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Foraging of the Pharaoh Ant, *Monomorium Pharaonis:* An Exotic in the Urban Environment

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History and General Biology

The Pharaoh ant, *Monomorium pharaonis* (L.), is a small species ca. 2 mm long which ranges from yellow to light red. This ant was first identified as *Formica pharaonis* by Linnaeus in 1758 and was given at least six other specific names (Bolton 1987) before receiving its current name (Mayr 1862). It was thought that this species originated in South America (Arnold 1916), or the Afrotropical region (Bernard 1952); however, Bolton (1987) suggests that its origin is India, an idea that agrees with Emery (1922) and Wilson and Taylor (1967). Because it has been introduced to many parts of the world through international trade, it is doubtful its place of origin will ever be determined. Smith (1965) thought it was so common a pest as to state "the Pharaoh ant is probably found in every town or city of commercial importance in the United States". The Pharaoh ant is a major pest ant in Florida (Bieman and Wojcik 1990) and the majority of the contents of this chapter reflect research conducted in this state.

The Pharaoh ant's unusual reproductive strategy undoubtedly contributes to its pest status. Unlike many ants, this species does not require mating flights for sexual reproduction; they reproduce by budding. To start a new colony, workers carry their brood to another location. This movement may be accompanied by queens, but it is not

necessary (Peacock et al. 1955). Workers then rear sexual brood and adult reproductives to perpetuate the colony.

Budding makes the Pharaoh ant difficult to control because there are often groups of related nests instead of only one. Factors that influence budding include changes in the environment such as temperature and food and water resources, or overcrowding (Edwards 1986). The presence of insecticides is also suspected to cause budding (Green et al. 1954).

Nest location can also make control difficult. Nests are usually located in inaccessible or difficult to reach areas for the pest control operator, including interior wall voids, areas under or behind window sills, toilets, sinks, switch plates, lights, etc. Edwards (1986) suggests that any warm area with high humidity can serve as a nest site. We have noticed at several hotels, motels and hospitals in North Florida that aluminum window and door frames are a popular nest site. Although there are reports that suggest the Pharaoh ant nests outdoors in South Florida (Creighton 1950), in temperate (nontropical or nonsubtropical) regions it usually nests indoors (Kohn and Vlcek 1986). In North Florida, we observed ants foraging both indoors and along the outdoor periphery of the building. Further south in areas such as Tampa, foraging is seen further from structures with trails often following fences.

Pharaoh ant foraging has been described by Sudd (1957, 1960). To initiate their search for a food source, scouts followed routes along cracks or edges of structures, a phenomenon described by Klotz and Reid (1992) as guideline orientation. As the scouts approach a food source, the trails branch. The return trips to the nest were more direct than the outgoing trips possibly indicating workers use visual orientation as well as odor trails. Workers in the nest were recruited by stimulating them to search for food. This stimulation was accomplished by workers returning to and rushing about the nest without any apparent stimulatory contact with other workers. Food location was identified by following the trail pheromone, faranal, which was laid by the scouts. Foragers also reinforced the trail pheromone. Faranal ($C_{17}H_{30}$), is a terpenoid produced by the Dufour's gland (Ritter et al. 1977).

Pharaoh ant control currently emphasizes the use of toxic baits. For a review and history of control methods, see Edwards (1986). Insecticidal sprays and dusts are often ineffective because they only affect a small percentage of the workers that forage (Williams 1990) and may also cause budding which amplifies the problem. Multiple nests within a relatively small area also reduce the effectiveness of sprays. Residual sprays may be used to reduce foragers in sensitive areas such as surgery and neonatal care units in hospitals, but use of sprays in hospitals is severely restricted in Florida. Unlike sprays which usually do not contact a nest, a toxic bait can be transported to the nest by foragers which feed on the bait and then distribute the toxin throughout the colony by trophallaxis.

Stomach poisons or insect growth regulators (IGRs) are the active ingredients in toxic baits. Stomach poisons used in some commercial baits include Maxforce Pharaoh Ant Killer (hydramethylnon, Clorox Co., Pleasanton, CA), Raid Max Ant Bait (sulfluramid, S. C. Johnson, Racine, WI), Pro-Control (sulfluramid, Micro-Gen Equipment Corp., San Antonio, TX), Drax Ant Kil Gel (orthoboric acid, Waterbury Co. Inc., Waterbury, CT)) and Terro Ant Killer II (sodium tetraborate decahydrate [borax], Senoret Chemical Co., St. Louis, MO). An early recommendation for Pharaoh ant control was the use of borax and sugar dissolved in boiling water and placed on broken crockery (Riley 1889). Although our use of boric acid in laboratory evaluations has given variable results, pest control operators (PCOs) use this option because they can choose the attractant. Foraging workers are attracted to many compounds and the PCOs mix the boric acid with their choice of attractive ingredient or combination of ingredients.

