Ant Parameter Specifications for the Area 5 and Area 3 RWMS Models

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Prepared by

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Neptune and Company, Inc.

1. Title: Ant Parameter Specifications for the Area 5 and Area 3 RWMS Models

2. File Name: Ant Parameter Specifications.sxw

3. Describe Use: This documents the statistical development of parameters used to define ants in the Area 5 RWMS model.

	Printed Name	Signature	Date
4. Originator	John Tauxe		17 Feb 2005
5. Reviewer	Michele Wolf		28 Mar 2005

6. Remarks:

This document was rebuilt using the OOoW template, and incorporates the ant model used in the Area 5 RWMS Model v3.0 et seq. The editing log starts at this point, even though Tom Stockton is the original author. The data contained in this report were used as the basis for the Area 5 RWMS Model v3.0.

Several automation features were added, in particular all figures (these use the Illustration style in this document), equations, and tables were given automated cross-references, and references in the Summary section to specific parts in the text (e.g. to the discussion of a distribution derivation) are linked to reference codes in the text in order to simplify QA.

Some references, such as parameter values in the Summary cross-referenced to text passages, are inserted near where the value is mentioned. These are inserted using the command Insert **|** Cross-reference **|** tab: References **|** item: Set Reference. Very handy.

Note that since OOoW does not use font formatting in the tables contents, figures, or tables, a bit of touching up (italics, subscripts, etc.) might be necessary after any of these tables is updated.

r3.02: Modified formatting in headers and footers.

r3.03: Fix minima (as reported in the Summary) for distributions of the burrow density with depth parameters *a* and *b* to 1.

CONTENTS

FIGURES

TABLES

1.0 Area 5 Summary

Listed below are the ant fate and transport model parameter distributions for version 4.0 of the Area 5 Radioactive Waste Management Site Model summarized in this document:

- *Pogonomyrmex* spp. nest volume:
  \TransportProcesses\AnimalTransport\Ant1Data\NestVolume

  ~ N(0.64, 0.091, min = 0, max = arbitrarily large) [m^3] (Figure 1 and page 5)
- *Messor pergandei* nest volume:

  \TransportProcesses\AnimalTransport\Ant2Data\NestVolume

  ~ N(0.94, 0.26, min = 0, max = arbitrarily large) [m^3] (Figure 2 and page 6)
- *Pogonomyrmex* spp. colony density:
  \TransportProcesses\AnimalTransport\Ant1Data\ColonyDensity

  ~ N(28, 4, min = 0, max = arbitrarily large) [colonies per hectare] (Figure 4 and page 10)
- *Messor pergandei* colony density:
  \TransportProcesses\AnimalTransport\Ant2Data\ColonyDensity

  ~ N(4.7, 1.8, min = 0, max = arbitrarily large) [colonies per hectare] (Figure 5 and page 10)
- *Pogonomyrmex* spp. colony lifespan:
  \TransportProcesses\AnimalTransport\Ant1Data\ColonyLifespan

  ~ N(20.2, 3.6, min = 1e-20, max = arbitrarily large) [years] (page 16)
- *Messor pergandei* colony lifespan:
  \TransportProcesses\AnimalTransport\Ant2Data\ColonyLifespan

  ~ N(9, 1.5, min = 1e-20 , max = arbitrarily large) [years] (page 16)
- *Pogonomyrmex* spp. *b* parameter for burrow density as function of depth:
  \TransportProcesses\AnimalTransport\Ant1Data\b

  ~ N(10, 0.71, min = 1, max = arbitrarily large) (Figure 11 and page 21)
- *Pogonomyrmex* spp. Maximum Depth:

  \TransportProcesses\AnimalTransport\Ant1Data\MaxDepth = 244 [cm]
- *Messor pergandei b* parameter for burrow density as function of depth:
  \TransportProcesses\AnimalTransport\Ant2Data\b

  ~ N(8.4, 1.5, min = 1, max = arbitrarily large) (Figure 12 and page 21)
- *Messor pergandei* Maximum Depth:

  \TransportProcesses\AnimalTransport\Ant2Data\MaxDepth = 415 [cm]

2.0 Area 3 Summary

Listed below are the ant fate and transport model parameter distributions for version 2.0 of the Area 3 Radioactive Waste Management Site Model summarized in this document:

- *Pogonomyrmex* spp. nest volume:
  \TransportProcesses\AnimalTransport\Ant1Data\NestVolume

  ~ N(0.64, 0.091, min = 0, max = arbitrarily large) [m^3] (Figure 1 and page 6)
- *Myrmecocystus mexicanus* nest volume:

  \TransportProcesses\AnimalTransport\Ant2Data\NestVolume

  ~ N(0.065, 0.015, min = 0, max = arbitrarily large) [m^3] (Figure 3 and page 6)
- *Pogonomyrmex* spp. colony density:
  \TransportProcesses\AnimalTransport\Ant1Data\ColonyDensity

  ~ N(28, 4, min = 0, max = arbitrarily large) [colonies per hectare] (Figure 4 and page 11)
- *Myrmecocystus mexicanus* colony density:
  \TransportProcesses\AnimalTransport\Ant2Data\ColonyDensity

  ~ N(4.3, 0.46, min = 0, max = arbitrarily large) [colonies per hectare] (page 11)
- *Pogonomyrmex* spp. colony lifespan:
  \TransportProcesses\AnimalTransport\Ant1Data\ColonyLifespan

  ~ N(20.2, 3.6, min = 0, max = arbitrarily large) [years] (page 16)
- *Myrmecocystus mexicanus* colony lifespan:
  \TransportProcesses\AnimalTransport\Ant2Data\ColonyLifespan

  ~ N(22.7, 8.8, min = 0 , max = arbitrarily large) [years] (Figure 6 and page 16)
- *Pogonomyrmex* spp. *b* parameter for burrow density as function of depth:
  \TransportProcesses\AnimalTransport\Ant1Data\b

  ~ N(10, 0.71, min = 1, max = arbitrarily large) (Figure 11 and page 21)
- *Myrmecocystus mexicanus b* parameter for burrow density as function of depth:
  \TransportProcesses\AnimalTransport\Ant2Data\b

  ~ N(3.4, 0.38, min = 1, max = arbitrarily large) (page 21)
- *Pogonomyrmex* spp. maximum depth:

  \TransportProcesses\AnimalTransport\Ant1Data\MaxDepth = 2.44 [m]
- *Myrmecocystus mexicanus* maximum depth:

  \TransportProcesses\AnimalTransport\Ant2Data\MaxDepth = 2.15 [m]

3.0 Introduction

While ants fill a broad ecological niche on the NTS as predators, scavengers, trophobionts and granivores, it is their role as burrowers that is of main concern herein. Ants burrow for a variety of reasons but mostly for the procurement of shelter, the rearing of young and the storage of foodstuffs. How and where ant nests are constructed play a role in quantifying the amount and rate of soil movement to the soil surface on the NTS. Factors relating to the physical construction of the nests, including the size, shape, and depth of the nest, are key to quantifying excavation volumes. Moreover, factors limiting the abundance and distribution of ant nests such as the abundance and distribution of plant species, intra-specific competitors or inter-specific competitors also can affect excavated soil volumes. Thus, parameterization of burrowing activities necessarily includes evaluating nest area, nest depth, rate of new nest additions, excavation volume, excavation rates, colony density and colony lifespan. These attributes are described in this section along with other considerations involving the impact of ant species on the NTS and their inclusion in the both the Area 5 and Area 3 RWMS models. Each section contains the following considerations:

- Determine the data sets that pertain to the construction of the ant biomass transport component. Evaluate whether those data pertain to the RWMS Area 5 or Area 3 site on the NTS and where they are lacking.
- Identify which of the ant species overwhelmingly contribute to the rearrangement of soils near the surface. Furthermore, group those species into two functionally similar categories called “ant1” and “ant2” for modeling, where these two categories are *Pogonomyrmex* spp. and *Messor pergandei* respectively for Area 5 and *Pogonomyrmex* spp. and *Myrmecocystus mexicanus* respectively for Area 3.
- Calculate soil and contaminant excavated volume using maximum depth, nest area, nest volume, colony density, colony life span, and turnover rate for each of the ant categories.
- Calculate burrow density as a function of depth to determine the distribution of contaminants within the vertical soil profile for each of the ant categories.

