*, which is slightly different from *N. apis*.

A recent report out of Spain verifies that *A. ceranae* has been infecting honey bees in Europe. While *N. apis* and *N. ceranae* are not visually distinguishable under the microscope, they are distinct genetically. Mariano Higes and colleagues used modern genetic techniques to confirm that bees collected in Spain have this new version of *Nosema*. Moreover, the symptoms are different from *N. apis*, where they do not seem to defecate inside the hive. Nonetheless, honey production is very low and colonies can collapse very readily (particularly over winter). While the parasite is still susceptible to antibiotics, colonies seem to collapse before feeding fumagillin can rescue them.

There are unconfirmed reports that *N. ceranae* has been found in the U.S. A paper due out in the *Journal of Invertebrate Pathology* will soon report the findings of a preliminary survey of this new nosema, at which point we will see if it is indeed a problem for our beekeepers and just how widespread it may be.

This potentially new disease is apparently different from another problem our beekeepers have been experiencing, termed "colony collapse disorder" (or CCD), where colonies across the nation have dwindled and inexplicably died. Quoting a recent report, "Initial studies on bee colonies experiencing the die offs has revealed a large number of disease organisms present in the dying colonies, with most being "stress related" diseases and without any one disease being supported as the "culprit" underlying the deaths. The magnitude of detected infectious agents in the adult bees suggests some type of immunosuppression. Case studies and questionnaires related to management practices and environmental factors have identified a few common factors shared by those beekeepers experiencing the CCD; but no common environmental agents or chemicals were easily identified by these surveys. The search for underlying causes has been narrowed by the preliminary studies, but several questions remain to be answered."

While it has been speculated that the new nosema might be the culprit behind this phenomenon, the internal symptoms of CCD appear to be quite different, making it very unlikely that this is the case. Several working groups have been formed to try and get to the bottom of CCD, and we hope to have some answers by the end of this upcoming season.

I'm sure you'll be hearing a lot about these two new threats to the beekeeping industry, so keeps your ears open for suggestions and treatments. For the time being, more information about CCD can be found at http://maarec.cas.psu.edu/.

Reference

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Review: McMullan and Brown. (2006). *Apidologie*, **37**: 471-479
Written: 12/21/06
Posted: January 2, 2007
Word count: 707

Q*uestion*: Which is more important for tracheal-mite resistance, temperature or grooming?

A*nswer*: While temperature is important, grooming is more so.

Tracheal mites are internal parasites of honey bees, living in their breathing tubes (called trachea). They were discovered and described as the causative agent of "winter disappearing disease". It is now known that if a colony has more than 30% of its adult bees infested with tracheal mites, winter mortality significantly increases even if the hive has sufficient food reserves. It has long been known, even before the mites were discovered, that some honey bee colonies are more likely to succumb to "disappearing disease" than others; that is, there is variation among bees for their resistance to tracheal mites, to the point where certain strains can be selected for mite tolerance (such as the Buckfast strain developed by Brother Adams).

Much research has gone into identifying the mechanism of tracheal-mite resistance. There are two potential means of resistance: physiological and behavioral. Since a bee's development often has important impacts on its physiology, prior research has investigated the link between the temperature during pupal development and mite infestation. Such tests have found that bees raised at 30^{o}C as pupae become infested with tracheal mites more readily than bees raised at the normal temperature of 34^{o}C. Moreover, knowing that mites actively migrate from one bee to another, it is also possible that resistance can stem from the disruption of horizontal transmission of mites within a colony. Research has shown that autogrooming—or a bee grooming itself—can be very effective at reducing mite levels. So, the question becomes: which is more important, temperature or grooming?

It is this question that John McMullan and Mark Brown at Trinity College in Ireland posed in a recent study. They obtained bees from two sources: a "low susceptibility" colony (derived from an apiary where the bees had never become infested with tracheal mites) and a "high susceptibility" colony (derived from a yard where the colonies had, in the past, become infested with tracheal mites). Capped brood frames from these two sources were raised in an incubator at either 30^{o}C or 34^{o}C. Once they matured, newly emerged—or callow—adult bees from each of these sources and temperature treatments were placed into plastic containers in an incubator. In some of the cages, both mesotarsi ("middle feet") of the adult bees were surgically removed to prevent effective autogrooming, while in the remaining cages the bees were left intact. Finally, each container was "inoculated" with foreign bees from another colony containing a large percentage of tracheal mites, and then the test bees were collected and measured for the number of tracheal mites they were infested with.

At the end of the experiment, the researchers were able to compare the levels of tracheal mites as a function of genetic susceptibility (low vs. high), developmental temperature (reduced vs. normal), and grooming behavior (restricted vs. unrestricted). They found that susceptible bees were not significantly affected by either temperature or grooming; in other words, all susceptible bees became equally infested with tracheal mites. In the mite-tolerant bees, however, they found that grooming had little effect on mite levels in bees raised at a reduced temperature, but that grooming had a very large effect on mite levels in bees raised at a normal temperature.

These results suggest that grooming ability of bees is the main means by which they are able to withstand tracheal mite infestations, but only if the bees are able to develop at brood-nest temperatures. This means that it is important for "winter" bees to develop in a well-populated colony so that the brood nest does not become overextended and the brood become chilled as the colony goes into winter. Moreover, the findings further suggest that autogrooming assays, much like those performed for hygienic behavior, should be incorporated into queen-production programs to help alleviate the levels of tracheal mites within our colonies.

Reference

McMullin, J. B. and M. J. F. Brown. (2006). The role of autogrooming in the differential susceptibility to tracheal mite (*Acarapis woodi*) infestation of honeybees (*Apis mellifera*) held at both normal and reduced temperatures during pupation. *Apidologie*, **37**: 471-479.

Review: Weinstock, G. M. et al. (2006). *Nature* **443**: 931-949.
Written: November 20, 2006
Posted: 12/04/06
Word count: 718

Q*uestion*: What can knowing the honey bee genetic sequence do for beekeepers?

A*nswer*: In the long run, plenty—and the sky's the limit

The art of beekeeping is literally an ancient practice, and much of what we do in the bee yard has not changed much since Langstroth revolutionized bee management in the mid 1800s. Honey bee science, on the other hand, has changed dramatically over the years as new technologies have been developed in the biological sciences. Apiculture and honey bee science is currently experiencing a quantum leap forward with the completion of the honey bee genome sequence. This is a project supported by numerous beekeeping groups and research programs across the nation. Collectively known as the Honeybee Genome Sequencing Consortium, the project involved 170 researchers (two of them, by the way, members of the NC Honey Bee Research Consortium) from 64 institutions in 15 countries, and has resulted in over 50 scientific publications. Implemented by Baylor College of Medicine in Texas, they have taken the DNA from honey bees and transcribed the millions of individual letters of the four-letter alphabet that encodes the molecule of life.

The way this process works is quite complicated yet elegant in design. The DNA is isolated from bees; easy enough. That DNA is then literally cut into thousands of small fragments. Those little snippets, then, are inserted into bacteria, which are allowed to grow and replicate these small pieces of bee DNA, creating what is known as a 'DNA library' that researchers can repeatedly access and reference to. Each little fragment is then read to transcribe the sequence of A's, T's, G's, and C's that constitute the entire DNA code of the honey bee.

The difficulty, of course, is putting all of the little snippets back together. This entire process is very much like something that the Beatles producer George Martin did on the *Sgt. Peppers* album. Taking a long section of tape at the end of the song "For the Benefit of Mr. Kite" (where John Lennon was improvising on the organ), he cut the tape into many foot-long sections, threw them into the air, and told his editor to pick them off the recording booth floor and piece them back together. The final result is a random progression of organ music in the closing part of the song. The process of assembling the honey bee genome is just like that, only the geneticists have to put the little fragments of DNA back in the correct order!

The genetic code of a bee's DNA is used to make proteins, those proteins are then assembled to make a bee, and those bees come together to make a colony. The honey bee genome, therefore, provides a road map for geneticists to locate regions of this long DNA sequence that encode particular traits of interest at the gene, bee, or colony level. Thus we are poised over the next few decades to make tremendous advances in bee science and management by understanding the genetic underpinnings of a wide range of topics. Here are just a few things that the Honeybee Genome Sequencing Consortium has learned so far:

– Conservatively, honey bees have at least 10,000 genes, which is lower than other insects. By contrast, humans have between 20,000-25,000 genes.
– The honey bee genome shows greater similarities to vertebrate (including human) genomes than other insect models (such as fruit flies) for many common Òhouse-keepingÓ genes, making the honey bee an excellent model system to investigate certain human diseases and behavioral disorders.
– The western honey bee, *Apis mellifera*—the species that we use—evolved in Africa rather than Asia, where all the other honey bee species are native. Moreover, they seem to have been introduced to Europe on two separate occasions, once through Eastern Europe and once directly to Western Europe via the Iberian peninsula.
– Honey bees have about two-thirds fewer genes for immunity than do other insects. This suggests that honey bees are poorly defended against pathogens at the individual level but rely more on social mechanisms of disease resistance. This can have important ramifications for understanding disease transmission and management.

In short, we are entering a new era of honey bee research: the genomic era. With time, it should yield tremendous benefits for bees and beekeepers.

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Review: Chen et al. (2006). Applied and Environmental Microbiology, **72**: 606–611.
Written: October 24, 2006
Posted: 11/05/06
Word count: 626

Q*uestion*: Are mites the only way that viruses are spread within a colony?

A*nswer*: No; queens can also directly pass on viral infections to their eggs

There is increasing evidence that viruses may play a much greater role in decreased colony health than we previously thought. The likely reason that we don't immediately think of viruses as a leading culprit of colony ill-health is because they are invisible, difficult to detect, and infected individuals are often asymptomatic. Research over the last few years has clearly indicated, however, that varroa mites are excellent transmitters of numerous viruses, such as deformed wing virus (DWV) and Kashmir bee virus (KBV), both of which have clear (but subtle) negative effects on colonies. As one apiculture researcher put it, "pretty soon we'll be saying that mites don't kill your colonies--mites pass on viruses that kill your colonies."

Understanding how a disease is transmitted, therefore, is an important aspect of understanding how we can minimize its impact. There are two general ways that disease can be transmitted. The first is the "typical" way we think disease is transmitted, from bee to bee. This is known as *horizontal* transmission, between members of the same generation. Horizontal transmission is the way that varroa mites pass along viruses to brood and adult bees, colonies can spread numerous diseases to each other (particularly through robbing and, to a much lesser extent, though drifting), and beekeepers can transmit any number of pathogens to other colonies by swapping diseased frames between hives. The second means of transmission is known as *vertical* transmission, spreading disease from one generation to the next. One obvious example of this process is by parent colonies passing along their diseases to their daughter colonies during the process of swarming.

A recent study by USDA researchers in Beltsville have identified another means of vertical transmission of certain bee viruses. Judy Chen and her colleagues have demonstrated that queens infected with certain viruses can actually pass them along to their offspring by directly infecting the eggs when they are laid. To determine this, they sampled queens to determine if they were infected with acute bee paralysis virus (ABPV), black queen cell virus (BQCV), chronic bee paralysis virus (CBPV), deformed wing virus (DWV), Kashmir bee virus (KBV), and/or sacbrood bee virus (SBV). They then sampled the colonies for eggs, larvae, pupae, and adult bees. Using the modern technique of reverse-transcription PCR, they were able to detect the presence and relative abundance of each of these viruses in various tissues of the queens and offspring. They found a very strong correlation between them, such that brood of all stages always had the virus(es) that the queen was infected with. Moreover, if queens were infected with either BQCV or DWV, their offspring were *only* infected with these viruses and no others. Given that horizontal modes of transmission, such as varroa mites, cannot pass along viruses to eggs or young larvae, this demonstrates a unique vertical mode of transmission for these diseases: from mother to daughter.

This finding is important, but we're still a long way from being able to address viral infections in our colonies as no antibiotic or pesticide can be applied to alleviate the problem. Currently, the best approach to minimizing viruses in our hives is to reduce the numbers of varroa mites that horizontally transmit them. However, with additional research on viral transmission within colonies, we may also be able to determine ways that we can prevent their vertical spread.

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Review: Connor (2006). *Increase Essentials*. Wicwas: New Haven.
Written: September 16, 2006
Posted: 10/02/06
Word count: 712

***Q**uestion*: What is the best way to counter winter losses?

***A**nswer*: Learn how to make strong, healthy colonies through *increases*

It may be hard to believe, but there was a time where a honey bee colony was expected to survive the winter as long as it has sufficient honey stores. Today, it is not unusual for beekeepers to see one-third to one-half of their colonies die during the winter, even if they were adequately provisioned. The leading culprits that are blamed for such drastic losses are, of course, varroa and tracheal mites, although the latter is probably not given as much credit as the former (even though it make be more deserving). But other factors, such as poor fall honey flows, prolonged winters, Indian summers (where the bees start rearing brood too early and waste their precious stored resources), and overstressed colonies can really stack the deck against a colony making it through the winter dearth.

It seems curious that if beekeepers lose up to half of their colonies every year, they why doesnÕt the honey bee population quickly dwindle to nothing? While there has been a slow and steady decline in the number of managed hives over the past 20 years, there hasnÕt been a total extinction of honey bees. Why? Because every year beekeepers grow *new* colonies of bees to try and replace the ones that died out. There is a real art to this practice, one that can take a lot more care and subtlety than one might think. Making new colonies from existing ones is the basis for a new book titled *Increase Essentials* by Larry Connor.

This is a book written for the experienced beekeeper, particularly for the larger, non-commercial or semi-commercial sideliner with enough hives and colonies to make the advice worthwhile. Beginners or strict hobbyists would probably not get as much from it, other than perhaps an optimistic enthusiasm for the art of beekeeping and possibly even an incentive to make their operations into larger ones.

The topic is quite straight forward (split one large colony into two or more smaller colonies), but surprisingly complex when all of the details are laid out. The author, however, does a very nice job at introducing and integrating the various topics as they apply to making splits, raising queens, and replacing colonies. Some of these issues include: swarming, initial worker and brood populations, ecology and seasonal timing, supplemental feeding and honey stores, and genetic quality. He provides just enough biological background to place each issue into a larger context, and then outlines some very practical advice without giving over-simplified (and therefore likely erroneous) step-by-step instructions on how to establish new colonies.

At its core, the practice of making splits requires that the initial unit is optimized for both size and timing. Using some simplistic (and therefore comprehendible) computer models, Dr. Connor illustrates why starting a colony that is too small or too large, or too early or too late, will produce sub-optimal colonies. Colonies started with too few resources or too late will struggle to grow their population and not be able to take advantage of the spring nectar flow. Colonies started with too many resources or too early may build up too quickly and swarm during the nectar flow. The propensity of bees to grow depends on both their genetics and the environment in which they are located, so understanding both is vital to make the most out of making increases (in short, know your bees *and* your backyard). The take-home message: make moderately sized splits *with brood* in early spring, maintain strict control over queens and genetic stock, and stay vigilant over the growth and development of the colony.

In the end, this book provides exceedingly helpful advice in the artistic application of bee management in an effort to propagate honey bee colonies through splits and divides. In doing so, the author makes a cogent argument that this is a powerful means of keeping a healthy population of honey bees, and one that pretty much any beekeeper, at any scale, can accomplish.

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Connor, L. J. (2006). *Increase Essientials*. Wicwas Press: New Haven CT, 128 pp.

Review: Branco et al. (2006). *Apidologie*, **37**: 452-461.
Written: August 21, 2006
Posted: September 6, 2006
Word count: 887

Question: How accurate are varroa sampling techniques?

Answer: About 92% accurate, so they are good tools for mite management

It is a tricky business, keeping on top of those pesky varroa mites. This time of year, beekeepers are particularly concerned with these parasites: their populations are usually at their highest because theyÕve been able to increase their numbers all summer long, the surplus honey supers have been or in the process of being taken off and extracted, and steps are taken to treat those colonies that have unacceptably high mite levels. Estimating this latter number can be laborious and time consuming, but it is critical for proper beekeeping management in the post-modern era.