Currently, the only insect growth regulator registered for Pharaoh ant control is methoprene, marketed under the name of Pharorid (Zoecon Corp., Dallas, TX). IGRs are much slower acting than stomach poisons because typically only the queen and brood are affected. Methoprene induces sterility in queens and disrupts the brood stages (Edwards 1975). Workers are unaffected and are still evident for weeks or months after treatment. Because the maximum worker life span at $27^{0}C$ is estimated at 9-10 weeks (Peacock and Baxter 1950), they may be present long after queens have ceased egg production and the brood has died. The advantage of using insect growth regulators is that they are more likely to be distributed throughout the entire colony because they do not adversely effect workers. Also IGRs are more acceptable to the consumer since they are considered safer compounds. The oral LD_{50} of methoprene to rats is >34,000 mg/kg (Ware 1983).

Stomach poisons work relatively fast compared to IGRs, i.e., worker numbers are reduced in a few days and complete colony elimination can occur in a few days to a few weeks. However, stomach poisons may work too quickly, thereby eliminating the worker force before the insecticide can be distributed to the entire colony. Relatively few workers and brood need to survive to perpetuate the colony. Peacock et al. (1955) have reported just 100 workers and 50 pieces of brood can initiate a successful colony. Vail (unpublished data) has found that 5 workers and 30 eggs, 19 larvae and 3 pupae can start a new colony.

Foraging study

In July 1990, we were asked to control a Pharaoh ant infestation at the Bachelor Officer's Quarters (BOQ), Jacksonville Naval Air Station, Jacksonville, FL. Fenoxycarb (Maag Agrochemicals now part of Ciba-Geigy, Greensboro, N.C.) an insect growth regulator, was evaluated for control of the Pharaoh ants in this approximately 7841 m^2 facility (Williams and Vail 1993b). Fenoxycarb affects Pharaoh ants similarly to methoprene: it decreases brood and egg production and has little effect on Pharaoh ant workers (Williams and Vail 1993a). The east wing (2319 m^2) of the BOQ was treated with Raid Max Ant Bait, the west wing (2040 m^2) with 0.5% fenoxycarb, and the south wing (2787 m^2) with 1% fenoxycarb. All wings, except the north wing, consisted of two floors. The north wing (412 m^2), which was separated from the other wings by a large auditorium, served as a control. Fenoxycarb baits were formulated by weight in peanut butter oil and this oil/IGR solution was then applied to a pregel defatted corn grit at 30% by weight.

Within six weeks after the last treatment, no ants were found in the Raid Max or 0.5% fenoxycarb-treated wings. Ants were still present in the 1% fenoxycarb-treated and control wings. Although ants were found in the Raid Max-treated wing at 12 wk, a re-application of baits at week 12 and 14 killed the remaining colonies because no ants were detected after this treatment. Ants were not found again until week 24 in the 0.5% fenoxycarb-treated wing indicating the IGR gave at least 18 weeks of control.

The presence of ants in the 0.5% fenoxycarb-treatment suggested to us that foragers from the south wing were entering the west wing where a vending machine area was located. To determine if Pharaoh ants could travel that distance for food, a foraging study was initiated. Sudd (1957, 1960) reported on foraging, recruitment and communication of Pharaoh ants, and Haack (1987) studied food flow in small colonies of the Pharaoh ant, but neither observed foraging in a building the size of the BOQ with such a large Pharaoh ant infestation.

