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A method for using ice to construct subterranean ant nests (Hymenoptera: Formicidae) and other soil cavities

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Abstract

Burial of a nest formed of ice in the shape of a subterranean ant nest forms an underground facsimile of a nest after melting. Any desired level of similarity to natural ant nests can be achieved. Such nests can be used as tools for the study of ant nest architecture, or to provide ready homes for study colonies.

Key words: Ant nest architecture, nest chambers, Formicidae, harvester ants, *Pogonomyrmex badius*, ant nests, ice molds, trap nests.

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Introduction

The introduction of high-strength dental plaster for making of casts of ant nests boosted the study of subterranean ant nest architecture (WILLIAMS & LOFGREN 1988). TSCHINKEL (2010) recently described several methods for casting ant nests using dental plaster, molten aluminum, molten zinc, and paraffin wax. It is now possible to render the empty spaces of ant nests as solid casts of exquisite detail (TSCHINKEL 2003, MIKHEYEV & TSCHINKEL 2004, TSCHINKEL 2004, 2005, CERQUERA & TSCHINKEL 2009, TSCHINKEL 2011), and thus to provide objects that record exactly what ants have constructed underground. The contrary has thus far not been possible, that is, to provide the ants with a subterranean nest constructed with experimental specifications. Offering architectural variations to ants to see how they accept or modify them could be a useful method for exploring nest excavation by ants. Returning excavated and censused (and possibly modified) colonies to nests similar to the ones from which they were excavated could avoid a large part of the energetic and risk costs of digging a new nest on their own, and improve the success of field experiments.

In this paper, I describe a method based on the burial of a nest constructed of ice. The hollow space that remains after the ice melts is a facsimile of the ant nest as designed by the experimenter. Although the examples shown here pertain to the Florida harvester ant, *Pogonomyrmex badius* (LATREILLE, 1802), the method can be adapted to a wide range of species.

Materials and Methods

Making ice molds: Trays were constructed of 1 cm wide strips of copper sheet, soldered to a copper sheet base with ordinary solder and a propane torch. The strip was first bent into the desired shape, and then clamped to the copper sheet base with document clips. Once the base was heated with the propane torch, the solder flowed to create a water tight joint between the rim and the base (Fig. 1).

Almost any shape of chamber from simple to complex can be created with these molds (Fig. 2). The molds were filled with water to a depth identical to the typical chamber height, and frozen. The ice was released by running cold water on the back of the mold, thawing a thin layer around the ice, releasing it from the mold (Fig. 3). The ice casts were returned to the freezer for storage.

Installing the ice casts: Ice nests were constructed in the deep, sandy soils of the Apalachicola National Forest, 16 km SW of Tallahassee. The ice chambers were transported to the field on dry ice, and kept on dry ice until immediately before installation. In addition to the frozen chambers, the installation required a plastic tube of the same diameter as the shafts of a natural nest. A pit large enough to work in was dug to the intended maximum nest depth. A frozen chamber was selected and a semicircular notch filed in one side to receive the plastic tube (Fig. 4a, b). The chamber was placed on the flat bottom of the pit and the plastic tube placed into the notch. This assembly was immediately covered with moist soil and packed down (Fig. 4c, d). Moist soil was added and packed until the spacing to the next chamber had been achieved. At this point, another chamber was placed with its notch engaging the plastic tube, and the packing of soil repeated. This procedure was repeated with the desired chamber spacing and orientation until about 30 - 40 cm of soil had been packed. The tube was then carefully withdrawn until only about 15 cm remained in the soil (this was more easily achieved when the tube had been previously marked 15 cm from its end). The procedure was repeated until the tube was finally withdrawn completely when the packed soil was even with the ground surface.

As the ice melted, it left a cavity in the soil of the exact shape and size of the frozen chamber mold. The withdrawal of the plastic tube created a shaft connecting all these hollow spaces, as well as providing an opening into the artificial nest from the surface.

To test the effectiveness of the method in a different soil type, an ice nest was also constructed in the deep-red, clay-rich soil of Tallahassee, Florida.

Installation of an ant colony: Harvester ant colonies (*Pogonomyrmex badius*) were released in a screen-bottom cage that had a hole in the screen positioned over the entrance to the artificial nest. Under these conditions, the ants immediately moved into the nest. The reduced energetic cost of digging a new nest, as well as the reduced exposure on the ground surface reduced stress and mortality, mitigating their effects on experimental treatments and improving post-excavation worker and colony survival.

Visualizing the artificial "ice nest": To check the success of this method, completed "ice nests" were cast in aluminum using the methods described in TSCHINKEL (2010).