Each of these is discussed in detail in the following sections.

4.0 Determine the Data Sets that Pertain to the Construction of the Ant Biomass Transport Component

There are 50 ant species known to occur on the NTS (Wheeler and Wheeler, 1986). These species are listed in Table 4 (starting on page 26) along with cross references to work on other ant species (Cole 1966). The original description of each ant species, the data collection methods, the various data sources and the ant-plant species associations are found in Hooten et al. 2004.

Tables 5, 6, and 7 (page 29 et seq.) contain other data sets of interest to the parameterization of the Area 5 model. Table 5 is reproduced from Table 14 in Hooten et al. 2004 and describes ant-plant affiliations of the NTS (Cole 1966) with cross references to the plant alliances of Ostler et al. (2000). Table 6 also is from Hooten et al. (2004) (Table 15) and lists parameters for estimating soil turnover rates by ants in the valleys and bajadas of the NTS. More specifically, Table 6 provides information on nest longevity, nest depth, nest width and nest density for a variety of ant species found on the NTS. Table 7 contains information from Porter and Jorgensen (1988) regarding the nest life of *Pogonomyrmex occidentalis*.

Taken together, these four tables contain all of the ant nest information relevant to Area 5 and Area 3 of the NTS. These data were used to construct the distributions and functions necessary for achieving the ultimate goal of evaluating the contribution of ant burrowing activities to the transport of soil contaminants.

5.0 Identify Which of the Ant Species Overwhelmingly Contribute to the Rearrangement of Soils Near the Surface and Group Those Species Into Functionally Similar Categories for Modeling

Based on a thorough evaluation of the abundance and presence of the ant species found on the NTS listed in Table 4, two functionally similar groups were formed for ease of incorporation into the Area 5 model. These two groups called “ant1” and “ant2” are composed of *Pogonomyrmex* spp. and *Messor pergandei*, respectively. These groupings represent 3 of the 5 species that burrow most extensively on the NTS. The other two genera, *Iridomyrmex* and *Formica*, may occur with some frequency but are most likely not found in the Mojave Desert region of the NTS (Hooten et al. 2004).

For Area 3, two groups also were formed and incorporated into the model. These two groups were again called “ant1” and “ant2” but were composed of *Pogonomyrmex* spp. and *Myrmecocystus mexicanus*, respectively. *Messor pergandei* does not occur in Area 3. The species that replaces *M. pergandei* in Area 3 is *M. mexicanus*. However, since *M. mexicanus* is found in relatively low densities, in the end it may be only a minor contributor to the redistribution of contaminants in Area 3 soils.

6.0 Estimate Nest Volume, Colony Density, Colony Life Span, and Turnover Rate for Each of Three Ant Species, *Pogonomyrmex spp., Messor pergandei* and *Myrmecocystus mexicanus*

In determining the impact of ant species to soil and contaminant movement, the total volume excavated by all ant colonies must be determined. Total excavated volume is a function of three components: nest volume, colony density and turnover rate. These three components are determined for each of the three ant categories (*Pogonomyrmex*, *Messor* and *Myrmecocystus*) of interest on the NTS. Data from *Pogonomyrmex* and *Messor* are used in the development of the Area 5 model while data from *Pogonomyrmex* and *Myrmecocystus* are used in the development of the Area 3 model.

6.1 Overview of Ant Nest Volumes

Nests were identified by locating soil that had been worked by ants and by the presence of ants and their chambers in the soil. Also, soil homogeneity and deposits of organic debris by ants played a role in identifying ant nests. During excavation activities, galleries and chambers were followed down through the nest to their lowest depths by carefully following the trunk routes of the ants. When the lowest chamber was reached, excavations were made approximately 50 to 100 cm deeper than the chamber to confirm the bottom of the chamber as the maximum depth. Based on these excavations, next volume, maximum depths and the underground dimensions of the nests were recorded.

Nest volume is based on field data collected by Neptune and Company, Inc. during the 2004 (Hooten 2004) field season. In February 2004, ten *Pogonomyrmex rugosus* and two *Messor pergandei* nests were excavated from Area 5 of the NTS. In April 2004, four additional *P. rugosus* nests and eight *M. mexicanus* nests were excavated. While these new nests were from Area 3 rather than Area 5 of the NTS, for *P. rugosus* Area 3 is similar enough in the plant and animal community structure that the *P. rugosus* data have been used in the development of distributions for Area 5. Finally, in October 2004, five additional *P.rugosus* nests from Area 3 and ten additional *M. pergandei* nests from Area 5 were excavated. Again the five *P.rusosus* nests from Area 3 were deemed similar enough to Area 5 to be used in the development of nest volume distributions for Area 5. In total, nineteen *P. rugosus*, twelve *M. pergandei* and eight *M. mexicanus* nests were used to develop nest volumes for the Area 5 and Area 3 NTS models.

6.2 Area 5 Nest Volume

For *Pogonomyrmex rugosus*, a bootstrapped distribution for nest volume was produced using the data from the excavation of the nineteen nests collected during field trips in 2004 to the NTS. The cumulative distributions for both the bootstrapped data and a normal distribution were compared (Figure 1) and the normal distribution was deemed a reasonable fit to the data. Thus, a normal distribution centered at 0.64 m^3 with a standard deviation of 0.091 m^3 was used to model nest volume. This distribution was truncated at zero in GoldSim to prevent nest volumes from taking negative values. If either tail of the distribution is to be truncated, then GoldSim requires both tails to be truncated. Therefore, the right-tail of the distribution is truncated at 1.0e+20 so as to not affect the simulation.

For *Messor pergandei*, data for nest volume has increased substantially from former modeling efforts. Previous versions of GoldSim used only two nest volumes obtained from a field trip in February 2004. Since that time, 10 additional nests have been excavated and added to the *M. pergandei* database. Therefore, for this version of GoldSim nest volume was parameterized based on data collected from twelve excavated nests. The twelve volumes were bootstrapped and the cumulative distribution function plotted. A normal distribution was fit to the bootstrapped data and upon comparison of the two functions, was deemed a reasonable fit (Figure 2). Therefore, a normal distribution with a mean value of 0.94 m^3 and a standard deviation value of 0.26 m^3 was used to model *M. pergandei (*"ant2" in the Area 5 model) nest excavation volumes. This distribution was truncated at zero in GoldSim to prevent nest volumes from taking on negative values. Again, if either tail of the distribution is to be truncated, then GoldSim requires both tails to be truncated. Therefore, the right-tail of the distribution is truncated at 1.0e+20.

6.3 Area 3 Nest Volume

The same distribution developed for *Pogonomyrmex rugosus* in Area 5 also will be used for Area 3. *Pogonomyrmex rugosus* nest volume distribution is based on data collected from the excavation of fourteen nests on the NTS (Figure 1). A normal distribution with a mean of 0.64 m^3 and a standard deviation of 0.091 m^3 is used to model *P. rugosus* nest volume for Area 3. This distribution was truncated at zero in GoldSim to prevent nest volumes from taking negative values. The right-tail of the distribution is again truncated at 1.0e+20.

For the second ant species *Myrmecocystus mexicanus*, found only in Area 3, eight nests were excavated in April 2004. Nest volumes were developed based on volumes obtained from the excavation of those nests. Nest volume data were bootstrapped and the cumulative distribution function plotted. A normal distribution with a mean of 0.065 m^3 and a standard deviation of 0.015 m^3 was fit to the bootstrapped CDF. The fit appeared to be adequate (Figure 3), thus the normal distribution was used to model *M. mexicanus* nest volumes in the Area 3 model.

