Estimating Foraging Populations of Honey Bees (Hymenoptera: Apidae) from Individual Colonies

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ABSTRACT A nondestructive trapping system to capture returning honey bees, *Apis mellifera* L., at the hive entrance is described. The system provided a direct estimate of the foraging population of a colony. Each bee passed through one of 24 access tubes in the lid of a box-like trap attached to the hive entrance. Bees could crawl, but could not fly, through the 1.27-cm-diameter tubes. To trap bees, the interior tube walls were coated with paraffin oil. Upon entering the oiled tubes, the bees slipped into a mesh bag fastened under the lid inside the trap. The number of captured bees was estimated by weighing.

KEY WORDS *Apis mellifera*, foraging, population estimates, trapping

ESTIMATES OF HONEY bee, *Apis mellifera* L., colony foraging populations are useful for many purposes. Pollination effectiveness and honey-production potential of colonies are each determined in part by the size of foraging populations. Food gathering by a colony is a major, conspicuous part of the behavioral repertoire; hence, foraging populations are also of interest in basic ethological studies (Seeley 1985).

Flight activity at the hive entrance is the usual parameter that is used to estimate foraging populations (Lundie 1925, Brittain 1933, Gary 1967, Spangler 1969, Burrill & Dietz 1973, Erickson et al. 1973, Spangler 1984). Koulichkov (1971) estimated foraging populations in the field by weighing hives. Inferences made from these methods may be used to assess numbers and proportions of foraging workers indirectly. More direct estimations, by determining the number of bees actually on foraging trips at any time, could provide an additional parameter useful for evaluating colony performance. Unfortunately, the behavior of returning foragers is such that there are problems in obtaining accurate counts, particularly with large colonies. Removing foragers from a colony is also a problem because young bees soon replace the lost foraging bees (Rösch 1930). Trapping returning foragers at the hive fails if the bees are disoriented by changed visual and odor cues at the entrance. Furthermore, excessive restriction of the hive entrance may alter colony activities and cause clustering at the entrance.

Here we describe a new method and trapping system that allows direct quantification of the foraging population of a colony while avoiding problems caused by the behavioral plasticity of bees. The foraging population at any given time was estimated by trapping all flying bees as they returned to the hive.

Materials and Methods

The main functional feature of the box-like trap chamber was the removable wooden lid (6.4 mm thick) which had four parallel rows of six 2.14-cm-diameter holes (Fig. 1). The holes were centered at 4.68-cm intervals along the rows, beginning 4.79 cm from each side of the lid. In the row of holes closest to the colony, hole centers were 2.34 cm from the edge; the remaining three rows of holes were parallel to the first row at 4.68-cm intervals. Pieces of polyvinyl chloride tubing (1.27 cm inner diameter) were fitted into the holes such that the tops were flush with the upper surface of the lid. The tubes were 6.35 cm long in the two rows closest to the hive and 3.81 cm long in the two outer rows; longer tubes were used where more intensive bee traffic was expected. On the underside of the lid, a wooden rim (0.68 cm wide by 1.27 cm deep) was located 5 mm inside the edges; the rim kept the lid in place and centered on the trap body.

The forager-trap body was mounted on the front of the hive (Fig. 1 and 2) at least 2 wk before trapping foragers, to permit all bees leaving and entering the hive to learn to pass through the tubes. The diameter of the tubes allowed bees to walk, but not fly, through. The trap body was a box (33 by 23 by 23 cm) made of 3.2-mm-thick wood. The open back of the box covered most of the hive entrance; any other openings in the hive were sealed to ensure that all bees passed through the trap. The bottom board of the hive was moved backward so it was flush with the front of the lowermost brood chamber. A 6.4-by-23-cm section of the trap's bottom was cut out and replaced with 8-mesh hardware cloth (3-mm openings) to permit debris to fall through. When the trap was first installed, the screen was covered for several days so bees did not cluster beneath the trap before they learned to use the access tubes in the lid. Bee movement vertically inside the trap was aided by ladders of fiberglass screen suspended by thumbtacks from the lid and pieces of string draped through the tubes from above.