There are a number of methods to estimate mite levels in beehives, but they generally fall into two categories. The first is an estimation of the *mite load* of a colony, usually performed by the Ôsticky boardÕ test. This method employs a paper or plastic sheet covered with a glue-like substance, which is placed beneath the hive to capture any mite that falls off of their host bee. Sticky boards are left in the hive overnight or up to several days, but the standard measure is a 24-hour mite drop. In essence, this method samples the natural death rate of the mites in a hive as a proxy of the total number of mites. The second method is an estimation of the *mite intensity* within a colony, performed by any number of techniques, by sampling brood or adult bees and calculating the percentage of them that have mites. One popular technique that estimates percentage infestation is the Ôsugar shakeÕ method, where 200-300 adult bees are taken from the brood nest, placed in a jar, and covered with powdered sugar. The mites are then shaken through a wire-mesh screen to estimate the number of mites per adult bee. Similar methods include the ether roll, alcohol wash, and drone-brood sampling techniques.

Each of these methods has their merits and drawbacks. Sticky boards donÕt require opening or manipulating a hive, but they donÕt give an immediate answer (not to mention going half blind from counting dozens or even hundreds of little dead mites). Sugar shakes give you an immediate answer, but it can take some work (not to mention the risk of inadvertently sampling the queen!). But one drawback that each of these measures has in common is that they derive *estimates* from only a *sample* of the mites in the colony, not the whole number. This means you can repeatedly measure mite levels using the exact same technique, but the precise estimate might be different each time. This is a statistical issue known as *sampling error*, where shear chance can actually cause your estimates to vary (for example, you just happen to collect bees from a varroa Òhot spotÓ in the hive, inflating your estimate of varroa intensity). So the question is: which, if any, of these sampling procedures gives an adequate estimate of *all* the mites in a particular hive?

This is what a recent study, published in the journal *Apidologie*, attempted to answer. A Welsh research team, led by Manuela Branco, sampled 22 beehives for varroa mites using three methods. First, they sampled natural mite mortality using the sticky board assay as described above. Second, they estimated infestation level of adult bees by sampling about 200 adult workers from the brood nest area and washing the mites from them. Additionally, they sampled worker and drone brood from each colony by physically removing them from their cells and calculating the proportion with mites. Third, they estimated the total number of mites in each hive by killing all of them with a pesticide (fluvalinate, by the trade name Apistan) and collecting them on a trap board.

They found a good relationship between all three measures. This means that both their measure of mite load (using the sticky board) and mite intensity (using the mite wash and brood sampling) were very well correlated with the total number of mites in the hive. In fact, their measure of mite load was 92% correlated with the total number of mites, and their measure of mite intensity was 89%-97% correlated (depending on the year). While this is not all that surprising, it is comforting that the sampling techniques are not arbitrary but rather quite accurate measures of the mite population in the hive. Moreover, in the long run, sampling error doesnÕt have much of an effect on management decisions. So, the economic thresholds for varroa mites (that is, the numbers above which you need to treat your hives) are still:

Sticky board: 100-150 mites in 24 hours (depending on the size of the hive)
Sugar shake: 5-6 mites per 100 adult bees

One caveat of this study is that they used a different race of bee in a very different environment, so the exact numbers may vary in different places. However, it does show that sampling methods are useful and accurate when done properly, and are important tools for varroa management.

Reference

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Review: Ibrahim, A. and M. Spivak. (2006). *Apidologie,* **37**: 31–40.
Written: August 6, 2006
Posted: 08/07/06
Word count: 827

***Q**uestion*: What is the mechanism of varroa resistance in the SMR stock?

***A**nswer*: Varroa-specific hygienic behavior, so now it's called the VSH stock.

As beekeepers, we are ultimately concerned with the final product. Many times, the final product is indeed a product that we harvest: honey (of course), but sometimes pollen, propolis, even royal jelly and venom. But we are also interested in different kinds of final "products", usually as a means to the above ends: healthy bees, good brood patterns, low swarming rates, etc... These "products" are the result of many factors that affect the overall productivity and character of a bee colony. Biologists call the overall character of an organism the *phenotype*, the physical properties of a living thing.

At the risk of being overly simplistic, the main task of honey bee research is to understand how a colony's phenotype is manifested. Many times, the factors that affect a colony's characteristics are enclosed in a metaphorical 'black box' that, only with intense empirical research and hypothesis testing, can be opened to reveal the intricate mechanisms that make things work to produce a final "product". Understanding the cause and effect of phenotype enables us to better understand the bees, which ultimately makes us better beekeepers.

Some new research has recently revealed to us just how deep the black box can be. Most of us are familiar with a genetic stock of bees, known as the SMR strain. Standing for the Supression of Mite Reproduction, this stock was artificially selected for varroa mite resistance by researchers at the USDA lab in Baton Rouge. They found that when mites infested bees of this stock, they entered the brood cells as they normally would but they produced fewer mites. Lower mite reproduction translates into better mite resistance of the bees. Thus the black box for mite resistance in the SMR bees was opened.

A new study by Ibrahim and Spivak, however, has opened a second black box within the first to reveal something unexpected. They tested the hypothesis that the mechanism of resistance in the SMR bees was not a physiological trait (such that mites had a "distaste" for bees of that particular strain) but rather a behavioral one. Most of us, if not all, have heard of hygienic behavior in bees, such that adult workers uncap and remove dead or dying pupae from their cells to lower the spread of disease. Their hypothesis was that bees in SMR colonies were merely exhibiting hygienic behavior in response to varroa parasitism. They tested three specific hypotheses. First, do bees of the SMR stock detect and remove mite-infested brood? Second, if they are hygienic for varroa-parasitized brood, do they preferentially remove pupae with many mites? Third, what is the reproductive success of mites from SMR colonies when bees do not remove the pupae?

To answer the first question, the researchers manually introduced adult mites to brood cells of SMR and Minnesota hygienic strains. They then measured the rate at which these cells were uncapped and emptied by the adult bees, compared to non-infested controls. To answer the second question, they removed the infested brood from each stock to calculate the reproductive success of mites by counting the number of mite offspring in each brood cell. To answer the final question, they parasitized brood stored in an incubator with mites that derived from colonies of both stocks.

They found that bees of the SMR strain were indeed hygienic, removing 84.5% of the pupae containing mites (compared to 61.7% in the hygienic strain and 10.8% of the uninfested controls). Moreover, the overall proportion of viable mite offspring was lower in the SMR strain compared to the hygienic strain, suggesting that SMR bees specifically target the removal of brood containing "better" mites. Finally, they found that mites that derived from SMR colonies actually had fewer offspring compared to mites that derived from hygienic colonies. This suggests that the mites themselves are not as good at reproducing more mites.

This study tells us quite a bit about varroa resistance in honey bees. The mechanism appears to be three fold: SMR bees specifically uncap and remove varroa-infested pupae, they preferentially remove the pupae that are infested with mites that reproduce at a higher rate, and the mites themselves seem to have a decreased capacity of reproducing (that is, they are less virulent). As such, the SMR strain is now referred to as the VSH strain, standing for Varroa-Specific Hygiene. This knowledge will further help us elucidate how our bees can live with parasitic mites, and thus we have a much better picture of a colony's phenotype with respect to how they can tolerate varroa.

Reference

Ibrahim, A. and M. Spivak. (2006). The relationship between hygienic behavior and suppression of mite reproduction as honey bee *(Apis mellifera*) mechanisms of resistance to *Varroa destructor*. *Apidologie,* **37**: 31–40.

Review: Francoy et al. (2006). *Apidologie* **37**: 91–97.
Written: 6/21/06
Posted: June 28, 2006
Word count: 591

Question: How can you distinguish different types of honey bees?

Answer: According to a new technique, by taking a picture of their wings

Nature is "noisy". Not noisy in the audible sense, like tree frogs chirping in the spring or crickets in the summer. It is noisy in the sense that there is a lot of variation. Much of this noise comes from the environment, as every place on earth is unique and the biotic conditions change over space and time. But there is also "noise" as a result of different genetic types of organisms; different species, subspecies, or even populations of the same subspecies can be quite different genetically.

Honey bees are no exception. Of the 20,000 species of bees in the world, only 9 are true honey bees. Most of these species are native to eastern Asia, and few of us have ever worked with them. The one we're used to, *Apis mellifera*, is native to Africa and Europe. Because of the wide geographic distribution of this species, there are dozens of subspecies (often referred to, somewhat inappropriately, as "races"). While they can interbreed with each other, these subspecies are genetically distinct and therefore their characters can also be distinct, albeit in subtle ways. For example, *Apis mellifera caucasica* (the "Caucasian" honey bee of Eastern Europe) is notorious for making a lot of propolis; *Apis mellifera carnica* (the "Carniolan" honey bee of Central Europe) is very gentle; and *Apis mellifera scutellata* (the subspecies that was transported to Brazil and eventually became the "Africanized" honey bee) is notoriously defensive.

Because of their importance in agriculture and high variation among different subspecies, researchers have made a concerted effort to distinguish the different types of honey bees. One classic approach to identify different types of insects is through morphometrics, which is the use of measuring body characters to categorize them into different groups. One of the most notable uses of this technique is to distinguish European from Africanized bees in the US, enabling researchers to identify the likelihood that a given colony is either EHB or AHB. The difficulty with the procedure, however, is that it can be quite laborious, time consuming, and not always yield a black-and-white answer.

A recent study by a Brazilian research team outlines a new rapid diagnostic technique for identifying honey bee races. The procedure involves removing the wings from a bee, taking a high-resolution digital picture of it under a compound microscope, and then identifying five landmarks on the wing veination. They then developed computer software that automatically calculates different measures among these different digital points and analyzes them. The researchers were able to take these measurements and distinguish the subspecies *carnica*, *ligustica*, and *scutellata* with very high (99%) accuracy.

This new procedure may be a great help to beekeepers and apiculture officials who are interested in quickly diagnosing whether or not a given colony is Africanized or not. With the AHB now in Florida, it is only a matter of time before beekeepers in North Carolina will be facing this possibility. Being able to secure a quick answer to the question "Are my bees Africanized?" will enable a beekeeper to take quick action (i.e., requeen) before the colony becomes unacceptable to work with.

Reference

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Review: Rademacher & Harz. (2006). *Apidologie* **37**: 98–120
Written: May 15, 2006
Posted: 06/05/06
Word count: 1070

Question: How effective is oxalic acid for varroa control?

Answer: According to a new review, quite effective, but probably not for NC

Controlling varroa mites is the primary management issue for the modern day beekeeper. Since they were introduced in the mid-1980Õs, they have plagued our colonies and together we struggle to keep our hives free of infestation. Beekeepers have been able to treat their colonies for varroa mites using tau-fluvalinate (Apistan¨). Many varroa mites have become resistant to fluvalinate, thus forcing beekeepers to use the Section 18-approved coumaphos (CheckMite+¨), but the mites are now beginning to show resistance to this organophosphate as well. It is now necessary that beekeepers incorporate sustainable management practices to ensure the long-term health of their colonies.

The result of this crisis has been a proliferation of alternative methods to control the varroa mite. These approaches range in their mode of action (mechanical vs. chemical), persistence (short- vs. long-term), degree of manipulation (passive vs. active), and efficacy (low vs. high). The following is a non-comprehensive list of alternative varroa control methods that have been developed in recent years.

Screened bottom boards. Several researchers have placed wire-mesh on the bottoms of their hives so that fallen mites cannot re-attach themselves to another honey bee host and re-enter the nest to parasitize brood. Several studies have shown a moderate (14-15%) but non-significant reduction in mite levels, while others have demonstrated a statistically significant effect.
Drone-brood trapping. Varroa mites prefer to parasitize the developing brood of honey bee males (drones) rather than the smaller female workers because their larger body size and longer development times enable the mites to produce more offspring. Beekeepers may then remove drone combs before the drones complete their development, and kill the next generation of mites within the cells by freezing the brood.
Mite-tolerant stocks and bee breeding. Researchers at the USDA Honey Bee Research Lab in Baton Rouge, LA. have imported bees from the Primorsky region in far-eastern Russia. Their research has demonstrated that they are over twice as resistant to varroa as other commercial stocks. Similarly, many queen breeders have actively bred for colony Ôhygienic behaviorÕ, based on research demonstrating lower levels of numerous diseases in colonies selectively bred to uncap and removed diseased or parasitized brood.
Colony dusting. Application of inert dusts, such as powdered sugar, has been shown to be effective for mite control by causing mites to lose their grips from their hosts.
Food-grade mineral oil (FGMO) foggers. Some beekeepers have used standard pesticide foggers to atomize mineral oil, which they blow into a hive to suffocate phoretic mites. Fogged FGMO alone does not appear to be efficacious, but it may be a valuable delivery system for other active ingredients, such as vinegar or essential oils.
Formic acid. Within the past few months, the EPA has permitted the use of formic acid for the control of varroa mites in the U.S. This method has been used by beekeepers in Canada and Europe for many years, and has been shown to be quite effective when applied correctly.
Sucrocide¨. The biopesticide sucrose octanoate has recently been developed for varroa control by the trade name Sucrocide¨. It is delivered by spraying adult workers with the substance once every week for three weeks to kill emerged, phoretic mites. Researchers have recently showed that it is 96% effective at killing mites when applied properly.
Thymol. These relatively new products—containing the essential oil from the thymus plant—is effective to treat both varroa and tracheal mites. Researchers have showed 65-97% effectiveness at killing varroa mites.

A new paper by two German researchers, published in *Apidologie*, reviews the efficacy and consequences of another possible treatment: **oxaclic acid**. Beekeepers in Europe and Canada have been using this biopesticide for many years with significant success. Below are some of the means of oxalic acid application with their respective efficacy, tolerability, and residues.

Trickling: a liquid formulation of oxalic acid is administered from above to the bee spaces between frames using a syringe or similar device. When 5 ml is applied to each bee space at a 3.0% or 3.5% concentration, oxalic acid provided >90% and >95% control for varroa, respectively, for most studies. The treatment was relatively well tolerated by the bees, with only a 8% drop in population and a slight reduction in winter survival. The treatment was only applied during the broodless period, since it does not work for mites in brood cells. Residues in honey were not significantly outside of the natural range of oxalic in honey.

Evaporation: solid crystals or tablets of oxalic acid are placed in a tray that heats them and turns the oxalic acid directly into a gas that fumigates the hive. Again, application only occurs during the broodless period for maximum efficacy. 1-2 grams of oxalic acid provided 90-95% control in most cases. Lower control (60-80%) was witnessed when humidity and temperatures were high. Applying oxalic acid with this technique seems to have little or no effect on the bee population, and there was no measurable increase in residues in honey.

Spraying: much like applying Sucrocide, oxalic acid can be sprayed directly onto the bees on each frame and on the side walls of the hive. In broodless colonies, this technique showed >97% control, but in colonies with brood, it provided only 61% control. Loss of bees and colonies is negligible, unless several treatments or higher doses are used, and brood loss can occur if applied to colonies with brood. Spraying oxalic acid does significantly increase residues in honey, but the levels can decrease back to within control limits over time.

Oxalic acid appears to be another viable alternative for beekeepers to control varroa mites. However, because it is largely only effective when applied during broodless periods and during cool and dry weather, it seems unlikely that it will be something that beekeepers in North Carolina will be able to use. More research is required, particularly here in the southern US. In the meantime, it is not legal to use oxalic acid or any other unapproved chemical for varroa control, even if it may help.

Reference

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Review: Liu et al. (2005). Behavioral Ecology and Sociobiology **59**: 582-588.
Written: April 24th, 2006
Posted: 05/01/06
Word count: 760

***Q**uestion*: How do bees know how much pollen they have stored?

***A**nswer*: By smelling it

Running a honey bee colony can be a lot like running a household. There are many chores to do in order to keep everything running efficiently and effectively. Often times, things need to be regulated so that they are kept at an optimal. For example, temperature can be regulated in a house in the winter time by heating a wood stove. The house is kept at a constant temperature by adding more wood when the temperature drops below the comfort zone and letting it burn when it exceeds the comfort zone.

Keeping something at an optimal set point, such as temperature, requires a balance between input and output. In the wood stove example, the input is the heat produced by the fire and the output is the heat escaping from the house through transduction. The perfect balance between input and output is what regulation is all about.