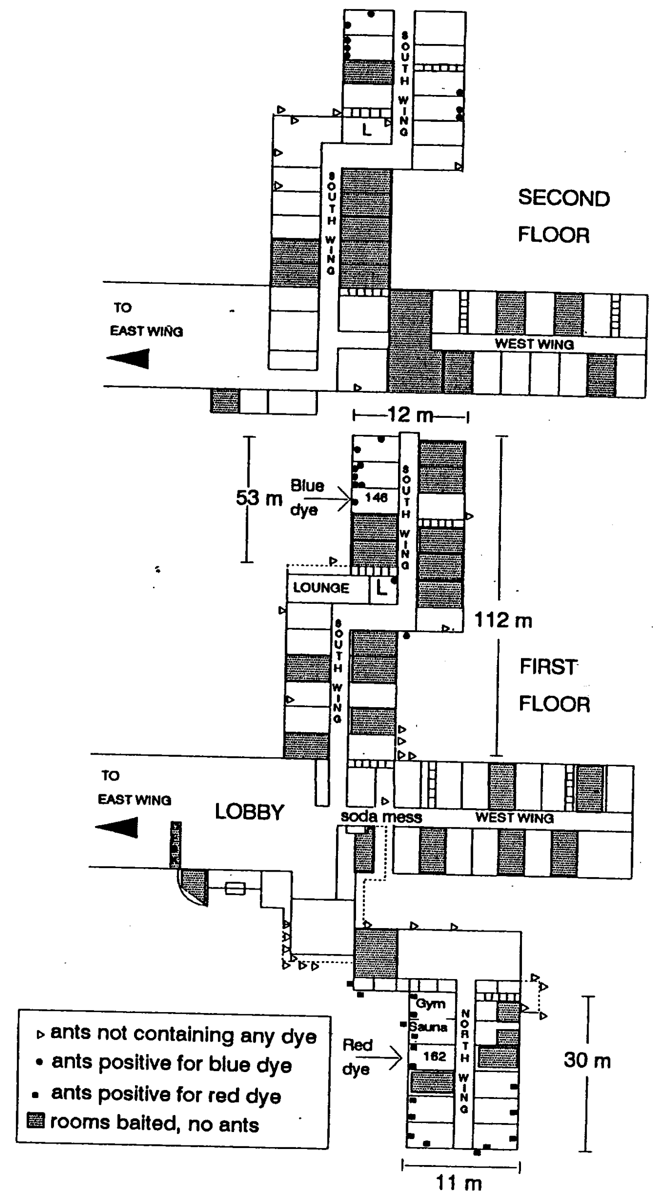
Materials and Methods

On 18 March 1991, Pharaoh ants were monitored at the BOQ by placing two to six baits per room (one to two in the bedroom and living room windows, and two on bathroom floors where applicable) in preselected rooms in all wings. The bait consisted of 2 cc's of natural peanut butter applied from a syringe onto an index card. Two h later, the baits were checked for the number of Pharaoh ants and removed. A bait card holding 6 cc's of 2% calco red dye formulated in peanut butter was placed in room 162, the room with the highest Pharaoh ant count in the north wing. A similar bait card with 6 cc's of 2% calco blue in peanut butter was placed in room 146, the room with the highest infestation in the south wing. Laboratory tests indicated that the dyed peanut butter did not cause mortality. Dye mixtures were left in place for 4 d, until 22 March 1991. On this day, we removed the baits containing dyed peanut butter mixtures and baited the BOQ again with plain peanut butter as on 18 March 1991 except that baits were not applied to the east wing because ants were not found there on 18 March 1991. We also placed baits on the ground near the outside perimeter of the building starting from the entrance by the desk continuing around the north, west and south wings in a counter-clockwise direction until we reached the east wing (see Figure 20.1). After 2 h, we collected the plain peanut butter baits. We tapped any ants found at the baits onto white paper, folded the paper over, placed the paper on a clipboard and crushed the ants with a heavy metal roller. If ants contained dye, we recorded the location where they were collected on a data sheet (drawn on a map for outside baits) and on the white paper on which they were crushed. The distance from the dyed bait at which ants containing dye were found was determined and noted. The percent of workers containing dye on each card was determined in the laboratory the next day.

We returned to the BOQ on 29 March 1991 (dyed baits had been removed for 7 days) and repeated the procedures of 22 March 1991 with a few exceptions. Only the lounge, soda mess (vending machine area) and rooms 228 and 229 were baited in the west wing. Also, baits found with ants were picked up and placed in a Ziploc® bag and the location marked on the bag. We placed the bags in a cooler with ice and then placed them in a freezer in the laboratory upon our return. The locations where ants were collected, percent of ants containing dye and foraging distance were determined in the laboratory.

Foraging distance was calculated under several assumptions. We assumed ants foraged along the outside wall because previous work in the BOQ indicated the majority of foragers were found near walls, windows or pipes. When ants were found in rooms on the other side of the building from where the dyed baits were placed, we assumed that they travelled along structural guidelines (Klotz and Reid 1992) following right angles because they would either be following pipes or beams. Sudd (1960) found Pharaoh ants using trails that followed edges of doors and floors. Also, we assumed that the colony was near to the position where the dyed baits were placed, since these positions had the highest infestations in each wing on 18 March 1991. All foraging dis-

FIGURE 20.1. Results of Pharaoh ant baiting in the BOQ on 22 March 1991. Building plan is drawn to show the locations of the wings and the baits, and is not drawn to scale.



tances were measured from the position of the dyed bait. We verified the foraging distance measurements by using blueprints obtained from the public works department at the Jacksonville Naval Air Station.