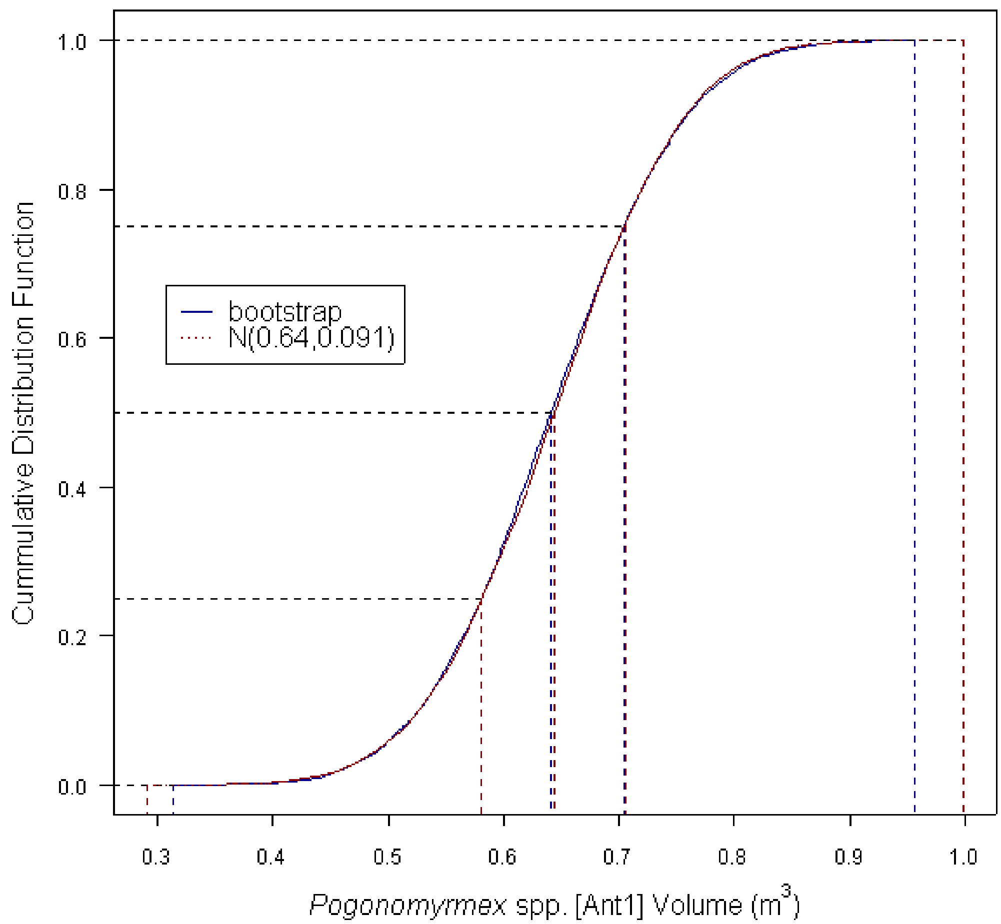

Figure 1. Comparison of bootstrapped and a normal distribution for *Pogonomyrmex* spp. nest volume. This distribution is used to model average excavated nest volume for *Pogonomyrmex* spp. for both Area 5 and Area 3.

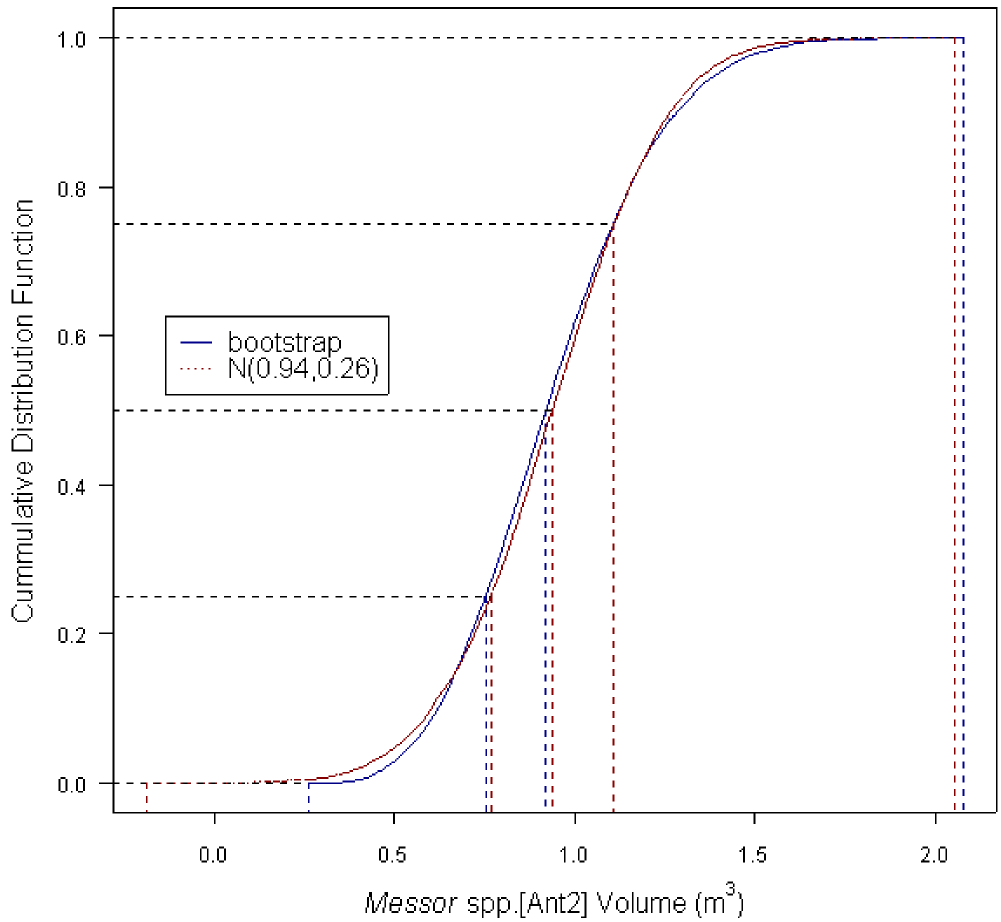

Figure 2. Comparison of bootstrapped and a normal distribution for *Messor* spp. nest volume. This distribution is used to model average excavated nest volume for *Messor* spp. for Area 5.

