Bee-Lining as a Research Technique in Ecological Studies of Honey Bees

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This is a very timely article, because of the imminent arrival of Africanized honey bees. One of the research questions concerning these bees is how the density of feral colonies changes with Africanization. In the recently completed Texas Africanized bee action plan, for instance, this is mentioned as one of the priorities for research. Also, locating feral colonies for monitoring or regulatory purposes will become more important. Dr. Seeley and I have performed the only quantitative survey of feral bee density yet done in the United States. This article is written to assist others who wish to do ecological studies of feral honey bee populations. As you probably know, there have been books published on how to hunt bees for more than a century. This manuscript will be a useful addition, because it gives a concise, quantitative, "how-to" description of methods which are somewhat buried and unclear in the honey hunting literature. Also, our focus is different, and the technique we describe for surveying colonies by triangulation has not been previously described. At the same time, I think the paper will be interesting to your hobbyist readership as a clear explanation of the techniques of bee-lining in finding bee trees, which is an engaging pastime.

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HONEYBEES have fascinated naturalists since Aristotle, and Apis mellifera is among the most intensively studied of animal species. That so many aspects of its biology are understood makes this species particularly attractive for ecological studies, since many of the behavioral, morphological and physiological components of its ecological adaptations are known. Nonetheless, only a handful of the studies of Apis mellifera have examined this bee as it exists in nature, so little is known about the ecology of honey bees in their natural state, although feral colonies are common in many places.

In order to better understand the social behavior of honey bees living in nature, we began studying feral colonies of honey bees living in temperate deciduous forests of New York State. This paper presents the bee-lining techniques we have used to locate more than 30 feral colonies. The techniques we describe are distilled from those long used by bee-hunters for locating the nests of honey bees living in the wild (e.g. Root 1877, Edgell 1949, Lockard 1956, Donovan 1980). Beelining consists of inducing bees to forage from a visually and olfactorily conspicuous food source, and determining the direction to the bees' nest from the direction of their homeward flight.
Equipment for Bee-lining

The principal tools of the bee hunter are listed below. 1) A bee-lining box, as depicted in Fig 1. 2) An opaque cloth for covering the bee box. 3) A brightly colored board about 10 inches (25 cm) square on which the bee box can be set. We used a board with a blue and yellow radial "flower" design painted on it to aid the bees' orientation. 4) Two squares of comb from a beehive, cut to fit loosely inside the bee box. These should be cut from empty brood comb, strengthened and blackened by repeated brood rearing. 5) A highly concentrated, scented, sugar syrup. This is prepared with about one and one-half cups (300g) of table sugar mixed with enough boiling water to make one pint (0.5 liters) of syrup. About 1 drop of anise extract is added per pint of syrup (other scents may be used, but anise works better than the others we have tried: orange, lemon, and peppermint). The syrup should be stored in a leak proof container such as a canning jar. 6) A dropper bottle for filling the comb cells with syrup. 7) A small bottle of paint for marking bees. Model enamel, shellac paints as described by von Frisch (1967) and typewriter correction fluid all work well. 8) A watch. 9) A magnetic compass, preferably one designed to sight bearings accurately. 10) A topographic map of the area, a notebook. and pencils. 11) A small backpack for carrying equipment.

Figure 1. Bee-lining box, in cutaway view to show construction detail. The drawing is to scale in all three dimensions to aid construction. F-Front door (the hinges of this door take considerable strain in use, so the bottom board should be cut with transverse grain, and preferably made of hardwood, to provide a strong attachment). D-Sliding divider separating front and rear compartments. P-Rear windowpane of clear plastic. B-Back cover (this may be hinged as shown or may slide like the divider). If painted or varnished, the box should be thoroughly aired in the sun before use.

Establishing Bee-lines

We begin by capturing a foraging bee in the bee box. This is done by snapping the front door shut around a flower with a foraging bee on it, then opening the back cover of the box to let in light, and raising the sliding divider. When the captured bee tries to escape toward the light of the window in the rear of the box, we trap it in the rear compartment by lowering the divider.
We then catch another bee in the front compartment, and lure it to the rear in the same way. This is repeated until about 10 bees have been captured, and it becomes difficult to lure a new bee into the rear compartment without admitting others in the rear to the front compartment. We then set the box down on the colored board, which is set on a rock or log, and we insert a comb filled with scented syrup into the front compartment. The divider is raised and propped up to allow the bees in the rear compartment access to the comb. Then we cover the box with a cloth to completely darken the box interior, and leave it undisturbed for about 3 minutes to give the bees time to discover and begin to feed on the syrup. Finally, we remove the cloth and gently open the front door. Usually several bees immediately flyaway, while several others remain feeding on the comb. As each of these remaining bees gets a full load, she flies off, usually circling the box to orient to this new, rich food source.

Then we wait for about 10 minutes. If conditions are favorable for beelining (good weather and not too much natural forage), the bees which fed at the comb will return, and eventually will recruit other bees from their colony. After a bee has made several trips, she becomes well oriented to the comb and will arrive and depart directly in a "bee line." We then determine the direction to her nest by taking vanishing bearings; we watch a departing bee until the point where we lose sight of her, and record the compass bearing of that point. This is facilitated by working in a clearing, so bees can be followed for some distance against the sky. Once well oriented bees are coming and going from the comb, they may be marked with individually distinguishable marks to estimate the distance to the food source. Fig. 2 shows the relationship between time from departure to return of marked bees and the distance from the bee box to the nest. Because foraging bees can stay in the nest for varying periods, minimum round trip times provide the best estimate. Even so, there is a great deal of variation in round trip times, so estimates of the nest-to-bee-box distance are approximate.