But what happens when there is a dramatic change? For example, what happens if the temperature drops well below the comfort zone? My immediate reaction would be to add more wood to the stove, concluding that the dwindling fire is responsible for the drop in temperature. Thus I would assume that the change in temperature is because of a lowering of input. However, it is also possible that the drop in temperature is because my wife opened a second story window to get some fresh air. In that case, the change in temperature is not because of a lower input but because of a higher output. Either way, restoring the balance is necessary in order to get back to the optimal.

Foraging for pollen by honey bees is a lot like regulating the temperature. Their input is the rate at which pollen foragers collect and store loads of pollen, and the output is the rate at which nurse bees consume the pollen in order to feed it to the developing larvae. The total amount of pollen stored in the comb is kept at an optimal; if there is insufficient pollen stores, foragers step up their pollen-foraging, but if there is too much pollen, foragers back off foraging for pollen.

The question becomes: how do individual pollen foragers ÒknowÓ how much pollen the hive has so that they may address the needs of the colony accordingly? There are two competing theories. The ÔindirectÕ hypothesis is that nurse bees often feed foragers, communicating to them the relative nutritional needs of the colony. If the nurse bees donÕt have enough pollen to feed the larvae, the amount of protein in their donated food will be less, prompting foragers to collect more pollen. If the nurse bees have excess pollen to feed larvae, the amount of protein in their food will be greater, prompting foragers to collect less pollen. Alternatively, the ÔdirectÕ hypothesis is that individual foragers can somehow sense how much pollen is stored in the combs. They then regulate their own foraging efforts according to how much pollen they perceive is within the colony.

A recent study by a Chinese research team, led by Fang-Lin Liu, provides support for the latter hypothesis. While honey bees cannot perceive the nutritional content of different pollens, they found that individual foragers can detect different chemical attributes of pollen. Specifically, bees can identify the relative amount of phenolic compounds in pollen, the chemicals largely responsible for the strong odors that different pollens have. The researchers collect pollen from returning foragers, identified the different plant species, and measured the phenolic content of each. They found that the bees preferred pollens with lower phenolic content, suggesting that the bees may indeed be able to discriminate pollens directly. They also fed phenols in sugar syrup and showed that the bees were more tolerant of collecting pollen with high phenolic content.

While the study doesnÕt make a clear distinction between the ÔdirectÕ and ÔindirectÕ assessment hypotheses, it does support the notion that individual bees can directly assess pollen stores by smelling how much pollen is stored; that is, by sensing the amount of phenolic compounds in the combs. Keeping the amount of pollen in the colony at the optimal keeps the hive running efficiently and effectively.

Reference

Liu, F. L., X. W. Zhang, J. P. Chai and D. R. Yang. (2006). Pollen phenolics and regulation of pollen foraging in honeybee colony. *Behavioral Ecology and Sociobiology* **59**: 582-588.

Review: Biesmeijer and Seeley (2005). *Behavioral Ecology and Sociobiology*, **59**: 133-142.
Written: March 20, 2006
Posted: 04/03/06
Word count: 726

Question: Who follows waggle dances more often, recruits or experienced foragers?

Answer: Experienced foragers, who are reactivated or need confirmation

Effective recruitment to food sources is really important to a honey bee colony. Floral sources are often very fleeting, since nectaries dry up over the course of the day, flowers wilt and loose their pollen in the heat of the sun, and the bloom period for the plant canÕt last forever. The ephemeral nature of floral resources require that honey bees make the most of their window of opportunity by recruiting as many foragers to a newly located patch of flowers as quickly as they can before it disappears.

The main recruitment method used by honey bees is, of course, their famous Ôdance languageÕ. Experienced foragers that locate a rich food source return to the hive and perform a figure-eight dance on the surface of the comb, which communicates both the distance and direction of the flower patch to other bees who follow the dance closely. Many researchers have studied this remarkable form of communication to determine how followers decipher the message encoded in the dance, what effect it has on the colony, and why the bees gain from using it as a recruitment strategy.

Despite all of the studies investigating recruitment through dancing, it is still unclear to what extent bees follow waggles dances during their foraging lifetimes. It is this question that Koos Biesmeijer and Tom Seeley at Cornell University asked in a recent study by following marked foragers in observation hives over their lifetimes (the bees, that is, not the researchers!). They fixed small plastic discs onto newly emerged bees that were color coded and numbered so that they could individually identify the bees. They then placed 120 of these tagged bees into 3 observation hives and recorded their behavior—from sunrise to sunset, day in day out—until the bees were not longer in the hive. They recorded everything that they could about each bee when she became a forager, including when she started foraging, how often she foraged, what she collected (nectar or pollen), and, most importantly, when she followed the waggle dance of another forager.

Their study categorized three different types of foragers: (1) novice bees attempting to find their very first food source, (2) experienced foragers that have been interrupted in their foraging efforts, either permanently (by their flower patch drying up) or temporarily (by a rainstorm or nightfall), and (3) experienced foragers that are actively engaged in foraging. For the first group (totally novice foragers), they found that 40% of the bees relied mainly on scouting, 37% relied mainly on being recruited by a dance, and 23% relied on both methods to be prompted to forage. This finding is quite interesting, as it demonstrates that there isnÕt a strict dichotomy in how novice bees become foragers (by scouting or by recruitment) but rather a combination of both methods. For the second group (interrupted experienced foragers), 63% started foraging again without following a dance and 37% started foraging again after following a dance. This suggests that about a third of experienced foragers get ÒreactivatedÓ by following dances after they cease visiting their prior food source. For the third group (active foragers), about 17% of engaged foragers followed dances before they exited the colony, a proportion that significantly increased if their previous trip was unsuccessful. This suggests that some bees need ÒconfirmationÓ that their current food source is profitable and worthy of their foraging efforts.

Not only is this study a Herculean undertaking by the researchers, it sheds light on how the dance language information is used by the foraging force of a colony. Their findings suggest that the dance is used *for food discovery* about 25% of the time and it is used *for reactivation and confirmation* about 75% of the time. Thus the waggle dance is not only used for recruitment, it is also an important means of regulating the overall foraging effort of a colony to ensure that they are collecting nectar and pollen from the best resources currently available.

Reference

Biesmeijer, J. C. and T. D. Seeley. (2005). The use of waggle dance information by honey bees throughout their foraging careers. *Behavioral Ecology and Sociobiology*, **59**: 133-142.

Review: Delaplane et al. (2005). *Journal of Apicultural Research*, **44**: 157-162.
Written: February 13, 2006
Posted: 03/01/06
Word count: 809

Question: Does varroa IPM really work?

Answer: Yes, but it’s not a cure-all

Sometimes I think that the modern beekeeper’s mantra is: “the only good varroa mite is a dead varroa mite.” While I admit that I would rather see dead mites than dead bee colonies, I think this sentiment is overly simplistic and ignores one implicit, inescapable truth about beekeeping today: *the varroa mite is here, it is here to stay, and we will never get rid of it*. Even though they were introduced to North Carolina almost 20 years ago, I sometimes think that many beekeepers are trying to go back to the days where our colonies were mite-free. Well, stop trying.

Our only recourse now is to *minimize* the number of mites in our hives and to decrease the damage that they do to our bees. For years, applying a single chemical treatment to kill off all of the mites in a hive was standard practice, one that has several downsides. First, the repeated use of any single chemical pesticide increases the likelihood that the mites will develop a resistance to that chemical, making it ineffective. Indeed, this has been the case with several of the common acaracides that we use today. Second, the residues from many of these chemicals have negative effects on the bees, so their repeated or prolonged use can have negative consequences on the very ones we're trying to save. Thus the "good mite/dead mite" attitude reflects the idea that the goal of varroa management is to kill off every mite in a hive with a single application of a single product. Well, stop trying.

The long-term solution to varroa management is through Integrated Pest Management, or IPM. This approach to pest control is more of a philosophy than a protocol, where the explicit goal is to greatly reduce (but not necessarily eliminate) the use of synthetic pesticides. The idea is to simply *manage* a given pest (not eradicate it) by *integrating* numerous, alternative prevention and treatment regimes, thus making it much less likely that the pest will adapt to any one of the measures of control. I've heard beekeepers complain that they are hesitant to try IPM tactics because they're too difficult to implement. Well, start trying.

A recent study by Keith Delaplane and colleagues demonstrates that varroa IPM can work, but only if the goal is to *delay* treatment (as opposed to killing off every mite). They report the results of two massive experiments that lasted 68 and 87 weeks, respectively, each involving 40 colonies. In the first study, they tested the effects of location (isolated versus in an apiary), bottom boards (screened versus solid), and bee stock (hygienic versus non-hygienic). In the second study, they also tested these same factors but using an SMR stock rather than hygienic [on a side note, recent studies have shown that the SMR stock is really a varroa-specific hygienic stock, so the stocks in the two experiments were actually more similar than originally thought]. In both studies, the researchers periodically measured the number of mites in the colony, as well as several measures of colony productivity (e.g., adult population, brood area, and stored honey).

They found that the isolation of colonies did not have any significant effect on mite levels. However, they did detect numerical differences between colonies with solid and screened bottom boards, but these differences were often not statistically significant (in other words, the effect was not overwhelming). Similarly, the differences between hygienic and non-hygienic stock were often different, but again not always statistically significant. They also found that colonies headed by SMR queens tended to have lower amounts of brood, and in one of their two studies they detected a lower amount of stored honey and pollen in colonies with screened bottom boards compared to solid bottom boards. In the end, they found that by using SMR queens and screened bottom boards, the time until reaching the economic treatment threshold—the level of mite infestation at which a beekeeper should treat the hive with a pesticide—was prolonged by about 22% (72 weeks without the need for treatment compared to 59 weeks).

These results are encouraging, but not if your goal is to completely get rid of mites. But if your goal is to delay, and possibly prevent, the use of in-hive pesticides, then the IPM approach appears to be quite favorable. In the end, IPM will help make varroa management sustainable for the long term, something that we all should try.

Reference

Delaplane, K. S., J. A. Berry, J. A. Skinner, J. P. Parkman, and W. M. Hood. (2005). Integrated pest management against *Varroa destructor* reduces colony mite levels and delays treatment threshold. *Journal of Apicultural Research*, **44**: 157-162.

Review: Danka, R. G. (2005). Journal of Entomological Science **40**: 316-326.
Written: January 16, 2006
Posted: 02/06/05
Word count: 878

Question: Can you force honey bees to pollinate cotton?

Answer: Not really, but you can make them collect more pollen overall

Upland cotton (*Gossypium hirsutum* L.) is grown quite a bit in North Carolina, with about 750,000 acres harvested in 2004 (NASS, 2005). It has not traditionally been a very good honey plant, as growers have often sprayed insecticides in the past to control pests such as the boll weevil. Recently, boll weevil reduction programs—and the resultant decreased spraying rates—have enabled beekeepers to consider having their hives pollinate cotton, which is beneficial for both beekeeper and grower. For the beekeeper, cotton plants have extrafloral nectaries; that is, much of the nectar produced by the plant are outside of the flower and thus the bees can collect nectar at a remarkable rate. For the grower, it has been estimated that 20% of the pollination is performed by insects, 80% of which is done by honey bees (Morse and Calderone, 2000). The result can be a 3-30% increase in yield as a result of honey bee pollination.

The problem, however, is convincing honey bees to visit the cotton flowers. Because of the extrafloral nectaries, nectar foragers rarely enter the flowers and cross pollinate among them. Moreover, pollen foragers usually avoid cotton pollen in favor of other sources outside of the crop, since the nutritional value of cotton pollen is inferior to most other sources. Both beekeepers and researchers have known for a long time how to manipulate the pollen-foraging effort of colonies. To decrease pollen foraging, one can increase the amount of stored pollen in the hive by inserting a frame full of pollen. The result is that most pollen foragers will switch to some other task until most of the surplus is consumed by the nurse bees who then feed it to larvae. To increase pollen foraging, one can increase the amount of larvae in the by hive inserting a frame of hungry brood. The result is that unemployed pollen foragers will start brining in pollen to meet the new demand of the colony.

A recent research study by Bob Danka (USDA Baton Rouge) tested to see if one could increase pollen foraging on cotton. He placed 16 Russian and 16 Italian colonies, equal in size and strength, next to a field of upland cotton. He then manipulated the hives to stimulate or deter pollen foraging by swapping frames of brood and pollen among them, such that the high pollen-collection colonies received frames of larvae (from the low pollen-collection hives) and the low pollen-collection colonies received frames of pollen (from the high pollen-collection hives). He then measured pollen foraging by both performing entrance counts (i.e., counting the number of pollen versus non-pollen foragers returning to the hive entrance during a certain period of time) and by direction sampling (i.e., temporarily closing the hive entrance and collecting the foragers at the entrance with a sweep net). He then distinguished between cotton pollen (which is white and loosely packed) and other pollen sources. He performed these measures at 1, 6, and 11 days following the colony manipulations to alter the foraging stimulus.

He found that hive treatment had a significant effect on the percentage of pollen foragers, as expected. He also found that Italian colonies had a higher proportion of pollen collectors and a greater number of foragers overall than the Russian colonies, but this effect was only seen the day following the hive manipulation and disappeared at days 6 and 11. Unfortunately, he found that fewer than 2% of the foragers collected cotton pollen during the first 11 days of the study. Surprisingly, however, the colonies then began to forage for a greater amount of pollen (with one-quarter to one-third of all foragers returning with pollen) after the initial study had ended. Moreover, 80% of the pollen foragers collecting cotton pollen.

These results tell us several things. First, you can boost the pollen foraging of a colony by adding frames of larvae, but you can't force the bees to forage on a particular source of pollen if they don't prefer it in the first place. Second, pollen foraging between Italian and Russian stocks don't seem to be very great and dissipate quickly. And finally, foraging conditions can change quite dramatically, resulting in bees switching the plants that they get pollen from. In the current study, it is most likely that the alternative pollen sources dried up, forcing the bees to "settle" for the lower-quality cotton pollen. These findings suggest that beekeepers may take advantage of cotton as long as they understand the greater picture of where their hives are located. It also remind us that beekeeping is a means of helping the bees do what comes naturally rather than being able to make them do something they'd prefer not to.

Reference

Danka, R. G. (2005). High levels of cotton pollen collection observed for honey bees (Hymenoptera : Apidae) in south-central Louisiana. *Journal of Entomological Science* **40**: 316-326.

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Morse, R. A. and N. W. Calderone. (2000). The value of honey bees as pollinators of U.S. crops in 2000. *Bee Culture* **128**: 1-15.

Review: Simon et al. (2005). *Apidologie*, **36**: 413-419
Written: 12/28/05
Posted: January 2, 2006
Word count: 647

***Q**uestion*: Do pseudo-queens smell like real queens?

***A**nswer*: Not all of them, but yes

We've all done it; accidentally mashed a queen between two frames, mistakenly shook her into a swarm box, or purposefully got rid of an old queen and then forgot to introduce her replacement. And once you realize it, you return to the hive only to find a dreaded "laying worker" colony.

Because queen pheromone inhibits workers from developing their ovaries, taking the queen away for a week or two causes them to forget their humble place in society. Given enough time, workers within the colony will start laying hundreds of eggs, all of which are destined to become drones (because workers don't mate and therefore cannot fertilize their eggs). Once you start to see multiple eggs in the cells, the colony's done for, as requeening a laying-worker colony is tricky at best and impossible at worst.

It's a common misconception that there is only *one* worker that becomes a laying worker within a colony. While only a minority of workers will ever become "pseudo-queens", there are many of them in the colony competing with each other to lay eggs. This brings up some interesting questions. For example, do all workers have an equal chance at becoming a pseudo-queen? And while they will never become "real" queens, how similar do they become? Specifically, do they produce queen pheromone? If so, does the level of queen pheromone have any bearing on how many eggs a pseudo-queen lays?

These questions were addressed by a German and South African research team led by Ute Simon. They took the queen away from a single colony of *Apis mellifera capensis*, the "Cape bee" in South Africa that is well known for its propensity for queenless workers to become laying workers. They sampled nurse bees from this colony right after dequeening, and then they sampled laying workers and worker-laid eggs after a couple of weeks. They used genetic analyses to determine each worker or egg's subfamily (that is, their paternal lineage) to determine if there were any differences in the likelihood that certain subfamilies would become laying workers. The genetic analyses also enabled them to determine which subfamilies were more successful at laying eggs. Finally, they performed chemical analyses on the laying workers to determine how much queen pheromone they produced, and correlated it with how well their ovaries were developed.