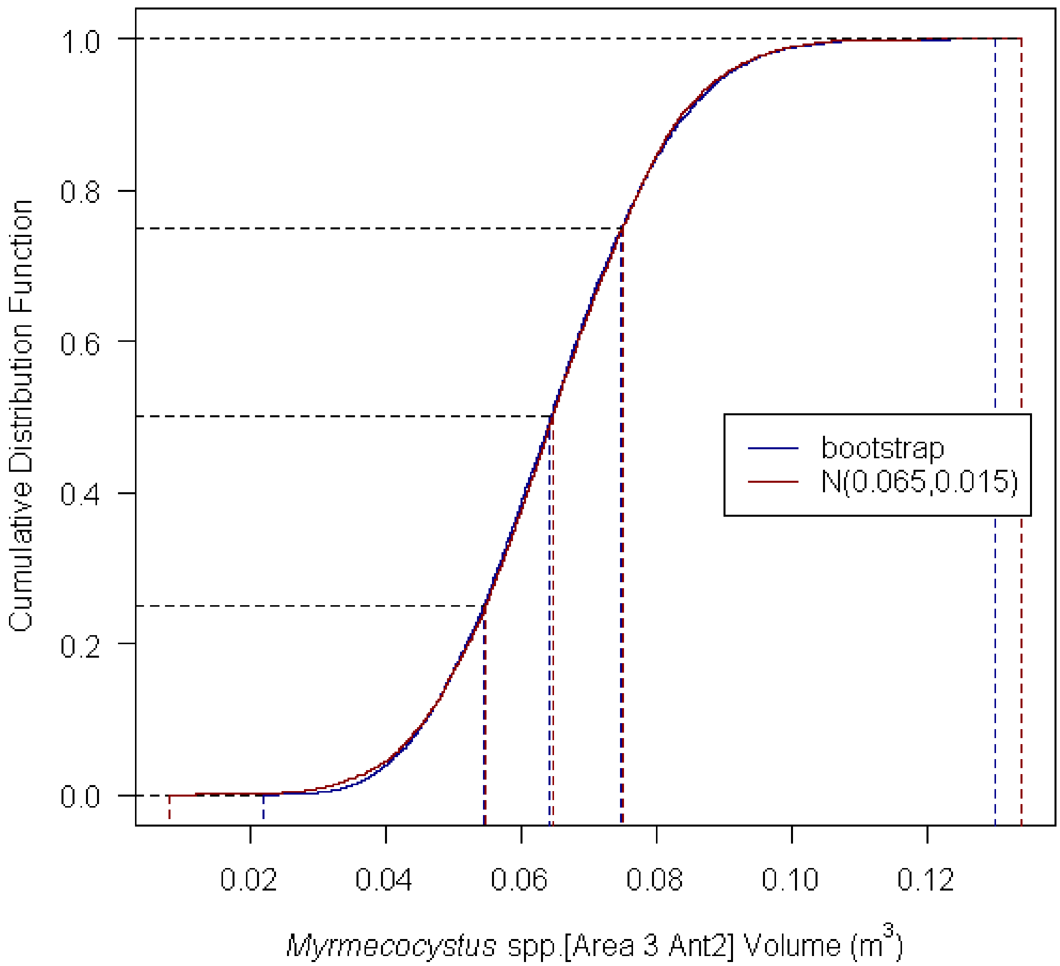

Figure 3. Comparison of bootstrapped and a normal distribution for *M. mexicanus* nest volume. This distribution is used to model average nest volume for *M. mexicanus* for Area 3.

6.4 Colony Density

The second component in determining total excavation volume is colony density. Data for colony or nest density for *Pogonomyrmex rugosus*, *Messor pergandei* and *Myrmecocystus mexicanus* is from data collected during field trips to the NTS in June 2001, April 2002, June 2002 and May 2003. Tables 1, 2, and 3 were produced to summarize the number of ant nests recorded for these three ant species encountered on the quadrats surveyed during these field trips. Ant densities were recorded for those habitats in which each species currently resides. For each species, some of the quadrats do not provide adequate habitat for the species to reside, therefore those quadrats are labeled as “NA” or not applicable to that species. Tables 1 and 2 are data from the main quadrats established for long-term studies on the NTS while Table 3 contains data that pertain to satellite quadrats established on the NTS. The satellite quadrats are hectare-sized quadrats that are in immediate proximity to the original quadrats and are used to enhance the ant nest density data. Finally, since data exist for multiple months in a particular year for certain quadrats, substantial overlap may exist in nest densities for those quadrats. The larger of the two data points is used during bootstrapping where this potential for overlap exists.

6.5 Area 5 Colony Densities

For *P. rugosus*, a bootstrapped distribution for nest densities was produced using the summary data in Tables 1 through 3. The cumulative distributions for both the bootstrapped data and a normal distribution were compared. These distributions are shown in Figure 4. The normal distribution was deemed a reasonable fit to the bootstrapped data, thus a normal distribution centered at 28 nests/ha with a standard deviation of 4 nests/ha is used to model *P. rugosus* nest density (Figure 4). This distribution was truncated at zero in GoldSim to prevent nest densities from taking negative values. However, in GoldSim if either tail of the distribution is truncated, then GoldSim requires both tails to be truncated. Therefore, the right-tail of the distribution also is truncated at 1.0e+20 so as to not affect the simulation.

For *M. pergandei* there exists only 3 valid data points for modeling colony density. The three data points are as follows, 9 nests from quadrat 1 in 2001 (Table 1), 4 nests from quadrat 6 in 2002 (Table 2), and 1 nest in satellite quadrat 2.2 in 2003 (Table 3). While there also is data recorded on quadrat 6 during the April 2002 field trip (3 nests shown in Table 1), it is likely that there is overlap with the number of nests present on quadrat 6 recorded during the June 2002 field trip. Therefore the larger of the two numbers was used to determine the density distribution for *M. pergandei*. Data were bootstrapped and a normal distribution fit to the mean nest density. Since this is the best available data and mean densities are of interest, the normal distribution was used for the Area 5 model. Thus, to model *M. pergandei* nest density, a normal distribution centered at 4.7 nests/ha with a standard deviation of 1.8 nest/ha (Figure 5). This distribution is truncated at zero in GoldSim to prevent nest densities from taking negative values. The right-tail of the distribution is truncated at 1.0e+20 for reasons previously stated.

6.6 Area 3 Colony Densities

The distribution developed for *P. rugosus* for Area 5 will be used to model *P. rugosus* colony density in Area 3 as well. These data can be found in Tables 1 through 3. Thus, Area 3 *P. rugosus* densities will be modeled using a normal distribution centered at 28 nests/ha with a standard deviation of 4 nests/ha (Figure 4). This distribution will be truncated at zero and at 1.0e+20 to avoid simulating negative densities and allow the GoldSim model to run properly.

For *Myrmecocystus mexicanus*, there exists data from a variety of quadrats and spans the 2001-2003 field seasons. The nest density distribution for *M. mexicanus* was determined by bootstrapping all data to arrive at a bootstrapped distribution of the mean nest density. A normal distribution was fit to the data and found to be a reasonable fit (Figure 6). Therefore this normal distribution is used to model *M. mexicanus* nest density. It is centered at 4.3 nests/ha with a standard deviation of 0.46 nests/ha (Figure 6). Again, this distribution will be truncated at zero and at 1.0e+20 to avoid simulating negative densities and allow the GoldSim model to run properly.

Table 1. Summary of the number of ant nests counted for *Messor pergandei, Pogonomyrmex rugosus* and *Myrmecocystus mexicanus* during the June 2001 and April 2002 NTS field trips.

Species	Q1 2 Jun 01	Q2 2 Jun 01	Q3 2 Jun 01	Q4 2 Jun 01	Q5 2 Jun 01	Q6 4 Apr 02
Messor pergandei	9	NA	NA	NA	NA	3
Pogonomyrmex rugosus	45	2	NA	24	47	18
Myrmecocystus mexicanus	NA	NA	3	NA	2	NA

Table 2. Summary of the number of ant nests counted for *Messor pergandei, Pogonomyrmex rugosus* and *Myrmecocystus mexicanus* during the June 2002 field trip to the NTS.

Species	Q2 7 Jun 02	Q3 7 Jun 02	Q4 7 Jun 02	Q5 7 Jun 02	Q6 7 Jun 02
Messor pergandei	NA	NA	NA	NA	4
Pogonomyrmex rugosus	5	NA	31	43	19
Myrmecocystus mexicanus	NA	5	NA	2	NA

Table 3. Summary of the number of ant nests counted for *Messor pergandei, Pogonomyrmex rugosus* and *Myrmecocystus mexicanus* during the May 2003 field trip to the NTS.

Species	Q2.1 28 May 03	Q2.2 28 May 03	Q5.1 29 May 03	Q5.2 29 May 03	Q4.1 30 May 03	Q4.2 30 May 03	Q3.1 30 May 03	Q3.2 30 May 03
Messor pergandei	NA	1	NA	NA	NA	NA	NA	NA
Pogonomyrmex rugosus	1	NA	23	29	33	15	NA	NA
Myrmecocystus mexicanus	NA	NA	5	4	NA	NA	5	5