Results and Discussion

Figure 5a, b shows that the subterranean structure created with ice is very similar to a natural, ant-excavated nest. With more care and work, greater similarity can easily be achieved. Practicing the method will reveal some finer points: (1) The chambers must be dry ice temperature when planted; (2) ice chamber thickness must be carefully standardized; (3) the tubing should fit snugly into the notch in the ice chamber; (4) the soil used for packing should be moist; (5) soil should be held down while the tubing is being drawn through the fingers; (6) if the ants are not to be released into the nest immediately, it is best to cut off the last 15 cm of tubing, leaving it in the nest to keep the entrance open. At the time of ant release, the piece of tubing should be withdrawn.

The sandy soils of our *Pogonomyrmex badius* study site in the Apalachicola National Forest are particularly suited for making casts of ant nests (TSCHINKEL 2010), and also for making ice nests. Other soils might be less suitable, requiring adjustments in the method. However, an ice nest in the more clay-rich soils of the Tallahassee Red Hills (Fig. 5c) was no more difficult to construct than was that in the sandy soils of the Apalachicola National Forest.

The "caliber" of the ant nest to be constructed is important. Whereas large ice nests such as those for *Pogonomyrmex badius* are easy to construct, as the nests of other species become finer and smaller, the construction and installation of an ice nest becomes ever more challenging. Clearly, there are lower limits, although these remain to be tested, and may yield to improved technology.

Whereas trap nests constructed of wood or straws have long been a standard method for studying cavity-nesting Hymenoptera (for example, CAMILLO 2005), including ants (e.g., BANSCHBACH & HERBERS 1999, DAVIDSON & al. 2006, PHILPOTT 2010), to the best of my knowledge, this is the first method for constructing subterranean nests that can mimic the architecture of natural ones.

This method opens new avenues of research. Once the relationship between colony size (worker number), total

Fig. 1: Close up view of an ice mold showing the water tight solder joint.

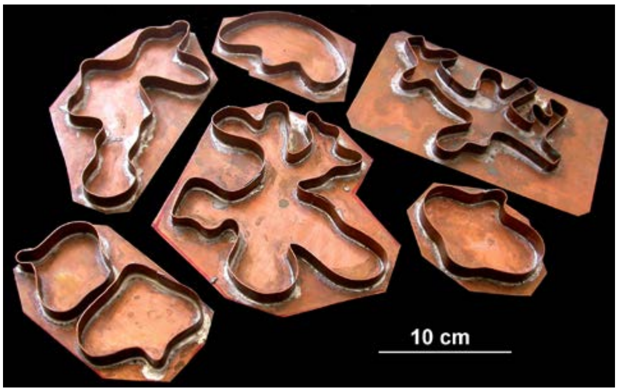

Fig. 2: The ice molds can be made in a wide range of sizes and shapes. These may be based on the natural chamber shapes (as shown here), or deviate from the natural shapes to suit the conditions of experiments.

Fig. 3: An ice chamber freed from its mold. This chamber should be cooled with dry ice before planting in the soil.

chamber area and nest architecture have been established, it becomes possible to test the behavioral rules that govern the excavation of ant nests. Using ice nests, the ants could be offered alternative artificial nest architectures that varied any element of nest architecture (TSCHINKEL 2003): chamber size, shape, orientation, spacing and connections. The modifications that the ants make to these altered nests, as revealed by casting, could reveal the "rules" of construc-

Fig. 4: The steps for creating an ice nest: (a) An ice chamber, ready to plant. (b) Filing the notch into the ice chamber to accommodate the plastic tube. (c) The chamber is placed on the soil and the tube engaged in the notch. (d) Soil is packed over the chamber to a depth equal to the spacing to the next chamber above.

tion. As a more specific example: Laboratory experiments have shown that group size, worker density and substrate type affect nest shape and digging activity (RASSE & DENEUBOURG 2001, BUHL & al. 2004, 2005, TOFFIN & al. 2009, 2010). Thus, one could test the question: Does worker density and therefore digging intensity affect chamber shape? Using ice nests, one could introduce the "natural" density of workers and multiples of this density. Casting these nests when the workers have enlarged them all to the same size (as estimated from the quantity of excavated soil) would reveal if the digging rate / intensity itself affects chamber shape and other aspects of nest architecture. By varying the initial chamber shape in these experiments one could test the effect of both worker density and chamber shape. Repeating such experiments with ice nests in different soil types would reveal the interaction of substrate with worker density and chamber shape.