The researchers found, as had been known before, that not all workers developed into pseudo-queens. However, they did find that workers from only 18 of the 30 subfamilies within the colony laid eggs, and that three of those subfamilies accounted for the majority of eggs. Thus it appears that not all workers have the same likelihood of becoming a laying worker.

Their chemical analyses showed a strong correlation between ovary development and queen pheromone, such that workers with well-developed ovaries tended to have significantly higher levels of 9-ODA (the main component of queen pheromone). In fact, the level of queen pheromone seemed to be highly associated with egg-laying success, since workers that had developed ovaries but did not lay eggs had significantly less 9-ODA that workers that had developed ovaries but did lay eggs.

While there is a lot of variation among workers in their ovary development, queen-pheromone production, and egg-laying success, it seems that pseudo-queens have very similar egg-laying "machinery" as do real queens. Moreover, whether or not they develop into a laying worker depends in large part on their genetic heritage. Now if we can just figure out how to convince them from not laying eggs in the first place…

Reference

Simon, U. E., R. F. A. Moritz, and R. M. Crewe. (2005). Reproductive dominance among honeybee workers in experimental groups of *Apis mellifera capensis. Apidologie*, **36**: 413-419

Review: Evans and Pettis. (2005). *Evolution*, **59**: 2270-2274.
Written: 12/05/05
Posted: December 5, 2005
Word count: 743

Q*uestion*: Why aren't all colonies immune to AFB?

A*nswer*: Because the genetics of resistance is complicated, and costly.

I have often heard the following logic from beekeepers with regards to disease: let your colonies get sick (with tracheal mites, varroa, chalkbrood, or whatever), don't use any chemical controls to minimize or reduce infection, and let the weak ones die off. Then, the survivors will have superior genetics and be resistant to the disease after only a couple of generations. If every beekeeper engaged in this practice, a proponent would argue, we wouldn't have many of the problems that we currently face; the reason we have problems with disease is because we medicate rather than let nature take its own course.

The above argument is logically sound, but I believe that it may be too simplistic to fully capture the way in which selection is implemented. Moreover, it ignores the complex relationship between a disease and resistance in its host. Take American foulbrood (AFB), for example. This noxious brood disease is caused by the spore-forming bacteria *Paenibacillus larvae larvae*. Colonies that acquire AFB exhibit tell-tale symptoms, such as partially uncapped brood cells, discolored brown larvae, a highly distasteful odor like rotting gym socks (hence the name), and hardened black scales laying on the bottom of brood cells. It is exceedingly difficult to eradicate AFB from a colony or even from contaminated hive equipment after infection, and our only measure of control is to administer oxy-tetracycline (Terramycin)—which only prevents further spread rather than kills the bacteria—or to scorch or destroy the entire hive (of course, here in NC, we are fortunate that the NCDA has a fumigation chamber that can decontaminate AFB-infected equipment).

Colonies can combat AFB infections themselves in two ways. First, they can exhibit hygienic behavior, where the workers uncap and then remove the infected brood from the brood nest, hence minimizing the spread of the AFB spores. Second, larvae themselves rely on their own immunity against pathogens, where they can combat microbial invaders by any number of physiological mechanisms. The genetics behind these traits are not tremendously complex, but they are not as simple as one might think. Nonetheless, if AFB-susceptible colonies are constantly dying off from the disease, why aren't all honey bees resistant to it?

Evidence for one possible explanation was recently provided by two of our top USDA honey bee researchers, Jay Evans and Jeff Pettis, both at the USDA Beltsville lab. They demonstrated that having an increased immunity to bacterial pathogens, like AFB, may be costly; that is, in order for larvae to have an increased physiological defense, the overall productivity of the colony may suffer. Thus there may be a trade-off between AFB resistance and colony productivity, which keeps those "susceptible genes" from being selected out of existence.

The researchers applied AFB spores to the brood nests of 16 colonies by spraying sugar syrup laden with ground-up scales. They inspected the colonies monthly to measure the level of AFB in each, as well as its productivity (as measured by the area of brood in each colony). They also removed 16 healthy larvae from each colony (256 total) and inoculated them directly by feeding them oral doses of AFB spores. After 24 hours in an incubator, they measured the expression levels of two antimicrobial genes, which enabled them to quantify the degree to which these genes were "turned on" following infection. One of these genes, abaecin, was significantly correlated with colony disease level, such that the *higher* the level of expression the *lower* the level of disease. More interestingly, they also found that the level of abaecin was negatively correlated with colony productivity, so that the *lower* the level of expression the *higher* the level of productivity. Thus it appears that having a high immunity to invading bacteria is good to stave off AFB infection, but it is at the cost of having a more productive colony.

These findings provide us with some very fascinating insights into the tit-for-tat struggle between pathogen and host in general, and with AFB and honey bees in particular. It also helps us better understand why simply letting our weak colonies die off doesn't necessarily leave us with the best colonies possible.

Reference

Evans, J. D. and J. S. Pettis. (2005). Colony-level impacts of immune responsiveness in honey bees, *Apis mellifera*. *Evolution*, **59**: 2270-2274.

Review: Janson et al. (2005). *Animal Behavior*, **70**: 349-358.
Written: October 26, 2005
Posted: 11/07/05
Word count: 661

***Q**uestion*: How do swarms find their way?
Answer: By following the "streaker" scouts.

Ever notice that there aren't as many reports of "streakers" as there used to be? You know, those attention-craving idiots who would disrobe and run naked through public areas with reckless abandon hoping to make the 6 o'clock news. While extremely popular in the 60's and 70's, this practice (thankfully) really isn't as popular as it was in its heyday.

This behavior of streaking, however, is practiced by honey bees every spring when they swarm. Not by flying naked in the hopes of getting some media coverage, but rather by using themselves as guides to steer swarms in flight. This was hypothesized some years ago by the famous bee scientist Martin Lindauer. He found it amazing that swarms could find their new nest site even though the majority of the swarm had never visited there, and he speculated that they did so by following the few scout bees who previously had learned the nest's location. He surmised that even though scout bees comprise less than 5% of the swarm's population, the other bees within the swarm follow them as they fly faster through the mass of bees towards their new home. While this "streaking" is generally believed by most honey bee scientists, there really never has been documented proof of this phenomenon.

A new study by Janson and colleagues suggests that these streaking scouts are indeed the way that a swarm finds its way. They utilized a very different approach to support this hypothesis, one that many beekeepers may not be familiar with. They constructed a mathematical model where they defined many different parameters about the behavior of scout bees and their swarming compatriots. These factors included things like swarm cohesion, alignment, flight velocity, and the degree that bees would avoid other bees. They then plugged these equations into a computer and simulated thousands of "flights" by hypothetical swarms to see how the collective whole behaved as they tweaked the values of the various parameters. This approach, therefore, allows the researchers to test the fundamental principles of the guidance of swarms and a replicate it many times under the same theoretical conditions, which allows us to elucidate the major components of the underlying system.

The simulation tested many different aspects of swarms and found the following relationships:

Swarms do not find the nest site if the scouts are removed (not surprising since the equations were based on this principle, but demonstrates that swarms can't locate the nest site without them).

The velocity of the swarm increases with increasing velocity of the scouts, but the relative increase in velocity of the swarm is much slower. This shows the disadvantage of scouts flying *too* fast, since the precision of the guidance decreases (that is, the rest of the swarm has difficulty following them).
There is a significant decrease in the accuracy of finding the new site when the number of scouts increases.
This process is relatively robust against changes in swarm size, so that this mechanism can work in large or small swarms alike.
The scouts can even lead the swarm around (or over) obstacles.

These findings support Lindauer's hunch that bees streaking thought he middle of the swarm are not only the ones that have been to the new nest site, but that they also guide the flying mass to their new home. This also demonstrates the utility of mathematics in understanding the complexity of nature and of our beloved honey bees. Now if we can just figure out how to keep bees from swarming in the first place… (as long as it doesn't require that they strip down to their skivvies!)

Reference

Janson, S., M. Middendorf, and M. Beekman. (2005). Honeybee swarms: how do scouts guide a swarm of uninformed bees? *Animal Behavior*, **70**: 349-358.

Review: Harano et al. (2005). *Naturwissenschaften*, **92**: 310-313.
Written: September 19, 2005
Posted: 09/29/05
Word count: 673

***Q**uestion*: What changes in a queen's brain after she mates?

***A**nswer*: The levels of certain hormones important in ovary development

The importance of a well-mated queen to a honey bee colony cannot be understated. A high mating number has obvious implications on the amount of sperm a queen stores in her spermatheca; the more matings, the more sperm she stores, the longer she can live and lay fertilized eggs. Other research suggests that by mating with numerous drones (upward of 20 or more), queens can produce colonies that are less susceptible to numerous diseases. A queen's pheromone profile also changes dramatically after mating, which means that a poorly mated queen is not treated properly by the workers. Thus having a healthy, productive queen requires that she be well inseminated.

Queens mate very early in their lifetimes, when they are about a week old, by briefly exiting the colony in the late afternoons and flying to drone congregation areas (aggregations of honey bee males) to mate with up to 15 drones in rapid succession. While males die immediately after copulation, a queen returns to her natal nest, often with the last males' reproductive organs still lodged in her sting chamber (the so-called 'mating sign') and with her abdomen significantly distended with 10-15 ml of semen. The majority of this semen is excreted within 24 hours, while a proportion of each male's sperm is stored in her spermatheca (the sperm storage organ). Queens can take anywhere from one to three mating flights on subsequent days, after which they begin to oviposit and never mate again during their 1-3 year life span.

Despite the importance of adequate queen mating, the physiological underpinnings of the process are not well understood. When queens emerge as adults, the development of their ovarioles (the hundreds of egg "factories" within their ovaries) is arrested until they are mated, shortly after which egg production begins. Previous researchers compared the brains of multiple groups of virgin and mated queens, and they found that certain regions decreased in volume by 25-50% upon mating. So what's going on in the brains of queens during mating?

A Japanese research team, led by Ken-ichi Harano, recently investigated the chemi (e) 0.2.2 (e) 0(he) 0nd thangeh(m) 0.2 hen quehe br variety of physiological roles in many, if not most, animals. For example, dopamine is responsible for many drug addictions in humans. More pertinently, however, is that it has been linked to ovary development in honey bees.

The researchers raised queens using standard practices, placing ripe queen cells into individual mating nucleus colonies. Half of the hives were fitted with queen excluder on the entrances so that the queens could not fly and mate, while the other have were left open for the queens to mate normally. They then sampled six unmated queens after six days, 12 unmated queens after 12 days, and a final 12 mated queens after 12 days. They then individually dissected out their brains and measured the levels of both dopamine and NADA (one of the products produced when dopamine is broken down chemically). They found that 6- and 12-day-old virgins both had significantly more dopamine and NADA than the mated laying queens.

These findings are a bit puzzling, as the authors discuss. Since dopamine increases ovary development, one might predict that laying queens have higher levels of the neuromodulator, not lower levels. It is possible, however, that dopamine is affecting queens in different ways, such as increasing a virgin queen's ability to locate and kill her sister rivals during competitive duels to reclaim the nest. Nevertheless, the findings are quite interesting and significant, and more studies will be needed to determine the physiological changes in queens following mating.

Reference

Harano, K., K. Sasaki, and T. Nagao. (2005) Depression of brain dopamine and its metabolite after mating in European honeybee (*Apis mellifera*) queens. *Naturwissenschaften*, **92**: 310-313.

Review: Danka & Villa. (2005). *Apidologie*, **36**: 331-333.
Written: August 11, 2005
Posted: 09/07/05
Word count: 635

***Q**uestion*: Does it pay for bees to groom themselves?

***A**nswer*: Yes, by reducing the number of tracheal mites.

Believe it or not, honey bees are, for the most part, neat freaks. You might not have guessed this, however, after a brief inspection of a typical hive. There is sticky propolis gluing the frames together, burr comb lining the inner hive walls, and brood nest debris littering the bottom board. Nevertheless, bees are adamant about keeping their home relatively clean. This can be evidenced by placing some old, moldy frame into a strong hive and watching the bees clean it up over night. Jerry Seinfeld, eat your heart out.

One cleaning behavior that most beekeepers have heard of is "hygienic behavior", where hive bees uncap the brood cells of dead or diseased individuals and remove them from the nest. Many strains of bees have been selected to be highly hygienic, since it has been repeatedly documented that this behavior can dramatically reduce the levels of certain brood diseases, such as American foulbrood, chalkbrood, and even varroa mites. Research into hygienic behavior has even revealed the genetic basis of such nest cleaning, which appears to be controlled by a few (2-7) genes (thus making it relatively easy to select for).

Another cleaning behavior is "allogrooming", where one bee solicits another to clean her. This is done by the recipient performing a trembling-like dance, stopping and opening her wings, and have another bee lick and groom the surface of her thorax. This can be particularly helpful to clean those areas that a bee cannot reach herself, and is the principle means by which the native host to varroa mites, *Apis cerana*, controls the prevalence of that particular pest.

Yet another important cleaning behavior was tested by Bob Danka and Jose Da Villa at the USDA lab in Baton Rouge. Known as "autogrooming", this self-explanatory behavior is where a bee cleans herself by rubbing the surface of her body with her hairy legs. It has been shown previously that there is a link between the level of autogrooming within a colony and the level of tracheal mite infestation, where increased grooming lowers the incidence and prevalence of the endoparasite. Danka and Villa wished to determine the effect of autogrooming on the incidence of mites in individual bees.

The researchers set up an observation hive with a colony known to have a tracheal mite infestation. When they observed a bee grooming herself, they quickly opened the hive, captured her, and anesthetized her with carbon dioxide. At the same time, they also sampled another nestmate in the same vicinity that was not engaged in autogrooming behavior to serve as a control. They tested 50 such pairs of bees, and inspected each for the number of tracheal mites crawling on the surface of her thorax.

They found more mites on grooming than on non-grooming bees. In fact, 72% of the bees performing autogrooming had tracheal mites compared to only 18% of the bees that were not autogrooming. They also observed that when bees were grooming only one side of their body, it was usually that side on which they found any tracheal mites.

Thus the apparent response of tracheal mite infestation is to groom oneself, which confirms the link between autogrooming and lower mite infestations. This also makes it another good behavior for selection programs, which has been done with great success in the past. Promoting self-cleanliness is helpful since tracheal mites can be an insidious parasite since they cannot be readily seen and account for significant winter losses.

Reference

Danka, R. G. and J. D. Villa. (2005). An association in honey bees between autogrooming and the presence of migrating tracheal mites. *Apidologie*, **36**: 331-333.

Review: Schneider et al. (2004). *Insectes Sociaux*, **51**: 359–364
Written: June 26, 2005
Posted: July 25, 2005
Word count: 746
Question: How has the Africanized honey bee been so ecologically dominant?
Answer: By several means, such as invasions from parasitic swarms.

"How often do you get stung?" is the most frequently asked question of beekeepers when they are first revealed as such. Most of us have the social graces to keep ourselves from groaning, then we simply bob our heads and reply "Sometimes" or some equivalent generic answer in the hopes of not requiring a more lengthy, involved response. [One of my favorite corollaries of this annoying question is: "How often do you get bit?!" Of course, because bees sting rather than bite, I take great pride in asserting "Never!" just to see the surprised look on their face]. The second most frequently asked question of beekeepers is: "Do you have those killer bees?" While most of us have canned replies for this question as well, the subject should be of much greater concern to most beekeepers since there is a very real possibility that they will someday inhabit most of the southern third of the country (including North Carolina).

The Africanized honey bee (AHB) gained notoriety in the 1970's, along with its very unfortunate 'killer bee' moniker, largely because of their increased defensiveness. Brought to Brazil in order to breed a locally adapted tropical bee, the AHB has become one of the most spectacular examples of a biological invasion in the Americas. They officially entered the U.S. boarder in 1990 and have since populated most of Texas, the desert southwest, and the lower half of California. Rather than interbreed with the resident European honey bee (EHB) population, which scientists first thought would mute their unfavorable characteristics, the AHB has successfully supplanted the more docile EHB colonies and has remained a genetically and behaviorally isolated strain. The means by which they have been able to maintain their genetic purity has been a curious puzzle for honey bee biologists, who wish to determine how they have remained so ecologically dominant over the EHB in an effort to better control them.