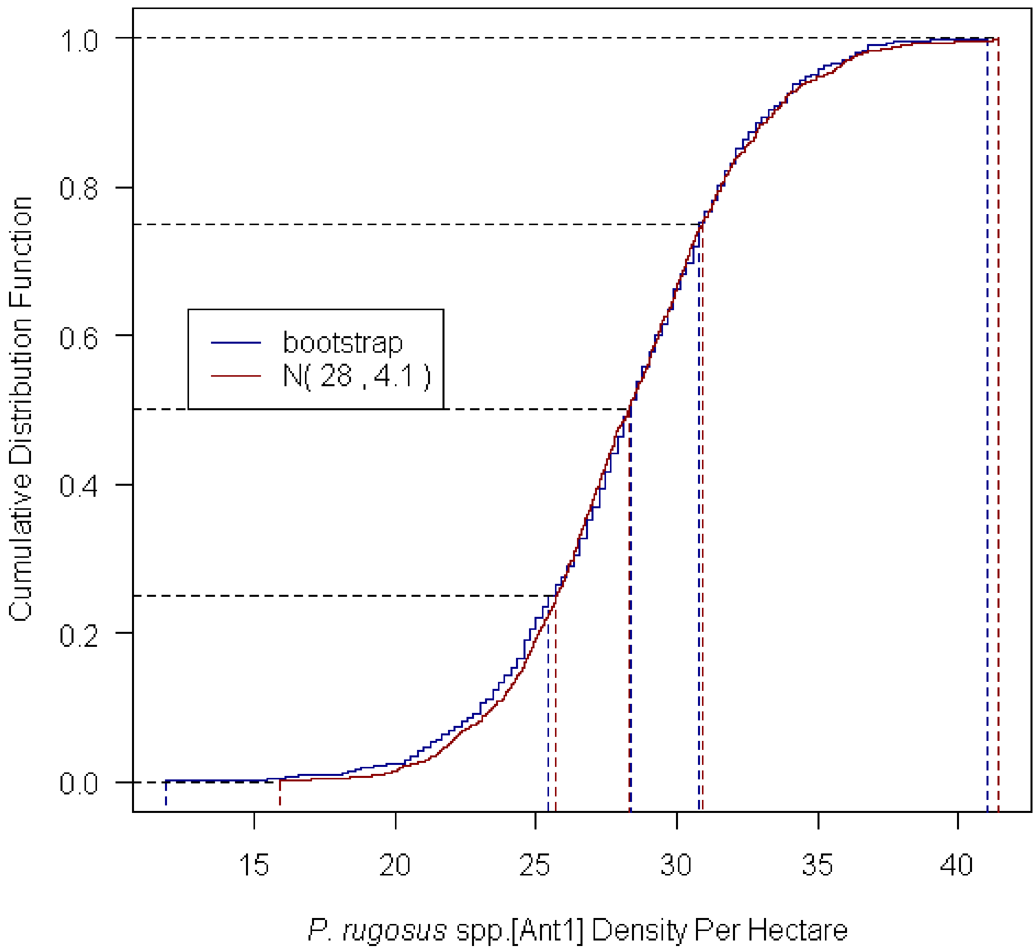

Figure 4. A comparison of the CDF of the bootstrapped distribution of ant nest densities for *P. rugosus* versus the CDF of the normal distribution. This distribution is used to model average *P. rugosus* nest density for both Area 5 and Area 3 models.

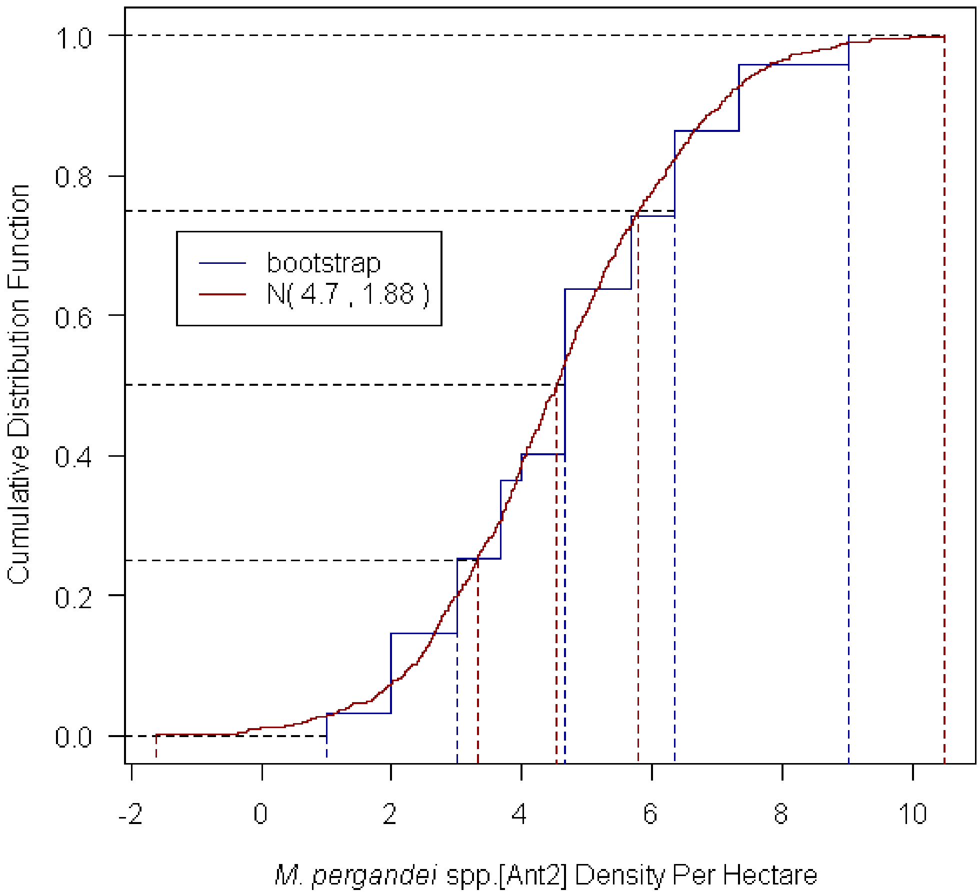

Figure 5. A comparison of the CDF of the bootstrapped distribution of ant nest densities for *M. pergandei* versus the CDF of the normal distribution. This distribution is used to model average nest density for *M. pergandei* in Area 5.

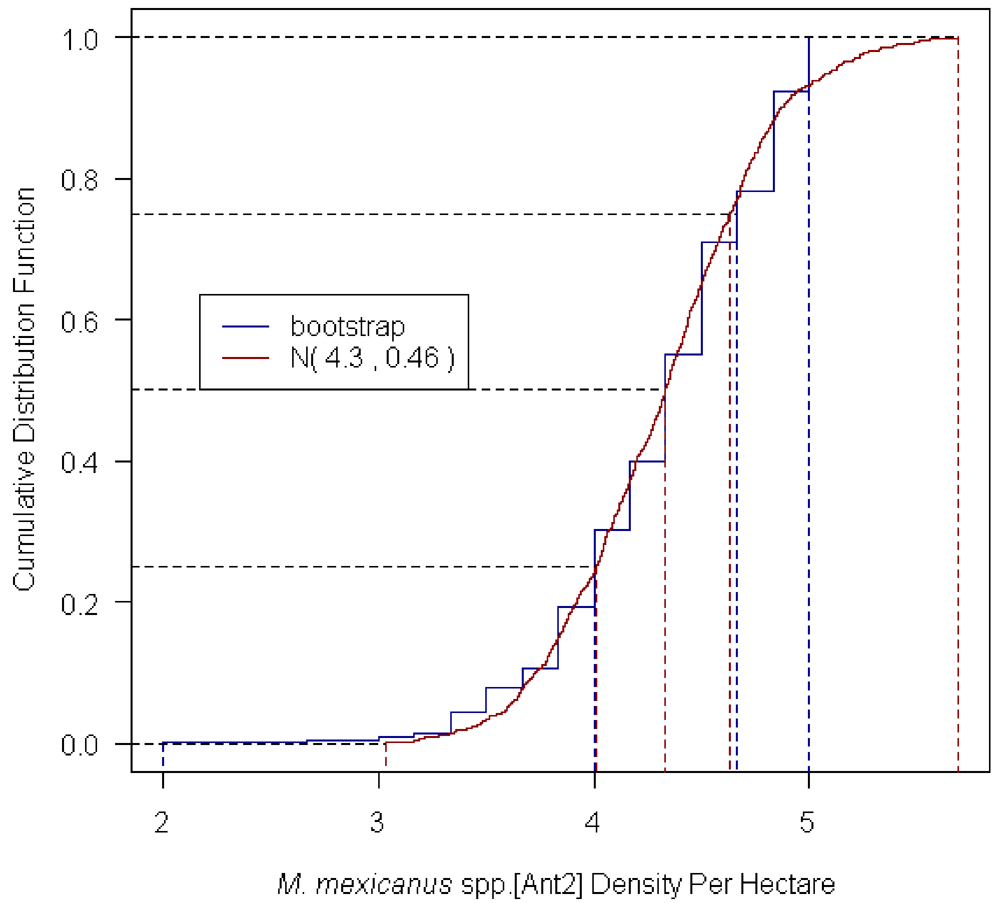

Figure 6. A comparison of the CDF of the bootstrapped distribution of ant nest densities for *M. mexicanus* versus the CDF of the normal distribution. This distribution is used to model average nest density for *M. mexicanus* for Area 3.