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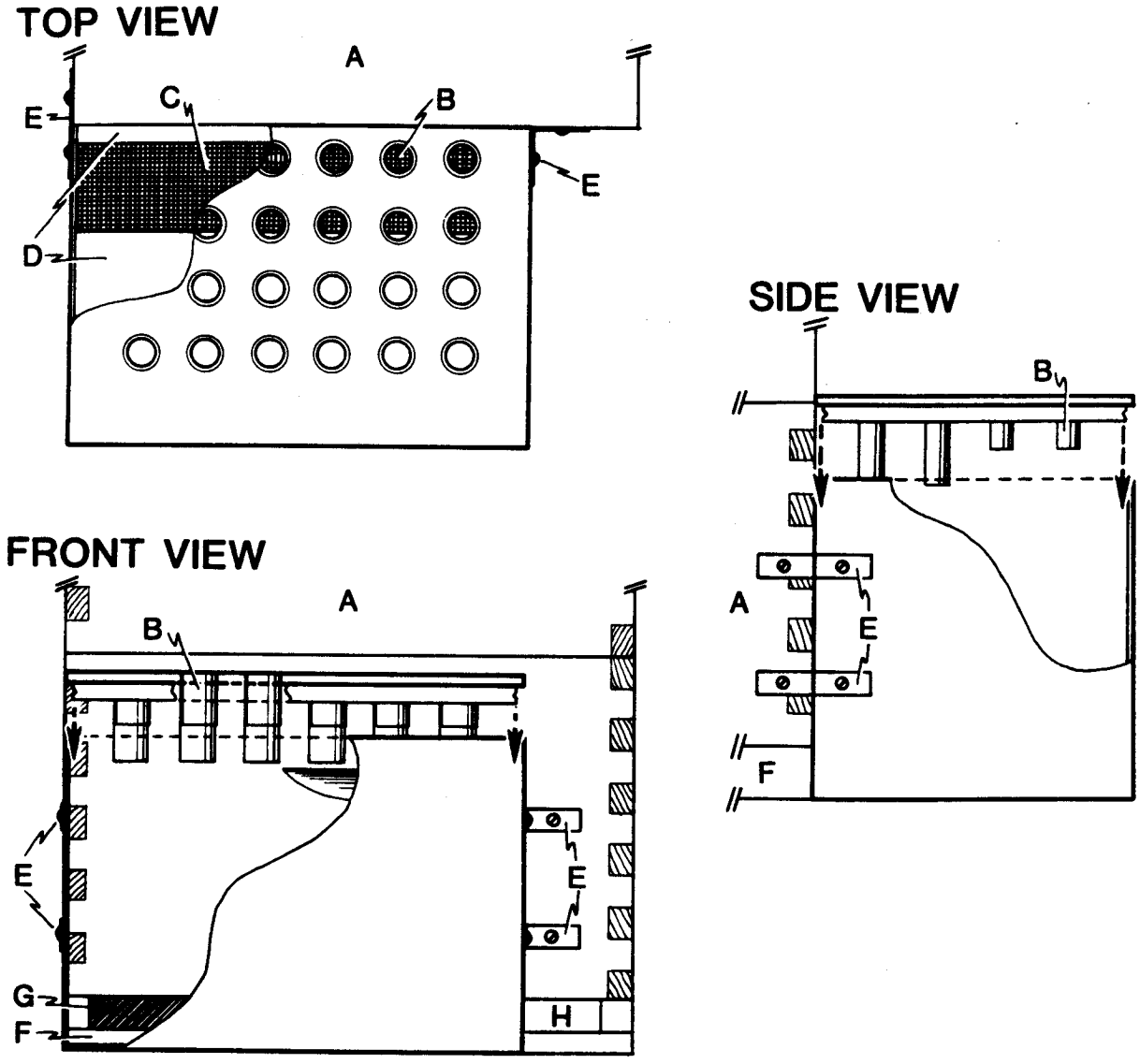

Fig. 1. Cutaway plan of forager trap in position on colony. (A) hive; (B) access tubes in lid of trap; (C) 8-mesh hardware-cloth screen in floor of trap; (D) trap floor; (E) mounting brackets; (F) bottom board of hive; (G) hive entrance; (H) block closing hive entrance beyond to trap.