Some other examples: One could reverse the vertical distribution of chamber sizes (chambers of many species become smaller with depth) while maintaining the same total chamber area. When a "natural" sized colony is planted in both natural and reversed ice nests, do the ants modify the vertical distribution of the reversed nest? Doing so would suggest that the ants respond to the distribution of area in addition to the total area. When the workers of one species are planted in the nest architecture of another, do they alter this architecture? Alteration we would suggest that they are responding to details of nest architecture, not simply to total area. The nest contents are also subject to experimentation: One could freeze seeds (or other contents) into the ice chambers and thus control their location in the resulting nest. If the ants move them, this would suggest that they actively prefer some locations over others.

Finally, and not trivially, after census or experimental modification, ant colonies could be returned to subterranean nests at greatly reduced energetic or mortality cost to them. We have used this procedure on *Pogonomyrmex badius* with great success, and it could easily be adapted to other species. The value of this particular application of ice nests is not that it indulges one's soft-heartedness, but that it could (and should) open the path to more experimentation on natural colonies that have been modified in the lab and returned to the field for the course of the experiment. For example, one could address the value of major workers in dimorphic species such as *Pheidole* spp. by modifying colony caste make-up, replanting the colonies in ice nests and tracking their subsequent performance. Many such experiments suggest themselves, and could move ant research beyond the artificial and unnatural circumstances of the laboratory.

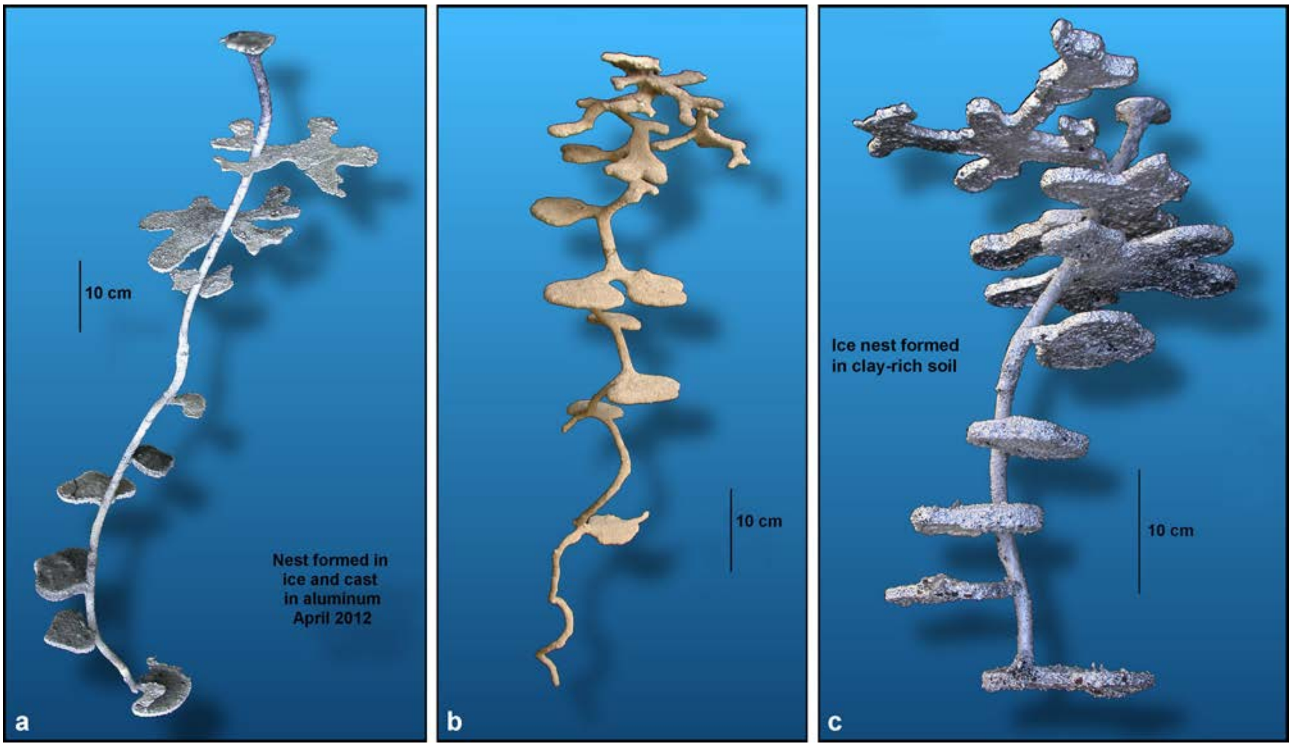

Fig. 5: Casts of an artificial "ice nest" (a), and a small, ant-dug nest (b). With more attention to details and more work, any desired level of similarity (or difference) could be achieved. (c) Cast of an ice nest made in the more clay-rich soil of Tallahassee, Florida.

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