We calculated foraging distance and compared foraging (number of ants at bait, percent marked and foraging distance) of ants outside to ants indoors using general linear models (GLM) (SAS Institute 1988). The same variables were compared for the two dates using the same test.

Results and Discussion

Both marked and unmarked ants were found on the plain peanut butter bait cards collected both indoors and outdoors on 22 March (Figure 20.1) and 29 March 1991 (Figure 20.2). In both the north and south wing, Pharaoh ant foraging was extensive. Both horizontal and vertical movement of foragers was detected. Marked foragers were found in rooms on the same side of the hall and across the hall from where the baits were placed (Figures 20.1 and 20.2) as well as on the floor above. The foraging territory (area where dyed ants were detected) was increased on the second monitoring date in the north wing. Ants were found containing dye further south on the west side of the building.

The results presented hereafter shall only refer to baits containing marked ants. The mean foraging distance (±SD) for both dates combined was 16.2 ± 9.6m. The maximum distance a dyed ant was found from the dyed bait card was 45 m. This was greater than that found by Sudd (1960), Peacock and Baxter (1949) and Ritter et al. (1977). The longest Pharaoh ant trail that Sudd (1960) measured in houses in Nigeria was 9.5 m. Peacock and Baxter (1949) measured a 12.2 m trail in Scotland. Ritter et al. (1977) mentions that Pharaoh ant trails are many meters long. The foraging distances recorded at the BOQ indicated the ants did have the potential to travel from one wing to the other.

The mean number of ants per bait card (117.2 ± 96.1) indicates the severity of the infestation. A mean of 49.9 ± 40.8% of the foragers crushed on the paper contained dye. There was a very weak negative relationship between the percent of the ants marked and the distance from the dyed bait (% marked=80.90-12.91*[ln(meters from the bait)], r^2=0.14). Percent of workers found containing dye on 29 March was significantly less than those found containing dye on 22 March 1991 (Table 20.1).

FIGURE 20.2. Results of Pharaoh ant baiting in the BOQ on 29 March 1991. Building plan is drawn to show the locations of the wings and the baits, and is not drawn to scale.

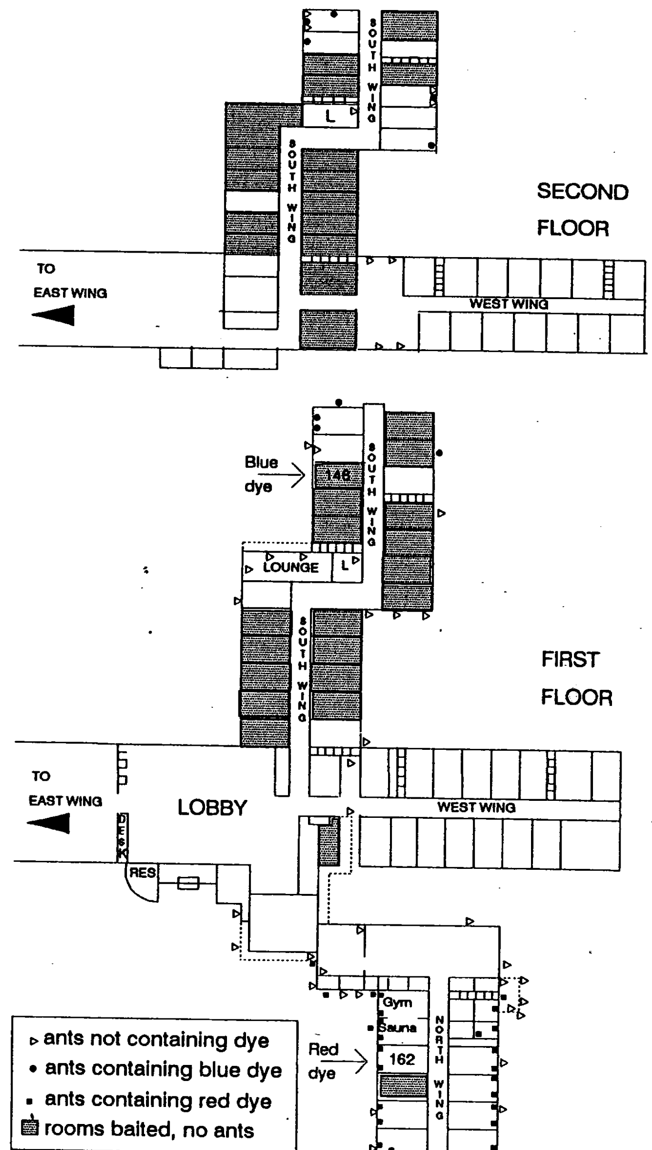


TABLE 20.1. Comparison by sampling date of percent workers containing dye, number of ants per bait card containing dye, and foraging distance