One means by which the AHB may supplant the EHB is through colony parasitism. Previous reports have shown that small AHB swarms, no bigger than the size of a softball, can cluster near the entrance of a colony. Over a few days, the workers in the swarm can overcome the defenses of the hive and usurp the resident queen, leaving the colony wide open for the AHB queen in the swarm to take over. Such a coup d'etat can change an EHB colony into an AHB colony literally overnight.

A recent study was published by UNC-Charlotte Professor Stanley Schneider and his collaborators in Arizona at the USDA Carl Hayden Honey Bee Research Facility that addresses this issue. They placed many five-frame nucleus hives in their bee yard, all headed by EHB cordovan queens, and they tracked the progress of these hives over the course of two years. They performed weekly or bi-weekly inspections of each colony and rated its strength (according to the amount of brood and number of adult bees) and queen status (thriving, weak, queenless, or superseded). They witnessed dozens of invading parasitic AHB swarms and the resultant usurpation of the EHB queen.

They found an average take-over rate of 21% over the course of the study, much higher than previously thought. Moreover, there was a seasonal effect of this process, such that most swarms were seen during the months of October, November, and December. There was also a highly significant effect of EHB colony status on the likelihood of being parasitized. Thriving colonies had only a 1.6% chance of being usurped each month, but weak and queenless colonies had a 2.2% and 12.8% chance of usurpation, respectively. These results suggest that the parasitic AHB swarms are somehow able to locate colonies with weakened defenses and take them over at a surprisingly high rate.

Knowing how this usurpation process works may enable beekeepers to take certain measures to minimize how often their colonies can be taken over by Africanized bees. It is for this reason, and many others like it, that make beekeepers the first line of defense against the AHB.

Reference

Schneider, S. S.,T. Deeby, D. C. Gilley, and G. DeGrandi-Hoffman. (2004). Seasonal nest usurpation of European colonies by African swarms in Arizona, USA. *Insectes Sociaux*, **51**: 359–364.

Review: Riley et al. (2005). *Nature*, **435**: 205-207
Written: June 20, 2005
Posted: 07/04/05
Word count: 753

Question: Does the ‘waggle dance’ really convey distance and direction information?

Answer: Yes, as determined by following foragers with harmonic radar.

The foraging area of a honey bee colony can be huge. Bees can fly up to eight miles, round trip, from their hive to collect nectar and pollen. This means that a single colony’s foraging area can cover a four-mile radius around the hive, or a staggering 1.4 *billion* square feet (4 mi x 5280 ft/mi = 21,120 ft; from geometry, the area of a circle is pr^2, which gives us 3.1416 x 21120^2 = 1,401,324,503 ft^2). Despite this enormous amount of real estate to cover, bees can still discover a modest patch of flowers and recruit other bees to it, even if the recruits have never been there before. This is a remarkable task, given that a 5 ft x 5 ft flower bed is 0.0000018% of the area within the total foraging area (25 ft^2 ÷ 1,401,324,503 ft^2 = 1.78x10^{-8}).

Let’s put that into perspective, using the tried-and-true “needle in a haystack” analogy. A 5’ x 5’ x 5’ haystack is 125 cubic feet in volume. The volume of a 1” long, 1/16” diameter needle is 0.00000178 cubic feet (1/32” radius = 0.0026 ft; 1” height = 0.0833 ft; volume of a cylinder = hpr^2 = 0.0833 x 3.1416 x 0.0026^2), making the volume of the needle 0.0000014% of the total volume of the haystack (0.00000178 ft^3 ÷ 125 ft^3 = 1.42 x10^{-8}). Thus it is safe to say that a naïve bee finding a food source in its hive’s foraging area is as difficult as finding a needle in a haystack; the chances of finding either, at random, is about 3 out of 200 million.

If bees were to gather food at random, they would likely starve; flowers are patchily distributed (i.e., they are clumped in space) and ephemeral (i.e., they often don’t provide food for very long). Thus honey bees, like most social insects, actively recruit nestmates to newly located food sources to take advantage of them while they still have the opportunity. Rather than laying scent trails or physically leading them to the resource, honey bees use the famous “dance language” where they convey both the distance and direction of the food source to novice recruit bees using specialized body movements. The dance language phenomenon has not been without controversy, however, and some scientists believe that floral odors are the main cues that guide recruits to food sources. The current conventional wisdom is that recruits use the information in the dance language to go to the general vicinity of the food, then home in to the flowers using visual and olfactory cues once they get there.

A recent study was published in the top-tier scientific journal *Nature* that tested this prevailing notion using a simple yet high-tech approach. The English and German research team, lead by J. R. Riley at Rothamstead Research Station, placed small transponders on individual honey bee foragers and recorded their flight paths using harmonic radar. The transponders are not unlike those used in airplanes (albeit much, much smaller), and they work by reflecting the radar signal at twice the transmitted frequency so that the bee can be distinguished from other objects by the radar echo. The researchers followed foragers that returned to an observation hive from an experimental dish of *unscented* food and recorded novice recruit bees that followed their dance. As these recruits exited the hive, they were captured and fashioned with transponders before being released. A total of 18 bees were tracked in this manner, and virtually all of them flew due east about 200 meters where the food source was located. Only two actually found the dish, however, since the syrup was unscented. Indeed, the flight paths for most of the recruits headed straight towards the general vicinity of the dish but then took on a local search pattern after they got there. This is exactly what the modern dance language hypothesis would predict.

Whether it be during a nectar flow or a nectar dearth, it should be comforting to know that our little bees are able to take full advantage of scarce blooms, rather than aimlessly searching for a needle in a haystack.

Reference

J. R. Riley, Greggers, U., Smith, A. D., Reynolds, D. R. and Menzel, R. (2005). The flight paths of honeybees recruited by the waggle dance. *Nature*, **435**: 205-207.

Review: Cully and Seeley (2005). *Insectes Sociaux*, **51**: 317-324.

Written: 06/05/05

Posted: June 5, 2005

Word count: 920

Question: How do swarms shield themselves from rain?

Answer: By creating a protective curtain of bees.

Ever wonder why swarms cluster on tree branches, sometimes for days, before they move to a new nest site? While beneficial for any beekeeper who wishes to hive up some free bees, wouldn't it make a whole lot more sense for them to go directly to their new home from their old one? It is likely that there are several benefits of forming these temporary swarm clusters (technically known as 'bivouacs'). First, if the queen gets lost, or for some reason she doesn't exit the hive during the swarm, the bees can return to the original nest. If a queenless swarm sets up shop in a new hive, their chances of survival are, needless to say, pretty dire. Second, it enables the newly separated group to form a collective decision about where to go. They accomplish this by the scout bees literally debating, using the dance language, among various possible nesting cavities and forming a consensus about which one is best. Doing so within the natal nest would undoubtedly cause much confusion over which workers are dancing to recruit to food sources and which workers are dancing to recruit to the new nest site.

One problem that arises from bivouacking is that the swarms can be exposed to the elements, sometimes for several days and nights, while they are forming their decision about where to go. While swarms will not depart their natal hive during unfavorable weather, the abiotic conditions can change quickly over the course of a few hours, and almost certainly over the course of a few days. Thus swarms must adjust to changing weather conditions, particularly cold temperatures and rain. How they go about protecting themselves from the elements was the basis of a recent study by Siobhan Cully and Tom Seeley at Cornell University.

The two researchers simulated 10 separate swarms by shaking approximately 7,500 bees into a shipping package, suspending the queen in a Benton mailing cage within the cluster. They provided the bees with 1:1 sugar syrup to fill their honey stomachs with nectar (as would a natural swarm before departing). They then established each swarm after a day or two by shaking the packaged bees onto one of three mounting structures. Five swarms were mounted on a wooden cross with a vertical board in the middle, which causes the swarm to be one bee deep (creating a swarm that is two dimensional rather than three dimensional). This set-up enabled the researchers to videotape the bees in the swarm as they experimentally changed the abiotic conditions. Two other swarms were established on a tree branch or a window sill to study the age demographics within the cluster (since these bees were marked on their thoraxes with paint according to their age), and another three swarms were mounted on wooden dowels to study the effects of rain on the swarm. In all cases, the queens remained within their cages to prevent the swarms from departing.

The swarms that were mounted on the wood crosses were recorded before, during, and after an application of water mist that was applied to the surface of the cluster with a spray bottle. For each time period, the video recording was analyzed for the behaviors of a sample of bees within the swarm, measuring their orientation with respect to vertical, whether or not they would tuck their head beneath an adjacent worker, the spread of their wings, and the average distance between bees. The application of water had an immediate and significant effect on each of these measures; the recorded bees became more oriented vertically, tucked their heads beneath the worker above them on the cluster, spread their wings, and clustered more tightly. Thus under rainy conditions, the bees form a distinctive curtain on the surface of the swarm, which remarkably resembles a tiled roof with each bee serving as one shingle.

The bees that tended to comprise the exterior curtain were older than average. Thus the younger bees tended to remain within the safer center of the cluster along with the queen. Since the younger workers have a longer expected lifespan, this tendency makes adaptive sense so that the bees can maximize their contribution to the new colony and increase the likelihood that they will survive.

Finally, Cully and Seeley purposefully applied significant amounts of water to each swarm on the dowels. They chose randomly one side of the cluster and sprayed water on it so that they formed an exterior curtain (while the other side did not). They then separately dribbled 5000 mg of water to each side of the cluster and measured the amount that was successfully repelled. They found that the sides of the swarms that had formed the tiled curtain were significantly more effective at shedding the simulated rain compared those sides that had not formed a curtain. These findings are quite interesting, since it demonstrates that bees on the exterior a swarm cluster create a protective curtain of bees so that the bees within the cluster are less exposed to the elements. This adaptation enables the bivouacked swarm to fulfill its purpose (i.e., locate a new nest site) while minimizing the effects of inclement weather.

Reference

Cully, S. M. and T. D. Seeley. (2005). Self-assemblage formation in a social insect: the protective curtain of a honey bee swarm. *Insectes Sociaux*, **51**: 317-324.

Review: Tautz et al. (2004). *PLoS Biology*, **7**: 915-923.
Written: 03/18/05
Posted: April 4, 2005
Word count: 770
Question: What determines a honey bee forager's "odometer"?
Answer: The terrain, and not the distance

Did you know that an estimated one-third of all the used cars for sale have rolled-back odometers? That's pretty disturbing, given the importance of the total distance traveled by a car on its sticker price. This practice, of course, is illegal, but it does demonstrate that one should never assume that odometers are inflexible.

Honey bees also have "odometers", albeit not the kind that keeps numbers and synchronously rolls over every mile. They use it to determine how far away a particular food source is from the colony. Indeed, this information is vital for them to recruit other bees to the food source using the famous dance language. The straight-run portion of the figure-eight 'waggle dance' communicates both distance and direction to a food source to a recruit bee that has never been to that food source before. The direction information is contained in the angle with respect to vertical, which is translated into the angle with respect to the sun. The directional information is contained in the duration of the waggle run, which is the straight-run section of the figure eight when the forager rapidly shakes her abdomen back and forth. This information relies almost entirely on the forager's odometer in order for her to communicate accurate information

There are two ways that a forager can "calibrate" her odometer. One way is that she measures distance by how much energy she exerts while flying to and from the food source. While such a measure can vary depending on wind speed and direction, this 'energy hypothesis' for a bee's odometer is relatively constant because a bee's energy expenditure during flight is relatively fixed. An alternative means of calibration is by a bee measuring how much the image of the landscape changes over time as seen through her large compound eyes. This 'optic flow hypothesis' is supported by some previous experiments that tested bees in a flight tunnel with varying patterns on its walls. Nonetheless, it is still unclear how robust a honey bee's odometer is during forager recruitment.

A group of researchers in Germany, with lead author Jürgen Tautz, performed a series of field experiments to distinguish between the energy hypothesis and the optic flow hypothesis. They trained foragers to two linear series of food sources, both running 580 meters away from the hive. The path of the first set of food sources was entirely over land, while the path of the other set of food sources was initially over land, then over a stretch of water (on a nearby lake), then finally over land again (on an island in the lake). They trained approximately 20 foragers to a food dish nearby the hive, and then moved the dish at regular intervals down each path. For the path over the water, they placed the food dish on a boat at different distances over the water so that both series were continuous. At each distance, they recorded the waggle-run portion of the foragers' recruitment dances to determine the precise distance information conveyed therein.

They found a significant linear correlation between distance of the food source to the duration of the waggle run, which was true for both the route over land and the route over water. This confirms that the foragers are using their odometer to recruit other bees to feeding stations. However, when they divided the water path into three sections—first over land, then over water, then over land again—they found differences in the slopes of the correlation. While over land, the changes in the dance duration per unit distance was quite high, but while over water, the changes in the odometer were significantly lower. Because the landscape is much less varied over water compared to over land, this finding clearly supports the optic flow hypothesis.

These findings suggest that a bee's perception to distance flown is not absolute but rather dependent on the landscape in which it is flying. Much like the direction information contained in the waggle dance is relative (to the sun) and not fixed (to the magnetic compass), the distance information is also relative (to the landscape) and not fixed (to the measured distance). Thus a bee's sense of navigation is quite different from ours. There is no evidence, however, that their odometers can be rolled back.

Reference

Tautz J., S. Zhang, J. Spaethe, A. Brockmann, A. Si, and M. Srinivasan. (2004). Honeybee odometry: performance in varying natural terrain. *PLoS Biology*, **7**: 915-923.

Review: Crewe et al. (2004). *Chemoecology*, **14**: 77–79
Written: 02/26/05
Posted: March 11, 2005
Word count: 685

Question: How do researchers analyze honey bee pheromones?
Answer: With some new technologies, quickly and more easily.

Most of us know that honey bees communicate primarily by smell rather than sight. This is logical, since much of a bee's life is spent inside a dark hive. Most of the chemical signals that bees use to communicate are called pheromones, and they usually have very specific intents. For example, the "alarm" pheromone, composed primarily of the chemical isopentyl acetate, signals workers to become more defensive, making them more likely to sting (which is why if you smell banana bread while you're working a hive, you best give the bees a few bellow-fulls of smoke!).

The most important pheromone within a colony is a blend of chemicals produced by the queen, specifically by a queen's mandibular glands located in her head. There are numerous functions to this pheromone, including attracting drones during her mating flight, to orienting workers during a swarm, to inhibiting the construction of queen cells. Queen mandibular pheromone (or QMP) was one of the very first insect pheromones ever to be identified, and the extent of our knowledge about this communication signal has provided extremely valuable insights into honey bee biology.

The way QMP was first identified was through some classical chemical procedures. You take a queen and extract all of the chemicals from her body. You then test the reactions of other bees to the extract to see if they behave normally. You then make various fractions of the extract by dissolving the chemicals in different solvents, and similarly test the reactions of the bees. You then keep making fractions of the fractions until you are left with only a small subset of chemicals that you started with. There are then machines that can identify the actual chemicals that are in these various fractions, called gas chromatograph and mass spectrometers (GC-MS for short). Clearly, identifying QMP was not a simple task.

There are some downsides to identifying pheromones in this way. First, you kill the queen. Second, the amount of pheromone can be small, so it is difficult to get accurate measures. Third, it takes the bee out of context, so the amount of pheromone that is given off may be different from the amount of pheromone that is actually in the gland that produces it.

Some new technologies have been introduced that have helped pheromone researchers. The first is the SPME, standing for Solid Phase Micro-Extraction. These are little plastic fibers coated with a special substance that absorbs chemicals from the air. Researchers can place these SPME fibers on or next to a bee to sample the chemicals that it produces and then run these in a GC-MS. The benefit is that destructive sampling is not necessary, and can even be done in a natural colony context.