6.7 Colony Life Span

The final component in modeling excavation volume is the turnover rate or the fraction of the volume of the ant nest that is excavated in any given year. It is critical to determine how much of the nest must be excavated anew each year due to the expansion of the colony or damage to tunnel structures from other animals or environmental factors. The turnover rate itself is inversely related to the life span of the colony, thus colony life span will be discussed. In the case of *P. rugosus* the relevant data are available in Table 16 of Hooten et al. (2004), which are reproduced as Tables 6 and 7 herein.

6.8 Area 5 Colony Life Span

There are no direct entries for *Pogonomyrmex rugosus* in the extensive literature review compiled by Hooten et al. (2004) but there are several entries for *Pogonomyrmex* spp. These "indirect" entries are used because we have no better information. These include two entries that suggest a range of 15-20 years, one that suggests a range for the queen of 17-30 years but only 2-17 years for the nest, and an entry of 20.2 ± 8.1 years (standard deviation) based on 5 observations. We used the latter entry including the information that there were 5 data points to develop the colony life span distribution. Since the standard deviation is based on 5 observations we divided 8.1 by the square of 5 to arrive at a normal distribution with a mean of 20.2 years and standard deviation of 3.6 years. To ensure non-negative values, as well as allow division by colony life, the distribution is truncated at 1e-20. Moreover, in GoldSim if either tail of the distribution is truncated, then GoldSim requires both tails to be truncated. Therefore, the right-tails of the distribution is truncated at 1.0e+20.

For *M. pergandei* data is taken from Hölldobler and Wilson (1990). These authors indicate a range for *M. pergandei* colony life span from 6 to 12 years. Thus, a normal distribution is used to model *M. pergandei* colony life span with a mean of 9 years and a standard deviation of 1.5 years. Again, to ensure non-negative values as well as allow division by colony life, the distribution is truncated at 1e-20 and the right-tails of the distributions are truncated at 1.0e+20 due to GoldSim specifications for truncations.

6.9 Area 3 Colony Life Span

A normal distribution with a mean of 20.2 years and standard deviation of 3.6 years is used to model *P. rugosus* colony life spans in the Area 3 GoldSim model. This is the same distribution used in the Area 5 model, its development is described in the Area 5 section above. This distribution is used because data is limited for *P. rugosus* regarding colony life span and the literature values mentioned in the section above are currently the only data available to develop colony life spans for *P. rugosus*.

For *Myrmecocystus mexicanus*, only a single observation of colony residence time could be found. This data point is from Hölldobler and Wilson (1990) and lists a residence time of 40 years for *M. mexicanus*. Two other data points were found for congeners of *Mymecocystus* in the literature. Observed queen lifespan and colony residence time was >11 years for *M. mimicus* and 17 years for an observed colony residence time for *M. depilis*. All three of these data points were used to develop the colony life span distribution for *M. mexicanus*. The mean and standard deviation of these three points is 22.7 and 15.3, respectively. The standard deviation is based on 3 observations thus the we divided 15.3 by the square of 3 to arrive at the standard deviation for the proposed normal distribution. Thus a normal distribution with a mean of 22.7 years and standard deviation of 8.8 years is used to model *M. mexicanus* colony life spans in the Area 3 GoldSim model. To ensure non-negative values, as well as allow division by colony life, the distribution is truncated at 1e-20. The right-tail of the distribution also is truncated at 1.0e+20 so as not to affect simulations in GoldSim.

7.0 Ant Nest Geometry for each of the Three Ant Categories, *Pogonomyrmex spp.*, *Messor pergandei* and *Myrmecocystus mexicanus*

7.1 Modeling Nest Volume as a Function of Depth

Excavation volume gives an overall picture of how much soil is being transported to the soil surface, however, it also is important in determining the extent of burrowing activities with depth within the vertical soil profile. The shape of the nest under the surface expression of the nest gives insight into the quantity of contaminated soils at various depths being excavated to the surface. Two functions were considered to model the fraction of the nest volume with depth. Equation 1 is a beta function parameterized using maximum depth (z_{max}) and *b*. A modified beta function (Equation 2) also was considered that had an additional parameter, *a*, to provide more flexibility in fitting nest shape. Note Equation 2 is equivalent to Equation 1 when $a = 1$.

$$F(z) = 1 - \left(1 - \frac{z}{z_{max}}\right)^b, \quad 0 < z < z_{max}, \quad b \geq 1 \tag{1}$$

$$F(z) = 1 - \left(1 - \left(\frac{z}{z_{max}}\right)^a\right)^b, \quad 0 < z < z_{max}, \quad b \geq 1, \quad a \geq 1 \tag{2}$$

Figures 7, 8 and 9 provide a comparison of Equation 1 (red coloration) to Equation 2 (green coloration) using *P. rugosus*, *M. pergandei and M. mexicanus* data (blue open circles) during simulation, respectively. Data are those collected during the 2004 field season at the NTS. For *Pogonomyrmex* and *Mermecocystus*, both equations appear to adequately fit the data. Figures 7 and 9 graphically illustrate the substantial overlap between the model output from Equation 1 and Equation 2. However, for the *Messor* data (Figure 8) there are instances where Equation 1 is a better fit and others where Equation 2 is a better fit. In Figure 8, Nest 6 is an example where the data more closely follow the plot of Equation 1, whereas Nest 7 is an example where the data more closely follow the plot of Equation 2. In general though, the two equations perform equally well for the majority of the nests.