Three simple trap adjustments were used to activate the trap and capture returning bees. The lid was lifted from the trap body and the screen and string ladders were removed. The bottom 4 cm of the inside surface of each access tube was coated with paraffin oil to prevent traction, thus causing incoming bees to slip and fall into a fiberglass-screen bag (32 by 22 by 22 cm) lining the inside of the trap body (Fig. 2). Finally, the open end of the collection bag was fitted over the outside of the rim inside the lid of the trap, and was secured in place with a rubber band. Activation of the trap required ca. 3 min.

The trap was allowed to collect bees until few or no bees were returning from the field (typically ca. 45 min). A few bees sometimes clung to the screen on the bottom of the trap; these bees were counted and added to the number caught in the trap. Small numbers of bees in the bag ($\leq$50) were counted directly. However, the number of foragers was usually estimated by the total weight of bees caught in the trap (full versus empty trap) and the mean weight per bee. Mean weight per bee was based on a 30- to 50-bee sample in the trap; these bees were simply retained for a second weighing after most bees had been released. The tubes were washed with a detergent solution before the lid was returned to the trap.

Results and Discussion

Foraging populations of five colonies selected randomly from an investigation that used the trap (Danka et al. 1986) exemplify the data obtained (Table 1). Colonies having different populations were tested under different nectar flow conditions.

Fig. 2. Trap on colony, showing mesh bag fastened under the lid after the tubes have been oiled. Once the lid has been replaced, the trap is activated and ready to capture returning bees.

The relationship between number of foragers and colony population is evident. Also, greater nectar availability caused an increase in foraging; this is in agreement with results of previous studies (Lundie 1925, Sekiguchi et al. 1962). With an estimated 1,500 bees per frame (Waller et al. 1985), an average of 9.5% of the colony populations were foraging when trapping occurred. Jaycox (1970) found that 4.3% of bees in small colonies were foragers.

The number of trapped bees represents the foraging population that was in the field when the trap was activated. The problems typically associated with capturing returning foragers seem to have been avoided through simplicity of theory, design, and implementation of the trapping system. Activating the trap did not seem to affect normal entry of bees into the tubes. Trapping during periods of ca. 45 min probably prevented house bees from starting to forage, which occurs when foragers are removed permanently from a colony (Rösch 1930). Constriction of the hive entrance was not a problem; bees did not cluster excessively outside the hive. Bees did not become coated with oil. The trap was inexpensive, durable, and easy to use. Performance has been verified during various times of the year in Baton Rouge and Venezuela.

Table 1. Foraging populations in colonies of various sizes and during differing nectar flows

Colony no.	No. frames covered with bees	Nectar flow[a]	No. returning bees captured ($\bar{x}$ ± SEM)[b]
12	6.3	+	1,972 ± 91
8	4.0	+	836 ± 99
9	3.5	+	832 ± 152
5	11.0	−	491 ± 163
4	7.0	−	288 ± 98

[a] +, colonies storing nectar; −, colonies consuming stores.
[b] n = 3; bees captured at peak flight activity on 3 consecutive d.

The method of trapping the entire population that was outside of a colony provides an improvement over indirect methods of estimating foraging activity. However, the dynamic nature of the foraging process makes it impossible to define the absolute size of a foraging population. Foraging intensity of a colony varies throughout the day; to increase accuracy of measurements, sampling should be repeated on several days during peak foraging activity. We used the previous days' flight patterns in choosing when to trap. Care must be taken to avoid sampling when young bees are making orientation flights.

All bees returning to the colonies probably may not have been foragers; some probably were on cleansing or orientation flights. Conversely, some members of the foraging population probably were confined inside the hive when the trap was activated. Augmenting the trapping scheme by sampling marked cohorts (Sekiguchi & Sakagami 1966, Jaycox 1970) can estimate the importance of these factors. Some of the trapped foragers can be sacrificed if necessary to collect and analyze their nectar and pollen loads (Erickson et al. 1973, Gary & Lorenzen 1976).

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