An even newer technology was recently described by a research team headed by Robin Crewe from South Africa. The technique used silicone rubber tubing to capture chemicals from the environment, much like the SPME fibers. The chemicals are then washed from the surface of the tubing and analyzed just like traditional fractions. Thus this technique has the advantage of the SPME technology but is much cheaper. Crewe et al. provide data of this new technique on QMP. They were able to replicate almost exactly the same chemical profile of QMP using silicone tubing as other methods.

This new technology may help researchers identify additional pheromones in honey bees. There are many glands that have been identified in bees, but they are either too small or too diffuse to be able to determine their chemical nature or purpose using traditional means. Making pheromone research cheaper and easier will provide even further insights into honey bee biology, and may even introduce additional chemical products to market that have practical applications.

Reference(s)
Crewe, R. M., R F.A. Moritz, and H. M. G. Lattorff. (2004). Trapping pheromonal components with silicone rubber tubes: fatty acid secretions in honeybees (*Apis mellifera*). *Chemoecology*, **14**: 77–79

Review: Phiancharoen et al. (2004). *Apidologie*, 35: 503–511
Written: 01/22/05
Posted: February 12, 2005
Word count: 698
Question: What happens when you cross different honey bee species?
Answer: No offspring, but differentially surviving sperm.

It has been a central question among biologists of what constitutes a 'species'. The simplicity of the question belies the complexity of the issue. One cannot easily define species by their form, since we all know that different individuals of the same species can look very different from one another. Similarly, individuals from completely different species can look a lot alike (recall that example of the Monarch butterfly and its mimic, the Viceroy?). It is generally accepted by biologists that the definition of a species is "a group of individuals that can mate and produce viable offspring"; that is, they can interbreed successfully. This latter distinction is important, because it draws a bright line within those murky hybrid boundaries that often overlap between species and complicate the issue.
The honey bees that we're used to are all of one species, *Apis mellifera*, a species name that is the Latin translation for "honey bearer". The different types of bees that we manage—such as Italians or Carniolans—are all *sub*-species, or races, and there are over two dozen documented types. There are, however, at least eight other species of honey bee in the world. And, as our definition of species dictates, they cannot interbreed successfully. This does not mean, however, that they cannot be inseminated experimentally, which is what an international research team has recently performed.
Mananya Phiancharoen and his colleagues instrumentally inseminated over 60 *Apis mellifera* queens with sperm from four species: *Apis mellifera*, *Apis dorsata* (the Giant honey bee, typically found in India and southern Asia), *Apis cerana* (the Eastern honey bee, a wide-spread sister species to our Western honey bee), and *Apis florea* (the Little honey bee, primarily found in southeast Asia). They inseminated each queen with approximately 8 million sperm. However, because drones of the different species can produce very different numbers of sperm, they inseminated each queen with either 1 *A. mellifera* drone, 5 *A. dorsata* drones, 8 *A. cerana* drones, or 20 *A. florea* drones. After the inseminations, they sampled the queens to determine how many sperm reached their spermathecae (their sperm storage organs), as well as how many of the sperm were still alive after 3 days and 4 weeks by measuring their motility. They also measured the viability of each queen's brood after they started to lay eggs.
The researchers found that all of the inseminated queens, irrespective of the sperm type, contained some sperm in their spermathecae. In fact, queens inseminated with *A. cerana* sperm had even more sperm in their spermathecae than queens inseminated with A. mellifera drones. They also found that the motility of the *A. mellifera* and *A. cerana* sperm was around 98% after three days, but that the motility of *A. florea* and *A. dorsata* sperm were 83% and 61%, respectively. After four weeks, these percentages were roughly the same for *A. mellifera* and *A. cerana* but significantly lower for the other two species, indicating significant mortality of *A. florea* and *A. dorsata* sperm over that span of time. Finally, the only viable brood produced by the queens were from those inseminated with *A. mellifera* drones, verifying that they are indeed different species.
These findings don't have a direct application to beekeepers in the U.S., because we don't have different species of honey bees. However, the findings may suggest future directions in research into the insemination process. The fluid within a queen's spermatheca is vital to keep sperm alive over her 2-3 year egg-laying lifetime. The apparent inhospitable environment of an *A. mellifera* spermatheca for *A. dorsata* and *A. florea* sperm suggests that the chemical and physiological differences among these species may shed light on how we may improve sperm longevity and the instrumental insemination process. Clearly, the better a queen is inseminated, the better she will be for beekeepers.
Reference
Phiancharoen, M., S. Wongsiri, N. Koeniger, and G. Koeniger. (2004). Instrumental insemination of *Apis mellifera* queens with hetero- and conspecific spermatozoa results in different sperm survival. *Apidologie*, **35**: 503–511.

Review: Rueppell et al. (2004). *Genetics*, **167**: 1767-1779.
Written: 12/20/04

Posted: January 3, 2005
Word count: 720
Question: Do genes affect when a worker will start to forage?
Answer: Yes, and only about four to six of them.

You don't have to tell a beekeeper that different colonies can be drastically different from one another. "This hive makes twice as much honey as that one." "Don't go into that one unless you have your gloves on." "I haven't treated that colony for over two years." I could go on. The challenge for biologists, and for apiculturists in particular, is to determine what causes such marked differences between colonies. Quite often such questions are couched in the age-old "nature versus nurture" debate, which asks: what is more important for a particular trait—the genetic make-up of a colony, or the environment that it is in?

While both genetics and environment influence virtually all traits, the relative magnitude of each can vary depending on the trait in question. Some traits have a strong genetic influence in honey bees, such as hygienic behavior or cuticle color. Other traits are more influenced by the environment, such as honey production or the type of pollen collected. A recent paper by Olav Rüppell and his colleagues investigated one important trait: the age that workers first start to forage. To a colony of bees, this trait represents a classic trade-off: start foraging too early, and there won't be enough nurse bees; start foraging too late, and the colony might starve. Thus the age at first foraging (AFF) is a complex trait, and understanding the genetic architecture of these decisions will give us insights into the effects that "nature" has on honey bee foraging.

Rüppell et al. used two breeding lines of honey bees that have been selected to store either high or low quantities of pollen in the combs (referred to as the high and low pollen-hoarding lines, respectively). They then created hybrid colonies of the two lines using instrumental insemination, and then "back-crossed" these hybrids to both lines (creating high back-cross and low back-cross colonies, or HBC and LBC). They then glued individual tags onto newly emerged worker bees from the low, LBC, HBC, and high lines and placed them into an observation hive to record when they started to forage. While they found considerable variation among individuals within each line, they found on average that workers from the high line started foraging very early (after about 16 days) and the workers from the low line started foraging much later (after about 27 days). More interestingly, the two back-crossed lines started foraging at intermediate ages (HBC at 17 days, and LBC at 21 days). This demonstrates that the AFF is significantly affected by genetics.

The researchers then went on to find the genes responsible for these differences, which needless to say is a lengthy and difficult process. They did this by extracting the DNA from the marked bees after they started foraging and making "maps" of their genes. This done by placing hundreds of genetic markers along the DNA chain, much like randomly planting flags along a long road. They constructed separate maps for the LBC and HBC lines, which enabled them to see which regions of their DNA (or genes) corresponded to AFF behavior. They found four candidate genes that correlated very strongly to the age at first foraging, and another two with lesser but still significant effects. This is a very interesting finding, since it is usually assumed that complex traits—such as the initiation of foraging—are controlled by many, many genes.

These findings are significant to bee management, although they do not have immediate applications. If researchers can determine what makes a bee forage earlier, it may be possible to create stocks that collect more honey with smaller populations of workers. The recent sequencing of the honey bee genome will likely make the process of identifying such genes much easier. In the meantime, we can take comfort in the fact that a bee's foraging age has a lot more to do with "nature" than we previously might have thought.

Reference

drugs and symptoms, or proper protocols for different medical procedures. The fact that I know precious little about medicine becomes an issue when the topic of honey bee allergies come up. Indeed, any answer that I tend to give on that subject is prefaced by an emphatic caveat that I'm not a "real" doctor. The same goes here.

My ignorance about allergies compels me to educate myself, albeit briefly. This search led me to a review paper by Dr. David Golden in the journal American Family Physician, titled "Stinging Insect Allergy". While I typically don't like to make these online articles reviews of review papers, I thought it would be a good idea to outline some of the bulleted points that he makes so that we as beekeepers will understand some of his take-home messages.
Systemic reactions to bee venom occur in approximately 3% of adults and 1% of children. These people have an increased risk of going into anaphylactic shock after being stung, but it is not guaranteed.
About 50 people die each year from insect stings, with fewer than half of them a result of honey bees. Still, this accounts for fewer deaths per year than penicillin allergies (300), dog or other animal bites (101), or even lightning strikes (85).
Almost one-half of fatal stinging cases involved people who were not previously diagnosed with venom allergies.
People with known allergies have, on average, a 50% chance of having a systemic reaction when stung. This declines to 35% if one is not stung within 3-5 years, and to 25% after 10 years.
There is no effect of family history on venom allergies. This means that you do not have an increased risk of developing an allergy if one or more of your relatives are allergic.
Epinephrine (also known as adrenaline) is the recommended treatment for anaphylaxis. One popular self-administered brand is the EpiPen® (0.3 mg). However, this is only a temporary treatment, which serves to delay life-threatening symptoms, and hospitalization is still required.
Sensitivity to insect stings can be diagnosed with either a venom skin test (where increasing micro-doses of venom are injected just below the skin) or a RAST test (which measures the venom-fighting IgE antibodies in the blood). Neither of these two tests, however, is an accurate predictor of the severity of future allergic reactions.
Immunotherapy can be given to people with high risk of anaphylaxis. This procedure involves injecting increasing doses of venom to build up a resistance to it, which can take several years to complete. In most cases, treatment is no longer required after 5 years, but routine monitoring is recommended.

Overall, this paper taught me several things. First, the medical profession has a pretty good idea about what to do about stinging allergies. While some mysteries persist about why some people become allergic and others do not, the ability to treat systemic reactions is pretty routine and standard. Second, therapies to desensitize people with allergies have made significant progress over the last decade. This gives increased hope for those who fear severe reactions if stung. Finally, doctors and allergists could benefit from beekeepers by relating their experiences. The more the medical profession hears about their patients getting stung, the more they will gain from our unique insights as beekeepers.

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Review: Pettis et al. (2004) *J. Econ. Entomol.*, **97**: 171-176
Written: 10/14/04
Posted: November 1, 2004
Word count: 614

Question: What kills larvae when you "dust" a colony to treat foulbrood?
Answer: The antibiotic OTC, rather than the "dust" itself.

It has become an unfortunate reality that beekeepers use a lot of chemicals to prevent and treat disease. These treatments come in various forms—from plastic strips impregnated with pesticides, to dissolved antibiotics in sugar syrup. If given a choice in the type of application, one major consideration for a beekeepers is how easily a treatment can be administered to a hive. Probably the ideal delivery method of any chemical for most beekeepers is something that can be scooped up with the end of a hive tool and simply dumped on top of the bees directly. While most disease treatments don't permit this luxury, one does: the antibiotic oxy-tetracycline (OTC) mixed with powdered sugar to treat bacterial brood diseases, commonly referred to as "dusting".

Dusting honey bee colonies with OTC is probably the best delivery method of antibiotic, since feeding it to bees in an extender patty is not recommended (since it prolongs exposure of AFB spores to OTC and has resulted in OTC-resistant bacteria) and dissolving it in syrup can be time-consuming and somewhat unreliable. Some beekeepers, however, have noticed significant loss of brood when they dust their colonies with OTC, but the effect of dusting on larval mortality has never been tested experimentally. Moreover, it is unclear if such brood mortality is due to the antibiotic itself or to the powdered sugar in which it is delivered.

A USDA research team from the Beltsville lab, led by Jeff Pettis, recently published the results of an experiment that sought to distinguish among these various possibilities. They purposefully dusted honey bee larvae with various substances. First, they tested OTC as well as two commercially unavailable antibiotics (tylosin and lincomycin), all of which were applied with powdered sugar, the standard medium of delivery. They used increasing concentrations of each chemical to determine larval mortality as a dose response. Second, they tested several inert dusts, such as powdered sugar (with no antibiotic), wheat flour, Bee Pro® (a commercially available pollen supplement), and talc. Such controls are necessary to distinguish between brood dying from the antibiotics, the powdered sugar delivery system, or the “dust” in general. These substances were chosen since some beekeepers have proposed that they may be an effective alternative for treating varroa mites.

The researchers found that OTC caused significant larval mortality (roughly 80%), even at concentrations that are typically used for AFB treatment (1 part OTC in 100 parts sugar). These levels of mortality were not seen by the other two antibiotics that are currently being considered for AFB treatment. While powdered sugar alone did not cause significant mortality, flour, Bee Pro®, and talc all showed between 65% and 80% mortality. Thus dusting can result in killed brood, which is a result of the OTC antibiotic and not the powdered sugar delivery system.

These results show that you can’t just throw whatever you want into colonies in whatever manner conveniences you. If you wish to dust your colonies with OTC and powdered sugar, be sure to apply the mixture across the tops of the *sidebars* of the frames, rather than directly over the brood nest. Similarly, using dusts as a non-chemical alternative to varroa mite treatment may be helpful, but care should be taken to apply the dust directly to the brood.

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Review: Woyke et al. (2004) *J. Invert. Path.*, 86: 1-6.
Written: 08/24/04
Posted: October 4, 2004
Word count: 1011
Question: Is hygienic behavior the same in all honey bees?
Answer: No; open-nesting species are different from cavity-nesting species.

If you leaf through the pages of any beekeeping magazine, you will quickly find dozens of advertisements for queens for sale. These ads vary in size, graphics, and most importantly the traits of the queens that they are selling. Examples include “gentle”, “Russian”, and “productive”. One of these selling points has been gaining increased recognition over the last decade, almost a majority of queen ads include it. This trait is “hygienic”, which implies that the queens have been bred so that their colonies exhibit higher levels of brood nest cleaning and lower levels of certain diseases.

Research of hygienic behavior has a storied history. It was first described by Walter Rothenbuhler at Ohio State in the 1960’s, who demonstrated that it involved two phases: workers first uncap the cells of dead brood, and then remove the corpse from the cell and the colony (Rothenbuhler, 1964). Moreover, he showed evidence that each of these two phases were controlled by a single recessive gene, so that bees uncap and remove dead brood according to separate, independent genes. Subsequent research has recently demonstrated that the underlying genetics is a bit more complicated (7 genes rather than 2) (Lapidge et al., 2002). Regardless, there exists ample proof that adequate hygienic behavior can minimize the impact of many brood diseases, such as American foulbrood and chalkbrood.

Our evolving understanding of hygienic behavior is a good example of how the scientific process works. Researchers tackle the same issue using different approaches, each contributing a small piece of a larger picture. Tactics range from simple observation, to experimental manipulation, to genetic analysis. One approach that many researchers have used over the years is to perform comparative (or ‘phylogenetic’) analyses, which investigates a particular issue in different populations or species. This type of analysis can be very powerful, since understanding the subtle differences in a single trait across different but highly related species can provide valuable insights.

It is this comparative approach that a Polish research team led by J. Woyke took recently to investigate hygienic behavior. The researchers investigated three colonies of *Apis dorsata*, the giant honey bee, in India, and two colonies of *Apis laboriosa*, the closely related "big back" bee, in Nepal. Both of these honey bee species build nests in the open air on one large comb. They also are migratory in nature, abandoning their nests and traveling hundreds of miles to establish new ones several times a year. Thus any subtle differences in hygienic behavior may be a result of their different life histories from the stationary, cavity-nesting species *Apis cerana*, the Eastern honey bee, and our own *Apis mellifera*.

Their assays for hygienic behavior were the two most common tests used by most beekeepers: the pierced-brood assay, and the freeze-kill assay. The pierced-brood test involves taking a pin, inserting it through the wax cappings of pupal cells to kill the brood inside, and measuring after a period of time the percentage of pierced cells that the workers uncap and remove the dead pupae (in their case, every day for 4 or 5 days). Moreover, Woyke et al. used two types of pins, one thick (0.75 mm in diameter) and one thin (0.30 mm in diameter). The freeze-kill assay involves just that, taking a section of comb with sealed brood and freezing it to kill the pupae inside. The researchers accomplished this by cutting out sections of comb and placing them in a –20oC freezer for 24 hours (as opposed to the standard field protocol often followed in commercial operations by pouring liquid nitrogen into a cylinder placed directly on top of the brood). They also looked at the brood from many nests abandoned by migrating swarms to see how many sealed brood cells were left behind.