At this point, with a number of vanishing bearings and distance estimates, one can infer the general location of the nest, but this inference is subject to large error because of scatter in vanishing bearings and especially the imprecision of the relationship between round-trip time and distance to the nest. A nest's location can be better defined in two ways; by following the bee-line toward the nest or by triangulation from several locations. These two methods are appropriate to different types of studies.

![Figure 2. Relationship between the time a foraging bee is away from the bee box and the distance from the bee box to the nest. The bold line is the minimum and light line the mean of times we recorded at a feeding station moved to known distances from a colony, over open terrain. The data generally agree with related data from von Frisch (1967), Edgell (1949), and Root (1877).](image-url)
Bee-lining to Precisely Locate Individual Colonies

Determining the precise location of the nest is necessary to some studies. We accomplish this by waiting until there are many bees foraging at the bee box, and then trapping as many of these foragers as possible in the box, luring bees to rear compartment as described above, and then also shutting bees into the front compartment while they are feeding on the comb. We then move the closed box down the bee-line toward the nest as quickly and gently as possible; when we reach a new site along the bee-line, we open the box and allow the bees to fly out. The size of the jumps is strongly influenced by the nature of the terrain, but will generally be 100-200 yards (meters), until we near the nest, when smaller moves are made. As mentioned above, in forested areas it is best to jump to clearings. In more open terrain large jumps can be made in the desired direction, and bee-lining is much easier in such terrain. In time, foragers will return to the new site, and recruitment will build up their number until another jump toward the nest can be made in the direction of vanishing bearings from the new site. When a jump is made beyond the nest, the bees return much more slowly, and vanishing bearings will reverse. Once near the nest, it must be located by a careful search with eyes and ears; usually one can see bees against the sky flying to and from a tree, and sometimes one can hear their buzzing.

The time required to establish a beeline and locate the nest varies widely, depending on the distance one must cover, the terrain, and the vegetation. Our experience has been that few sites more than 1 mile (1.6 km) away are discovered, because recruitment over long distances is much less likely than over small distances. Finding a nest has taken us as little as 1 hour and as long as 3 days, at distances from 100 yards to 1 mile (100-1600 m).

Bee-lining and Triangulation to Census All Nests in an Area

Bee-lining individual colonies is time-consuming, and in broad surveys concerned with many nests, where their density and approximate locations are the only information needed, triangulation is the most appropriate technique, especially in forested areas. We conducted such a study in Cornell University's 4,045-acre (1637 ha) Arnot Forest Reserve, located at about 42°N, 76°W, near the town of Cayuta in New York State, USA (Visscher and Seeley 1982). This forest, and most of the surrounding area, consists of a patchwork of second and third growth mixed hardwoods, and occasional pine plantations, open areas and shrubby areas. The bees inhabiting the forest are descended from the colonies kept by beekeepers in nearby areas, and are of mixed racial stock of European origin. No honey bees are maintained domestically in the Arnot Forest itself, but there is a low density of hives outside its boundaries.

Taking vanishing bearings is difficult in dense forest, because the bees first circle up above the canopy, then fly homeward. In our census of the feral colonies of the Arnot Forest, we relied on the limited number of clearings in the forest which allowed good sightings, and these were also the sites where there were herbaceous flowers on which we could capture foraging bees. In each clearing, we obtained vanishing bearings from a large number of bees (see Fig. 3). Usually these included bees from two to four different colonies, as indicated by different homeward directions, with obvious clusterings of bearings by bees from the same nest. Plotting these bearings on a map, as in Fig. 3, and extending the averaged bearings until they intersected with another bearing line yielded an inferred location of the nest. These locations were confirmed in most cases by intersection of a third or fourth bearing line, and in four out of 11 cases by following bee-lines, as described above, to the very tree containing the nest (filled circles on Fig. 3). The actual locations were in all four cases within 200 yards (m) of those inferred by triangulation. A total of 11 feral colonies were censused in 13 days of bee-lining.
Figure 3. Map of the Arnot Forest showing bee-lining sites (triangles) and the observed bearings for bees as they departed these sites (arrows represent the mean of each cluster of bearings). The inferred locations of honey bee nests are indicated by circles; filled circles indicate nests which were precisely located by following bee-lines back to them. Mean bearings along the east side converge on an apiary off this map to the northeast.
General Considerations

Because many bees from the same colony flying to and from the syrup filled comb are essential to the success of bee-lining (many are lost during moves), bee-lining is only practical where there is little enough natural forage that bees readily recruit to the comb. On the other hand, since beelines must be initiated with foraging bees, bee-lining is only practical when there are bees foraging on flowers within the study site. The ideal conditions for bee-lining are when there is a low but significant level of natural forage available.

The appropriate spacing of sites for bee-lining censuses depends on the density of bee colonies in an area. In the Arnot Forest study, we established beelines at sites spaced throughout the forest about one half mile (1 km) apart, and this worked well for the density we encountered. Since multiple bee-lines were established to every nest, it is unlikely that there were any colonies within the study site which we did not detect. If the density of feral colonies had been greater, we would have needed more sites to ensure an exhaustive census, and to permit discrimination of vanishing bearings to nests located near each other. If the density had been lower, the number of sites we used would have been unnecessarily large, and we could have better spent our effort enlarging the study site. The sampling scheme of future studies should be evaluated with respect to the considerations above as the study progresses.

Bee-lining has been proposed for eradication programs for Africanized bees. Our experience suggests this will prove very difficult. Eradication presumably requires locating all of the feral colonies in an area, and this is extremely time-consuming. However, bee-lining can be a valuable technique for assessing the density of feral colonies in a limited area, and for sampling a limited number of colonies in the feral population.

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American Bee Journal, August 1989, Pages 536-539

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