	3/22/91 Mean (SE)	3/29/91 Mean (SE)
% workers with dye[a]	74.7(6.0)	26.6(5.5)*
number ants/card[b]	98.8(13.7)	136.1(18.2)NS
foraging distance (m)[c]	15.7(1.7)	16.7(1.6)NS

[a]percentages were arcsine transformed before GLM (F=33.7; df= 1,64; P=0.001) was performed. Untransformed percentages are presented.
[b](F=2.7; df=1,67; P=0.11).
[c](F=0.16; df=1,67; P=0.69)
*significant, NS=not significant.

Foraging distance along the outdoor periphery was significantly longer than that occurring indoors (Table 20.2). However, the number of ants per card was higher indoors than outdoors indicating that more workers were foraging indoors than outdoors. A similar study conducted in quadraplex units (buildings consisting of four apartments) in September and October in north Florida indicated a majority of the Pharaoh ant foraging occurred outdoors (Oi et al., in review).

TABLE 20.2. Comparison by indoor and outdoor foraging environment of percent workers containing dye, number of ants per bait card containing dye, and foraging distance.

	Indoors Mean (SE)	Outdoors Mean (SE)
% workers with dye[a]	49.9 (5.4)	50.4 (14.1)NS
number ants/card[b]	128.4 (13.0)	64.0 (18.4)*
foraging distance (m)[c]	14.8 (1.2)	22.6 (2.7)*

[a]percentages were arcsine transformed before GLM (F=0.01; df=1,64; P=0.94) was performed. Untransformed percentages are presented.
[b](df 1,67 F=4.7, P=0.03).
[c](df 1,67 F=7.11, P=0.01).
*significant, NS=not significant.

Because dyes used could be spread to other colonies through trophallaxis, we are uncertain whether we measured the foraging of one colony, several colonies or the degree of trophallaxis between colonies.

Because of the lack of aggression between colonies, these colonies could be considered one supercolony. A supercolony as defined by Holldobler and Wilson (1990) is a "unicolonial population, in which workers move freely from one nest to another, so that the entire population is a single colony". This study documented the spread of a bait through an area, regardless of whether one colony or several colonies fed on the bait. Less than 6 cc's and 2 cc's of peanut butter was spread throughout the north and south wing, respectively, indicating that the use of baits as a control for Pharaoh ants should be very efficient.

To better quantify foraging of Pharaoh ants, a dye should be used that would mark workers and could be observed without killing the ant yet not be transferred to other individuals through trophallaxis. A dye which marks fat bodies would achieve these results; however, such a dye has yet to be located. Also, offering the baits containing dye for a shorter period of time may ensure that foragers from only the closest colony would have time to find the bait and be marked. Such modification of our techniques may allow for the estimation of colony size using a mark-recapture method similar to that developed by Su and Scheffrahn (1988) for termites. The ability to estimate colony size would enhance greatly the development of more judicious and efficient methods of Pharaoh ant control.

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Resumen

El regulador del crecimiento, Fenoxycarb, fue muy efectivo contra la hormiga faraona, *Monomorium pharaonis* (L.). El fenoxycarb, reduce la producción de abejas en las hormigas reina y las colonias mueren debido a la atrición. Los mejores resultados de experimentos de laboratorio se obtuvieron al usar concentraciones de 0.25, 0.5 y 1% en aceite de mantequilla de maní. Doce semanas después, estas concentraciones redujeron significativamente el numero de obreras y el numero de cría fue reducido a las 5 semanas o antes; sinembargo, se necesitó mas de un cebo para eliminar completamente las colonias. En algunas pruebas, las colonias alimentadas con cebos en concentraciones de 0.1, 0.25 y 0.5%

tuvieron una demora significativa en la producción de individuos alados. Cuando se utilizaron concentraciones menores (0.05, 0.1 y 0.25%) se observó que en las castas intermedias, los individuos eran mas grandes que las obreras, pero mas pequeños que las reinas. Las concentraciones altas de 2.5 y 5% no fueron efectivas quizás por la repelencia de las hormigas al material. Estos resultados demuestran que fenoxycarb es tan efectivo para el control de la hormiga faraona como el cebo comercial, Pharorid (metropeno).

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