They found that 74% and 37% of the *Apis dorsata* brood killed with the thick and thin pins, respectively, were removed after one day, suggesting that the thinner pin did not adequately kill the brood (or, at least, damage it enough to elicit the nest-cleaning behavior of the workers). In contrast, on 7% of the freeze-killed brood was removed, and those that were removed were those on the edges of the comb sections that were physically damaged. These findings suggest that *Apis dorsata* workers rarely uncap undamaged brood cells even if they are dead. This supposition is supported by their results from the abandoned nests of *Apis dorsata* and *Apis laboriosa*; about 30-50% of the total brood was still capped in those colonies, even though many were infested with Varroa or another mite, *Tropilaelaps clareae*.

These findings may shed some light onto why hygienic behavior is a recessive trait in honey bees rather than a dominant one. While uncapping and removing diseased brood may be helpful in cavity-nesting species to reduce the spread of pathogens and parasites, it could be more beneficial in open-air-nesting species to keep those cells sealed to prevent their spread. Moreover, if infestations get too severe in a colony, then it can migrate to a new nest site, something that is not as great an option for *Apis mellifera*. Clearly more work needs to be done, particularly in the genetic aspects of hygienic behavior, but this study demonstrates how understanding hygienic behavior in all honey bee species is important, and highlights the benefits of comparative analyses.

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Review: Jones et al. (2004). *Science*, **305**: 402-404
Written: 08/18/04
Posted: September 8th, 2004
Word count: 900
Question: Does colony diversity promote stability?
Answer: Yes, for thermoregulation (among other things).
At the beginning of every fall semester, the repopulation of undergraduates on campus always reminds me of my own college days: the all-night study sessions, the late-night pizza runs, and throwing frisbee in the quad. The most recent influx of students has started me thinking about two very different living arrangements that I had back then. The first was in a dormitory, where our resident assistant outlined, in detail, the duties that everybody on the floor was to perform. These tasks were assigned and rotated among everyone to pitch in and keep everything in order. The

other experience was living off campus in a house of many different people with very different backgrounds. In this house, we had no organized means of keeping order. Rather, it just happened on its own. What we found was that some house members would tend to do chores depending on their tolerance for it. For any given job (say, washing dishes), some had low thresholds (and would perform them readily), while others had high thresholds (and perform them only when the sink was overflowing with dirty pots and pans). These two forms of social living were quite different—one having centralized control, the other having decentralized control—but both resulted in the same end: a division of labor that created an organized living environment.

While headed by a single monarch, a honey bee queen is by no means despotic over her subjects. Queens do not "tell" all of the workers directly what to do. Rather, work in the colony is decentralized, where each individual worker assesses her immediate surroundings to determine what she should do at any given point in time. Her choice in task depends in large part on her thresholds for performing various duties (nest cleaning, nursing, guarding, etc..). These thresholds can be low or high, depending on many factors such as age, nest location, and her genetic make up.

Colonies are a genetic mixture of workers because queens mate with many drones. Workers that share the same father form a subfamily of related sisters within the colony. Since thresholds to perform certain tasks are, in part, controlled by genetics, these different subfamilies may collectively perform tasks at different levels of stimuli. Thus, just as division of labor emerges from a group of housemates with different thresholds, the same may be true for a more complex social environment such as a bee hive.

This process of division of labor was recently tested by Julia Jones and her colleagues from the University of Sydney, published in the top-tier journal Science. Specifically, they investigated whether colony genetic diversity influences one specific yet important task: thermoregultation, or the control of nest temperature. They tested the hypothesis in a series of three studies. First, they wished to determine the basal assumption of this process by determining if different subfamilies have different response thresholds for evaporative cooling by fanning (one main mechanism that workers regulate nest temperature in the summer). In two observation hives, each containing five subfamilies (established by instrumentally inseminating the queens), they steadily increased hive temperature and then sampled workers when they started fanning. They then determined each worker's subfamily using molecular genetic techniques. They found striking differences in the propensity to fan among the different subfamilies, as might be expected; some genotypes started fanning at low temperatures, whereas others required a much higher temperature to begin fanning.

Just because different subfamilies behave differently, however, does not necessarily imply that colonies with many subfamilies thermoregulate differently. In another experiment, Jones et al. established four two-frame colonies headed either by singly inseminated queens or by multiply inseminated (open-mated) queens. They then measured fluctuations in nest temperature for two weeks. They found that in the colonies with only one subfamily, temperature fluctuated much more widely than it did in colonies with numerous subfamilies. This suggests that having genetic diversity within colonies tempers environmental fluctuations, so colonies can more readily respond to changes in ambient temperature and keep the nest closer to optimal temperature.

In a final study, the authors used the same hives but artificially increased the temperature to see if this variation could be manipulated experimentally. They placed pairs of colonies, one headed by a singly inseminated queen and the other by an open-mated queen, into an insulated room with outside access for the bees. They then raised the temperature to 40oC (104oF) for one hour, measured the brood nest temperature, then lowered the room temperature to normal. They averaged the single- versus multiple-subfamily colonies across three replicates of four colonies, and found the same pattern in temperature fluctuation: genetic diversity reduced temperature variation by almost four-fold.

What this study suggests is that genetic diversity—or, more specifically, behavioral diversity for thresholds for specific tasks—is a good thing for a well-honed division of labor. Just like a household consisting of roommates with various thresholds for chores spontaneously creates order, a genetically cosmopolitan colony enables it to respond to a wider range of conditions and challenges. Thus this is further evidence for us to ensure that our queens are properly mated.

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Review: Amdam et al. (2004). *Journal of Economic Entomology*, **97**: 741-747.
Written: July 27, 2004
Posted: 08/02/04
Word count: 982
Question: Does varroa affect winter mortality?
Answer: Yes, and in more ways than you may realize.
If one were to ask how long a bee lives, the typical answer is six weeks: the first three weeks performing in-hive tasks (such as nursing, comb building, and honey processing), and the last three weeks for out-hive tasks (foraging). This textbook answer is misleading in several ways. First, it is clearly referring only to worker bees, and not queens or drones (who live a few years and a few weeks, respectively). Second, there is a lot of variation in worker lifespan and the tasks they perform. Some bees can start foraging less than a week old and die soon thereafter, while others may never forage and live for 60 days or more.

Third, such an answer refers to the typical lifespan of bees during the *active* season. This neglects how long bees can live during the *non-active* months, which in some regions of the country can last as long as half the year. So-called "winter" bees are reared in the late fall and stay alive in the winter cluster for months, far longer than the lifespan quoted from the standard textbook.

What's interesting about these long-lived winter bees is that they are not different *genetically* from their summer-time sisters; that is, a queen lays the same types of eggs sired by the same types of drones during both the summer and late autumn. What is different about the winter bees is that they are different *physiologically*, so that their internal cellular machinery causes the workers to have markedly different characteristics. These differences are manifested by the interaction with the environment, so that genes are differentially turned on or turned off depending on the bee's surroundings to create these physiololgical differences. In particular, the main stimulus for winter bees to develop is a queenright colony without any brood for their first 3 to 4 weeks of adult life.

If the brood environment has such a profound effect on a winter bee's physiology, then it stands to reason that other major environmental factors may effect this process as well. Most notably, parasitism by the varroa mite might well cause significant changes in how winter bees develop at the end of the summer. It is this effect that a research team lead by Gro Amdam from Norway investigated in a recent study published in the *Journal of Economic Entomology*.

The researchers created winter bees in the middle of the summer by placing newly emerged workers into broodless colonies. Since their experimental treatment was varroa parasitism, they tagged both parasitized and non-parasitized workers with individual markings and placed them into the broodless colonies to develop as winter bees. Over a period of 30 days, they removed samples of the tagged bees and took samples of their hemolymph, the insect equivalent of blood, with small glass syringes. They then tested these hemolymph samples for the levels of several physiologically important compounds. First, they measured vitellogenin levels, a protein that serves as the major internal reservoir of protein that workers use to produce brood food. Second, they measured the proportion of normal hemocytes, a qualitative measure of a bee's cellular immune system. Third, they measured ecdysone levels, an important hormone that regulates a bee's general physiology.

What they found was that varroa parasitism does indeed have a significant effect on these physiological characters of induced winter bees. For example, non-infested workers increased their vitellogenin levels by almost 30 to 40-fold as they aged, whereas parasitized workers increased their levels only by 5 to 10-fold. Similarly, they had fewer normal hemocytes and higher ecdysone levels, although these trends were less clear and not consistent. Nonetheless, parasitism appears to play an important role in how winter bees develop and how good they turn out to be.

There are some caveats in this study. First, the winter bees were artificially created and therefore may not be representative of the physiological effects in "real" winter bees. However, it has been shown in previous research that the methods used by the authors are analogous to using actual winter bees. Second, because of limited sample sizes, the analyses did not incorporate the different levels of parasitism among workers in the parasitized group, so it is unclear if the variability in the results are a function of differential infection rates or if there are actual hidden effects.

Regardless, these findings raise some important issues about bee management for varroa. If winter bees that are parasitized by varroa have lower protein titers in their hemolymph, then colonies may not have sufficient protein reservoirs to last them throughout the winter months, particularly when brood rearing begins again the following spring. Thus the indirect effect that varroa has on the development of winter bees may be a major cause for winter mortality experienced by many beekeepers. This can be problematic because many varroa treatments, particularly the chemical treatments, are normally performed after the future winter bees emerge, so the winter bees are reared in high varroa conditions (in fact, among the highest levels a colony experiences, since it occurs at the end of the season). Thus some varroa treatments may be applied too late to address the negative impact that varroa has on winter bees. Clearly additional work is needed to determine the indirect effects that varroa has on colony survival, but this study suggests that the future research should bear in mind the important role that winter bees play in the life cycle of the colony.

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Review: Albo et al. (2003). *Apidologie* **34**: 417-427
Written: July 21, 2004
Posted: 07/21/04
Word count: 757

Question: Are essential oils a viable alternative to terramycin?
Answer: Unfortunately, no.
If you stop to think about it, adaptation can sometimes be a really scary thing. Take tuberculosis (TB) for example. Back when antibiotics and sulfa drugs were first used, *Mycobacterium tuberculosis*, the bacterium that causes TB, was 99.99% susceptible to treatment. If these remaining TB bacteria infected another individual, they will be less susceptible to the drug, so that the same treatment would kill only 99.90% of the TB. Over time, treatments such as penicillin were only 99%, then 90%, then 50% effective, and eventually, not effective at all. This prompted doctors to use alternative antibiotics, and eventually TB developed resistance to these drugs as well. This adaptive process were accelerated by patients not completing their antibiotic regime, or by taking lower doses of their drug. At the present day, there are numerous strains of TB that are resistant to at least *six* common antibiotics. Again, scary.

Beekeepers are currently facing a similar scenario. *Paenibacillus larvae larvae*, the bacterium that causes the American foulbrood disease (AFB), has slowly but surly developed a resistance to the one and only licensed treatment for its prevention, oxy-tetracycline (OTC) or Terramycin™. Once 99.99% effective, there are now documented strains that are almost completely resistant in many states along the eastern seaboard (luckily, NC is not one of them, yet). Scientists can tell whether or not a strain is resistant by growing the bacteria on a petrie dish and placing a paper disc soaked in a chemical. If the AFB is susceptible to the chemical, it will not grow close to the disc, leaving a clear ring around it that can be measured. If the AFB is resistant to the chemical, the "bacteria-free zone" will be small or even absent. Developing alternative means of AFB treatment is therefore of great importance to the beekeeping community.

A recent study addressed this issue, lead by Graciela Albo and her colleagues from Argentina. Their goal was to test the efficacy of several alternative methods of treatment for AFB control. These treatments were the essential oils from savory, thyme, lemon grass, and oregano, as well as some of the possible combinations of these four plant sources. Tylosin, a yet-to-be registered alternative to OTC, was used as a positive control. Their methods were not the standard lab assay as described above, but rather took place in actual bee colonies that they infected with AFB. They caged the queens onto empty comb to let her lay an area of brood of similar age, and then they applied the treatments to see how much of the brood became infected with AFB.

Their results were not encouraging, at least for those hoping the essential oils would work. In their words "Neither pure essences nor blends of essences were effective to control AFB at the doses and formulations tested in this study. On the contrary, colonies treated with essences showed higher levels of infection than those receiving control treatments. This may be related to a certain level of toxicity of the essences to larvae and adults." Thus these essential oils are clearly not a viable means of control and prevention of AFB. Their take home message is that tylosin is the next best hope for AFB treatment, something that the USDA is currently working on.

So what can we do as beekeepers? Well, pretty much what people have been recommending for a long time. First, avoid using OTC indiscriminately or at doses below the label recommendation. Second, do not use OTC in extender patties, since it exposes AFB spores to low levels of the chemical and therefore accelerates resistance. Third, remain hyper-vigilant for any signs of AFB, which include sunken and perforated brood cappings, brown or discolored larvae, or hardened black scales on the bottom of brood cells. Fourth, whenever possible, impose a quarantine on any colonies in which AFB is detected by not swapping combs among colonies and never—ever—letting a diseased colony get robbed out by its neighbors. So with good management practices, maintained vigilance, and proper use of treatment was lower in the treated groups than in the control group (1598 cm2 for the control; 1090 cm2 for the Api Life VAR®; and 902 cm2 for the Apigard®).

The persistence of thymol in the delivery media of the two products diminished over time, as would be expected. However, the Api Life VAR® formulation released approximately 50% of its thymol after one week, whereas the Apigard® formulation released almost 85% of its active ingredient. This is not surprising, since the gel delivery system increases the volatility of thymol. Finally, Floris and his colleagues detected thymol residues in honey and wax after treatment. One week after the first treatment, they found 1.97 ± 1.54 mg thymol per kg of honey using Api Life VAR® and 3.07 ± 1.80 mg/kg using Apigard®. Both products yielded residues under 1.0 mg/kg after 14 days post-treatment. In wax, however, the final residues of thymol were 21.6 ± 13.0 mg/kg for Api Life VAR® and 147.7 ± 188.9 mg/kg for Apigard®. The higher residues in wax is largely attributable to thymol being a fat-soluble essential oil.

These findings suggests several things to beekeepers who wish to use Api Life VAR® to control Varroa. First, one should not expect as effective results as when using "heavier" treatments such as coumaphos or fluvalinate (where it is still effective, that is). Therefore one's threshold for treatment should be proportionately lower, and one's expectations for mite kill should be similarly so. Second, the use of Api Life VAR® may be best reserved for fall treatment as opposed to spring treatment. If thymol does indeed reduce how much brood a colony can rear, then using it during the spring buildup may have noticeable negative effects on colony population and resultant honey yield. Finally, it reinforces the need to follow the product label by not using thymol anywhere around the honey flow since their detected average thymol levels after one week exceed the human taste threshold of 1.1 mg/kg in honey.

Overall, I think having Api Life VAR® is better than not having it available, particularly in light of increasing ineffectiveness of fluvalinate and, more recently, coumaphos. But, like most treatments that we apply to combat pests, we must be fully aware of the effects that it has on our bees, both good and bad, so that we can use it most effectively.

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Written: May 17, 2004
Posted: 05/18/04
Word count: 730
Question: What causes workers to start foraging?
Answer: There are many things, but add one more important factor to the list
To humans, the windows to the world are through our eyes; we communicate with each other primarily by sight. For mammals, this is actually the exception and not the rule, since most of our furry brethren communicate largely by smell. (Just think of the color-blind dog, who goes around sniffing everything). The same is true for honey bees, who, like most other insects, have tremendously bad eye sight but have a very keen sense of smell thanks to highly sensitive chemical receptors located on their antennae.

Living in a social group requires a lot of information transfer. For honey bees, it is only logical that most of this communication occurs by scent. Some information is passed around using smells that are derivative, meaning that they are not originally intended to be used for communication. Scientists call these secondary smells *cues*. For example, bees distinguish nestmates from non-nestmates using the odors on each others bodies that are picked up from the unique blend of floral and bee odors from the combs of their home colony. Since the original source of odor (the smell of the comb) was not derived "on purpose", these are referred to as nestmate recognition cues. On the other hand, some scents have been specifically adapted for communication. These smells are called *signals*, and often take the form of chemicals known as *pheromones*.