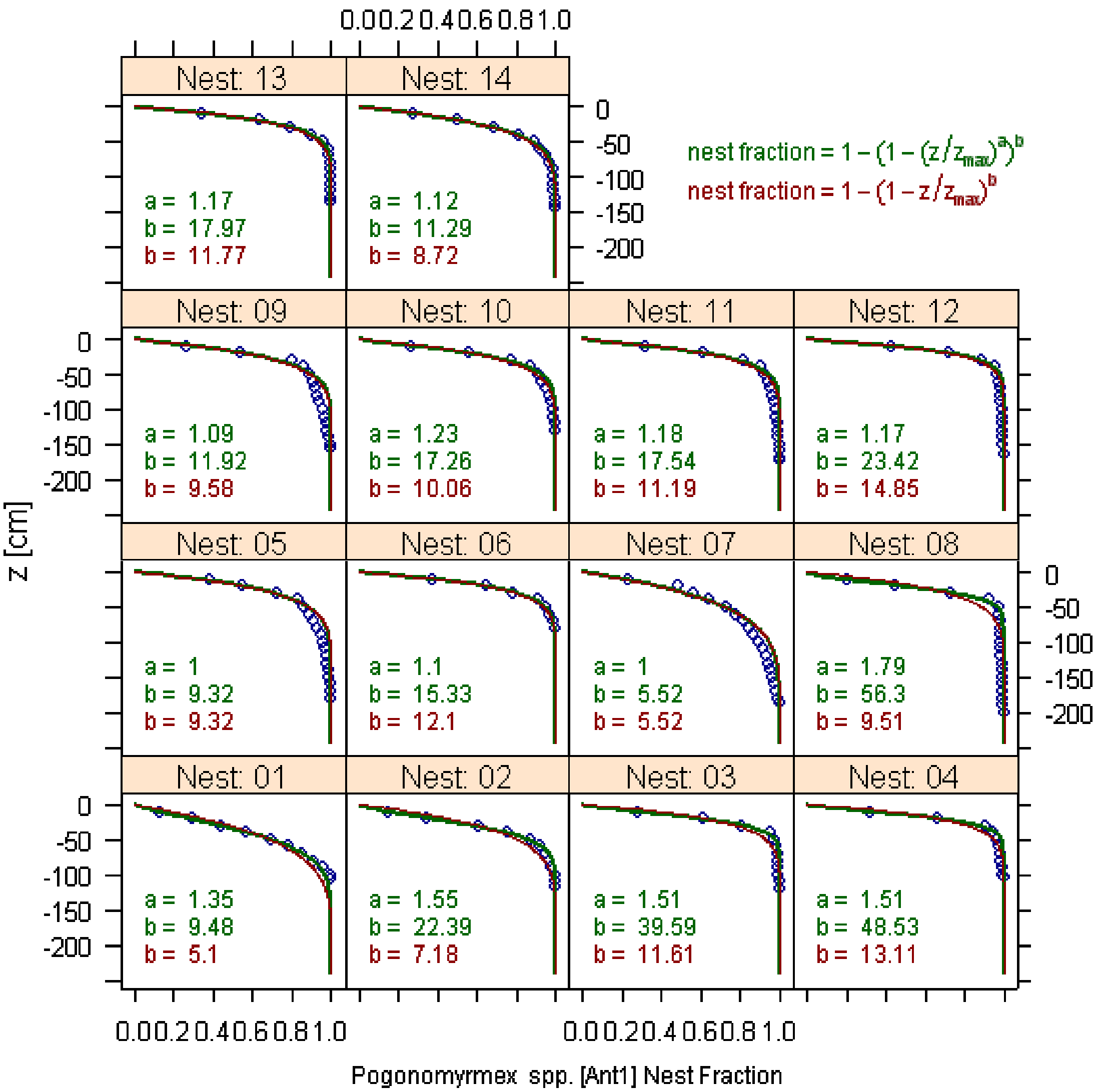

Figure 7. Comparison of models of nest volume fraction with depth for *Pogonomyrmex* spp. data collected during the 2004 field season on the NTS.

It is clear that both equations are well suited to modeling ant nest volume with depth. Based on the comparisons of the model output from the two equations and the data in Figures 7, 8 and 9, both equations provide a good fit to the current data and are viable candidates for use in the apportioning soil volume through the subsurface vertical profile. Therefore to decide which model should be used in the current version of the GoldSim model, the trade-offs between the two models were explored. Equation 1 is simple and easy to implement, however based on our understanding of nest morphologies it does not describe the shape of ant nests with depth as well as Equation 2. Equation 2 incorporates a second parameter into the model that allows the shape to be more flexible, allows for a better fit of nest volume with depth and more closely represents our understanding of ant nest morphologies. Unfortunately with the added parameter in Equation 2 comes added complexity, not only in modeling nest volume with depth but also in determining the joint distribution between the two parameters, *a* and *b*. Therefore, Equation 1 was used in the current version of the GoldSim model. The appropriateness of using Equation 1 in future versions of the GoldSim model will be re-evaluated when new field data are obtained.

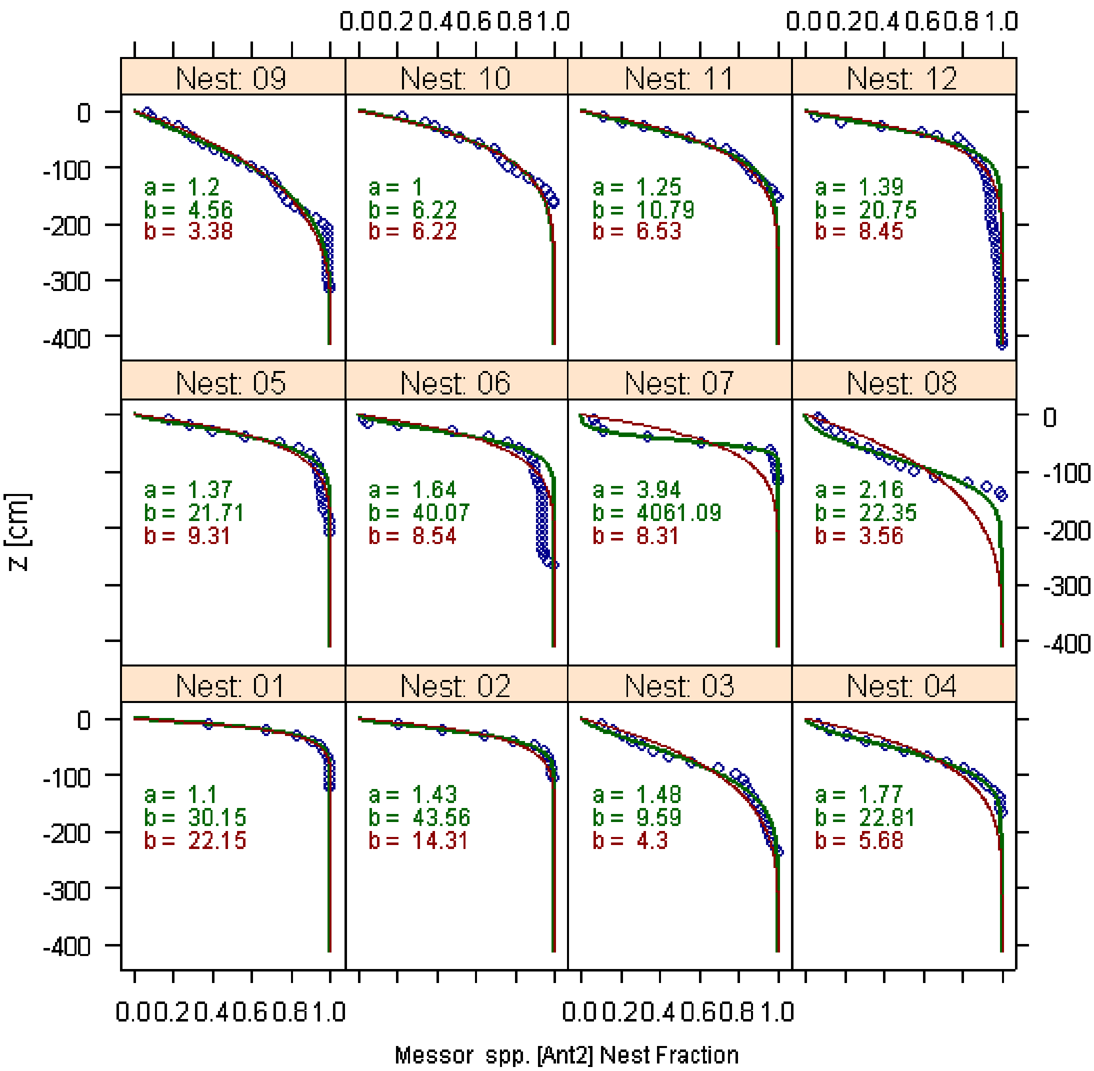

Figure 8. Comparison of models of nest volume fraction with depth for *Messor pergandei* data collected from the 2004 field season on the NTS.