Pheromones are something that most of us are familiar with. Probably the most familiar example is the alarm pheromone produced by startled or defensive bees, a scent which is eerily similar to freshly baked banana bread. Often what ensues after a beekeeper smells alarm pheromone when working a colony is a rapid string of stings from guard bees who seem very intent in doing so. This is because the guard bees smelled the alarm pheromone and became immediately more defensive. These types of pheromones are called *releaser* pheromones, because it “releases,” almost immediately, specific and intentional behaviors of those that smell them. Releaser pheromones are different from *primer* pheromones, which act on a longer time scale. For example, queen mandibular pheromone, or QMP, is a pheromone produced by the queen that inhibits workers from rearing new queens. Thus the effect of QMP is not immediate, but rather works over many hours and days. Because their effects are not as direct, there are very few examples of primer pheromones compared to releaser pheromones.

A recent study by Dr. Tanya Pankiw at Texas A&M University has revealed a previously unknown primer pheromone in honey bees. She washed off the chemicals from the bodies of either young, pre-foraging nurse bees or older, foraging bees. She then added these scents to colonies housed in observation hives and recorded the ages that paint-marked workers began to forage. She found that, compared to unscented control colonies, the age at first foraging was earlier for colonies exposed to nurse bee pheromone and later for those exposed to forager pheromone. Thus adult workers may have scents on their bodies that regulate the behavioral development of their nestmates, effecting when they make the transition from in-hive duties to foraging. While this may suggest that workers have evolved pheromones specifically designed for this purpose (i.e., signals), it is also possible that they are using odor cues similar to those used in nestmate recognition. Additional research will likely reveal this distinction.

Although I think that there needs to be a lot more work on the subject, I find these results to be quite exciting. Not only does it enable us to better understand the close coordination of workers within a hive and how colony members behave so harmoniously, it also has potential in being developed into a useful technology for apiculture. If workers can be “tricked” into foraging earlier than they would otherwise, beekeepers or growers might be able to add nurse bee pheromone to colonies during the blooming period and increase the pollination efficiency of a hive. Thus while much more study is needed before such technology is available, it certainly has some intriguing potential.

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Written: April 19, 2004
Posted: April 19, 2004
Word count: 746
Question: Do colonies benefit from using the dance language?
Answer: It depends where the bees are located.

In case you haven’t heard, honey bees have their own language. Instead of being based on their predominant chemical communication system using pheromones, it involves specific body movements performed by foragers who “dance” on the surface of the comb to recruit other foragers to its food resource. This recruitment system was first described by the late Karl von Frisch at the University of Munich in Germany, who later went on to received the Nobel Prize for his contributions to science.

I see from my dictionary that one definition of language is “any means of expressing or communicating, as gestures, signs, or animal speech”. Following this (overly) broad definition, I think you could say that many animals have “language” (e.g., dogs bark, crickets chirp, etc...). However, these many examples in the animal kingdom are *direct* forms of communication (dogs bark to warn other dogs, crickets chirp to attract mates), and thus most biologists do not define them as languages *per se*. The recruitment dance of the honey bee, however, is *indirect*. Returning foragers do not directly point in the direction of the food source, but rather translate the angle of the resource with respect to the sun into the gravitational vertical. It is the only known form of animal communication that is *abstract* rather than direct, other than, of course, human language. Thus even though human language is vastly more complex than the dance language, it seems, nonetheless, to meet the fundamental basic requirement of a true language.

Recently, two researchers at the University of Würzburg, Anna Dornhaus and Lars Chittka, noted that the vast majority of research on the honey bee dance language investigated the mechanisms of recruitment rather than the benefits that it provides the colony. That is because von Frisch, and those who followed, tested the recruitment process in glass-walled observation hives, not in full field-sized colonies. So the question that Dornhaus and Chittka posed was “What is [the dance language’s] benefit to colony foraging efficiency under natural conditions?”

They tested this question using a simple yet elegant design. They built field-size hives with *horizontal* combs (please, don’t try this at home!). This configuration prevented foragers from using gravity as a reference to the sun (their normal method of recruitment) and thus taking away the directional information contained in the dance.

However, they were able to experimentally provide this information to the bees by opening a window in the hive to permit sunlight to enter (in the absence of a gravitational cue, bees will use the sun itself as a reference). Thus the researchers could establish colonies with the same horizontal comb configuration, but some were able to recruit using the dance language but others could not.

They then established pairs of such colonies in various locations around the globe. Each colony was weighed every night to quantify its change in weight during the course of the previous foraging day. The comparisons were then made between the colonies that could recruit and those where the dance was obscured. What they found was that in temperate regions, the disrupted colonies did just as well (if not better) than those that were able to use the dance language. In tropical regions, however, the undisrupted colonies had a significant advantage over the obscured colonies. Thus it seems that the functional significance of the dance language seems to be context dependent: it helps a colony's foraging effort in areas where floral sources are patchily distributed (i.e., the tropics), but not in areas where flowers are more uniform (i.e., the temperate zone). Of course, only one tropical site and two temperate sites were tested, thus it remains unclear if this is a general or local phenomenon.

So what does this mean to us as beekeepers? In essence, very little. That is because most beekeepers are only concerned with the end result (the honey crop), and not the minute details of how the colony actually carries it out. Thus while this finding does not change our management practices, it does provide some more insight into the inner workings of the creatures that so fascinate us.

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Also see the NCSU Apiculture web site at http://www.cals.ncsu.edu:8050/entomology/apiculture/Dance_tutorial.html

Al-Abbadi, A. & I. K. Nazer. (2003). *Agricultural and Marine Sciences*, **8**: 15-20
Written: March 15, 2004
Posted: 03/15/04
Word count: 661

Question: How effective are various aromatic oils and plant materials for Varroa mite control?
Answer: In a recent study, not very, but they are still worth pursuing.

Why is Varroa so difficult to control?! The main reason is because our Western honey bee is not its original host, a distinction that belongs to its Eastern sister taxa Apis cerana. This also explains why many different control tactics are needed to combat the pest, since no one approach is a "magic bullet" or, if it seems to be one, it doesn't stay one for long (remember when fluvalinate used to work everywhere, all the time?). Synthetic chemicals are one common method of pest management, and they can be very effective. One drawback to using them, however, is that they leave residues in honey and the nest substrate that can have negative effects on bees and humans alike. As a result, alternative means of control frequently been sought.

Two researchers in Jordan recently performed a research experiment testing the possible benefits of several essential oils and plant materials on varroa control. Essential oils, as their name suggests, are lipid-based compounds produced by plants that are used in their own natural defenses of insect herbivores. Different plant materials may also have the same properties even though they cannot be distilled easily into extractable oils. Thus logic suggests that such compounds may either repel or kill certain arthropods (i.e., varroa mites) but have little or no negative consequences on other arthropods (i.e., bees).

Al-Abbadi and Nazer tested several of these compounds in a random fashion. They tested five volatile oils (clove, lavender, peppermint, sage, and thyme) and three other plant materials (cumin fruits, eucalyptus leaves, and worm wood flowers). The essential oils were administered to the colonies by soaking florist foam blocks (that hard, porous stuff you get with flower arrangements) in one of the oils and placing the block in the brood nest area. The eucalyptus leaves were tested in another fashion, namely by burning a standard quantity in a like hive smoker, puffing inside the hive entrance 15 times, and sealing the entrance for 15 minutes. The cumin and worm wood were administered by separately grinding each into a powder and making bouquet garnis out of them (i.e., spices tied up in some cheese cloth). Colonies with no treatment (negative control) and treated with Apistan (positive control) were used as comparisons. All mite counts were performed with a four-day sticky boards on the bottom of each hive.

Unfortunately, the results were not all that enlightening. Some of the trials yielded no significant differences among any of the treatments, including the negative control; others showed positive effects of all treatments but none better that the Apistan treatment. No result was consistent across the six trials of the two-year study, although the data suggest that wood worm flowers, peppermint oil, and clove oil gave the best results, increasing the mite drop by 3.92, 3.62, and 3.34-fold, respectively.

This is certainly not the first test of essential oils for their efficacy in varroa control. Others have shown that they can be effective, particularly those that have tested thymol. Therefore, even with moderate or mixed results, such control methods are still likely to be useful. This is because they fit nicely into an IPM strategy, or integrated pest management, a philosophy that holds that many different approaches, each having small but additive effects, is much better than one standard method of control. Given the abundance of essential oils, it behooves us to keep looking for others that work better than our current chemical treatments.

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Review of: De Guzman et al. (2002) Apidologie, 33: 411-416.
Written: September 29, 2003
Posted: 02/13/04
Word count: 829
Question: Are Russian bees resistant to both types of parasitic mites?
Answer: Apparently yes, which is terrific news.

The Russians are coming! Put your shotgun away, militia man, it's not the unlikely cold war scenario coming to fruition. And no, it's not the mail-order bride business skyrocketing. It's some of the better news that beekeepers have had for a while.

Parasitic mites have been the bane of beekeepers for decades. The Varroa mite Varroa destructor (previously V. jacobsoni) was first found in the US in 1987 and quickly spread throughout the country. If you've never seen a varroa mite, you probably haven't been keeping bees for very long. Because the mite co-evolved with the eastern honey bee (Apis cerana), our poor western honey bee (A. mellifera) has no natural defenses against it. Entire feral populations have since been decimated as a result of these pests, and the number managed colonies has declined dramatically. For example, the North Carolina Department of Agriculture estimates that the number of managed honey bee colonies in the state has dropped from 180,000 to around 100,000 since the mite's introduction. As you might expect, there has been a concerted effort in the apiculture community to reduce the impact of Varroa.

Many of you who keep your ear close to the ground have probably heard that researchers at the USDA Baton Rouge lab have imported a particular strain of bees from the Primorsky region in Russia to combat Varroa. These bees are sympatric with Apis cerana (i.e., they live in the same area), and so they have probably been exposed to the mite for longer than any other strain of western honey bee. Indeed, repeated research has documented Varroa mite resistance in the Russian bees.

The question that Lilia de Guzman and colleagues posed in a recent research project was whether they are also resistant to that other pesky parasitic mite, the tracheal mite Acarapis woodi. These microscopic critters live in the air passageways of adult bees, chewing holes in the tube walls and feeding on hemolymph. Low infestation levels can be difficult to detect, but their impact can be serious since they compromise the immuno-defenses of workers, making them more susceptible to other diseases. The researchers compared 22 colonies headed by Russian queens with 22 colonies headed by queens of standard domestic stock. Each colony was housed in standard equipment and initially given 3 lbs. of workers. The researchers followed the colonies over the course of two years, requeening each in the spring to ensure healthy brood production. Samples of 30 workers were collected from each colony ten times during the experiment to quantify the levels of tracheal mite infection. They found that none of the colonies had a significant mite infestation at the beginning of the experiment. However, tracheal mite levels rose dramatically in the second year for the domestic bees, whereas the Russian bees remained at or near zero mite levels. The last sampling period showed that an average of 13.3 ± 20.7% of the domestic workers were infected, compared to an average of 0% of the Russian workers. Clearly, workers of the Russian strain have a natural tolerance to tracheal mites.

A shortcoming of this study, one that the authors point out, is that the colonies were not "inoculated" with a controlled number of tracheal mites. The only way to infect colonies with A. woodi is to introduce parasitized adult workers, and there is no sure way of distinguishing infected workers from healthy workers without killing them. Thus it is possible that the reason the domestic colonies were more heavily parasitized at the end of the experiment is because they had more mites at the beginning. However, all colonies were kept in the same apiary, and cross contamination through drifting foragers undoubtedly occurred, so mites would still be expected to become established in the Russian colonies if they were susceptible.

I think that we're all pretty excited about the recent work coming out of the USDA labs. The "quarantine" phase of the project has been over for some time, and queens from the Russian strains are now available commercially from any number of bee breeders. I have only recently begun to use these bees, and the prospect of not having to treat for Varroa, as well as not having to worry about tracheal mites, is very intriguing. One word of caution, however. I would hesitate anyone to limit themselves to only Russian bees (or any other single strain, for that matter). Variation among our colonies enables us to address all of our problems, not just parasitic mites. But if you wish to reduce mite levels, by all means, go Ruski.

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Seeley (2002) Apidologie, 33: 75-86.
Written: September 26, 2003
Posted: 02/13/04
Word count: 839
Question: Does adding drone comb to your colonies reduce your honey yield?
Answer: Yes, by as much as half, but don't let that stop you!

Female honey bees are notorious for performing all the work within a colony. Queens are egg-laying machines, cranking out hundreds of eggs a day, and workers perform all the duties inside and outside of nest, such as brood care, comb construction, and foraging. Male honey bees, or drones, are equally notorious for not performing any work within a colony. Their only purpose in life is to mate with queens from foreign colonies. Beekeepers have long regarded drones as "useless consumers" of colony resources, particularly since honey is the fuel source of their energetically expensive daily flights from the hive. Nonetheless, the conventional wisdom is that the practice of adding drone combs to bee hives has little impact on one's honey harvest.

Thomas Seeley at Cornell University has recently performed an experiment to test whether the addition of drone combs within managed hives significantly reduces their weight gain. Each year, he tested five colonies that contained no drone comb, and five colonies that contained a "normal" amount of drone comb (about 20% of the total comb area, which amounts to two full frames of drawn drone foundation per Langstroth hive body). His experimental design was simple: weigh each four-story hive at the beginning of the summer before any nectar flow begins, and then weigh each hive at the end of the summer after the major honey flows have ended. He repeated this procedure for a total of three years, requeening each colony with newly mated queens each spring. He then compared the changes in weight between the two groups (those with and without added drone combs) over the course of the experiment. He found that those that contained added drone comb gained 25.2 kg (11.4 lb) on average, whereas those that did not gained 48.8 kg (22.1 lb) on average, almost a 52% difference! Since honey is by far the largest contributor to a colony's weight gain, this clearly suggests that the addition of drone comb dramatically reduces honey yield.

So what might cause this dramatic difference? Dr. Seeley entertains several possibilities. First, the addition of drone comb may have, in some way, promoted the colonies to swarm during the summer, and thus loose a significant number of bees and colony resources. However, only 7 of his 30 newly introduced queens were missing by the end of the summer, and an almost equal number were missing in both groups, so it is unlikely that differential swarming can explain the discrepancy between the two treatments. Second, the increased amount of drone comb increased levels of Varroa within those colonies, reducing their populations and nectar collection. It is true that Varroa mites prefer to reproduce in the larger, longer-developing drone brood (a fact that can be taken advantage of to control the pest without the aid of chemical treatments; just periodically freeze drone pupae to kill the mites before they get out of their cells). However, Dr. Seeley did not find a (negative) correlation between mite loads and weight gain, suggesting that the observed effect cannot be explained by differential parasitism. Finally, the addition of drone comb encourages drone rearing, which may be energetically costly. Dr. Seeley goes through numerous calculations to show that rearing and maintaining drones within a colony can, theoretically, account for 15-20 kg (or about 9 lbs) of honey over the course of a summer. While this may not be responsible for the entire difference between the two treatments, it certainly would help explain it considerably.

I have very mixed feelings about these findings. Most beekeepers, particularly the larger commercial operations, want to maximize honey yields for obvious reasons. For those of you who are interested only in your honey harvest, then I would (reluctantly) recommend not using drone combs in your hives. My general recommendation, however, is to continue placing one or two drone combs in each brood chamber. There isn't an issue of any major bee publication that goes by that I don't see some mention of the importance of drones and their need to adequately inseminate queens. If this isn't reason enough (but I hope it is), drone brood is a great indicator of the local foraging conditions and therefore the overall health of a colony; it reduces the amount of drone comb built in the worker combs, resulting in a more organized brood nest; it serves as a reservoir for Varroa mites and may be used to control them (see above); and it may even reduce the incidence of swarming (although I know of no good study that documents this conclusively). So if you're concerned with factors in addition to your honey harvest, particularly having well-mated queens, keep putting those drone combs in.

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