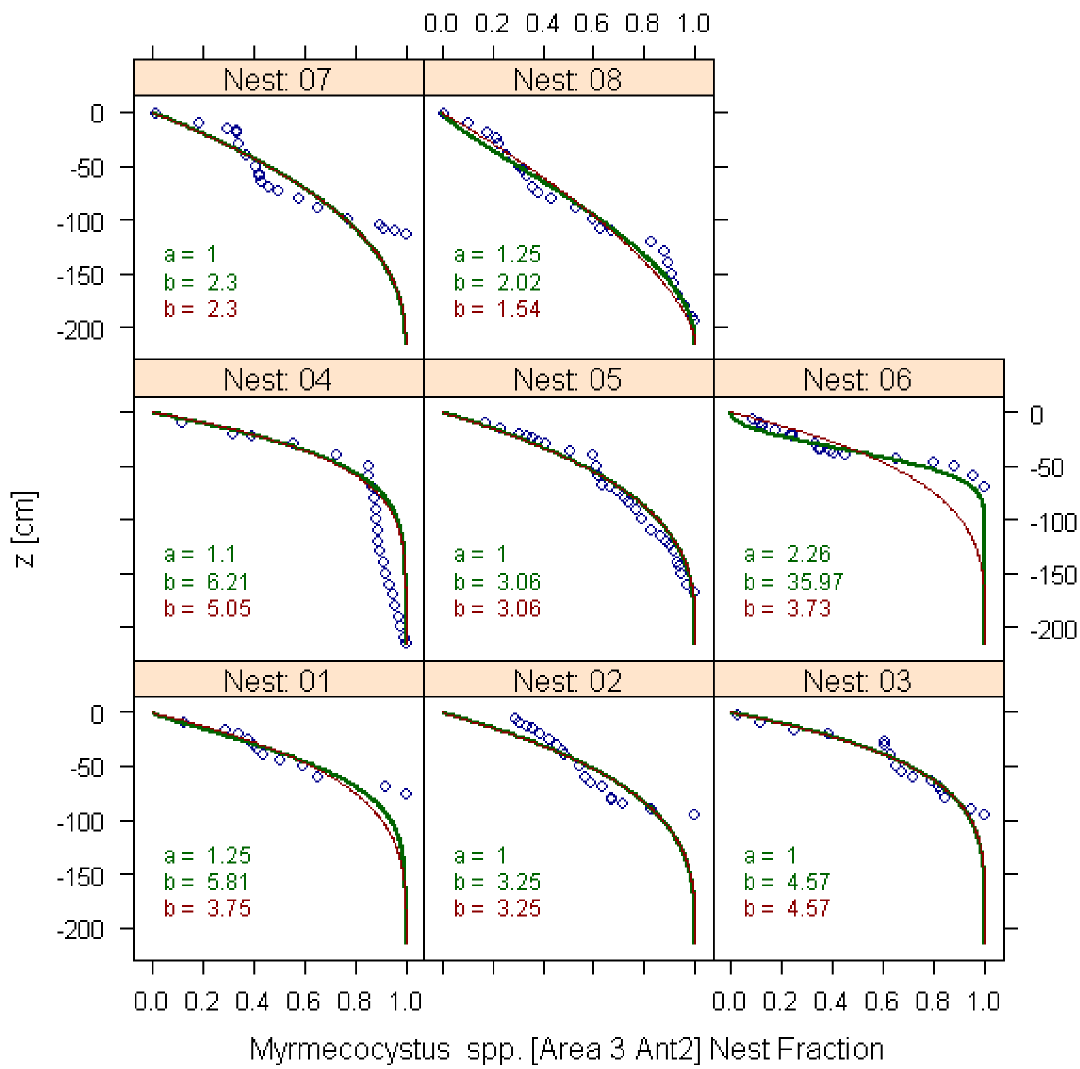

Figure 9. Comparison of models of nest volume fraction with depth for *Mermecocystus mexicanus* data collected from the 2004 field season on the NTS.

7.2 Estimating *b* for Area 5

Equation 1 was used to model ant nest volume with depth in the Area 5 GoldSim model. For the estimation of *b*, the overall maximum depth was fixed at 244cm for *P. rugosus* and at 415cm for *M. pergandei*. The overall maximum depth was used for z_{max} rather than the maximum depth for the individual burrow because the overall maximum is the maximum likelihood estimate of maximum burrow depth. Moreover, if z_{max} does not fall at a GoldSim depth interval, then only a negligible percentage of the predicted burrow volume will fall below z_{max}. The *b* parameter is truncated at 1 to limit the shapes ant nests can structurally obtain. As the value of *b* increases, the fraction of burrow excavated at each depth moves from being evenly distributed to a highly skewed distribution with most of the excavation occurring near the soil surface (Figure 10). Therefore by limiting *b* to values greater than 1, the nest shapes obtained from the model fit well with our current understanding of ant nest structure.

For *Pogonomyrmex* spp., a normal distribution with mean 10 and standard deviation of 0.71, truncated at 1, is estimated for *b* (Figure 11) based on bootstrapping. For *Messor pergandei,* bootstrapping also was used to determine the distributional form of the *b* parameter. A normal distribution with a mean of 8.4 and a standard deviation of 1.5 was fit to the bootstrapped *b* values (Figure 12). Truncation at the lower end of the distribution was performed for the reasons described above. Truncation was performed for the upper tail because GoldSim requires that if either tail of the distribution is truncated, then both tails need to be truncated. Therefore, the right-tail of the distribution is truncated at 1.0e+20.

7.3 Estimating *b* for Area 3

The best available data for modeling nest volume with depth for *Pogonomyrmex* is the data collected during the 2004 field season from Area 5. Since Area 3 is similar to Area 5 these data are used to model nest volume with depth in Area 3 as well. Therefore, based on the development described above for the Area 5 model, for *Pogonomyrmex* spp. in Area 3 a normal distribution with mean 10 and standard deviation of 0.71, truncated at 1, is estimated for *b* (Figure 11) based on bootstrapping.

For *Mermecocystus mexicanus,* eight nests were excavated during the 2004 field season and for each, subsurface nest dimensions were recorded. Based on that information and Equation 1, an estimate of b was obtained via simulation. The overall maximum depth for *M. mexicanus* was fixed at 215 cm. Simulations were conducted to determine the best fit *b* parameter for Equation 1. The average *b* was plotted and a normal CDF fit to that distribution (Figure 13). A normal distribution centered at 3.4 with a standard deviation of 0.38 was deemed to be a reasonable fit to the simulated distribution. Therefore, a N(3.4, 0.38) was used for the distribution of *b*.

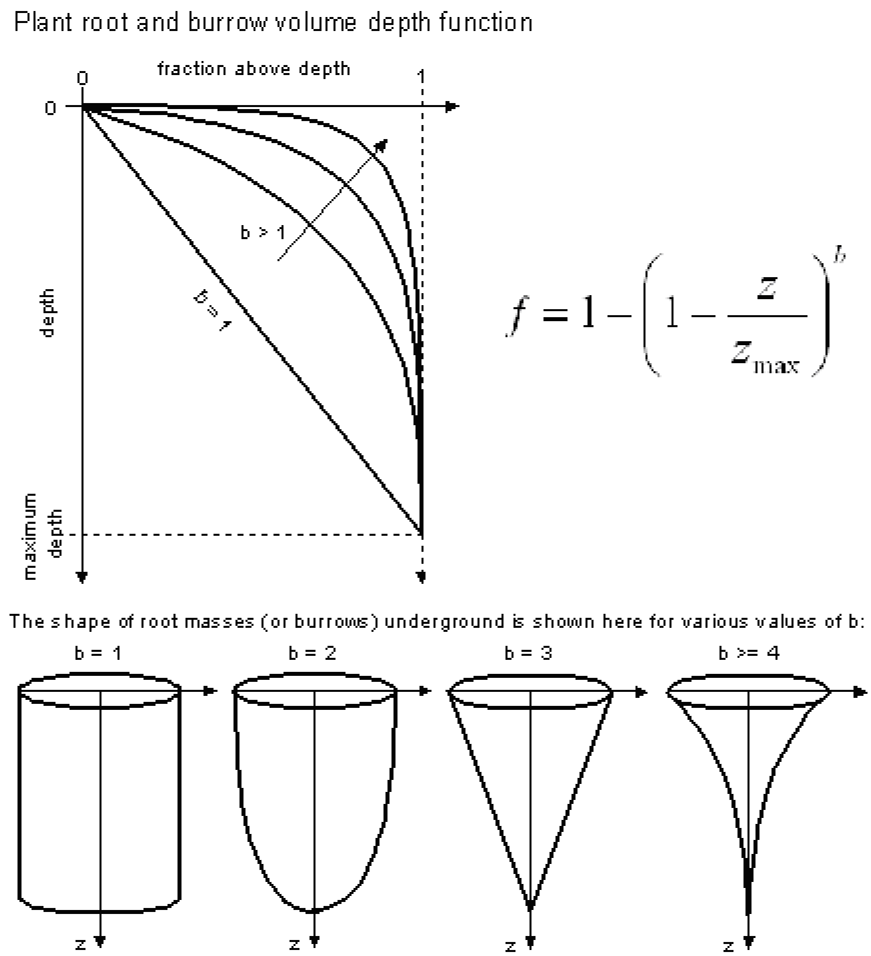

Figure 10. Graphic representation of Equation 1, illustrating how different values for the *b* parameter alter burrow volumes.

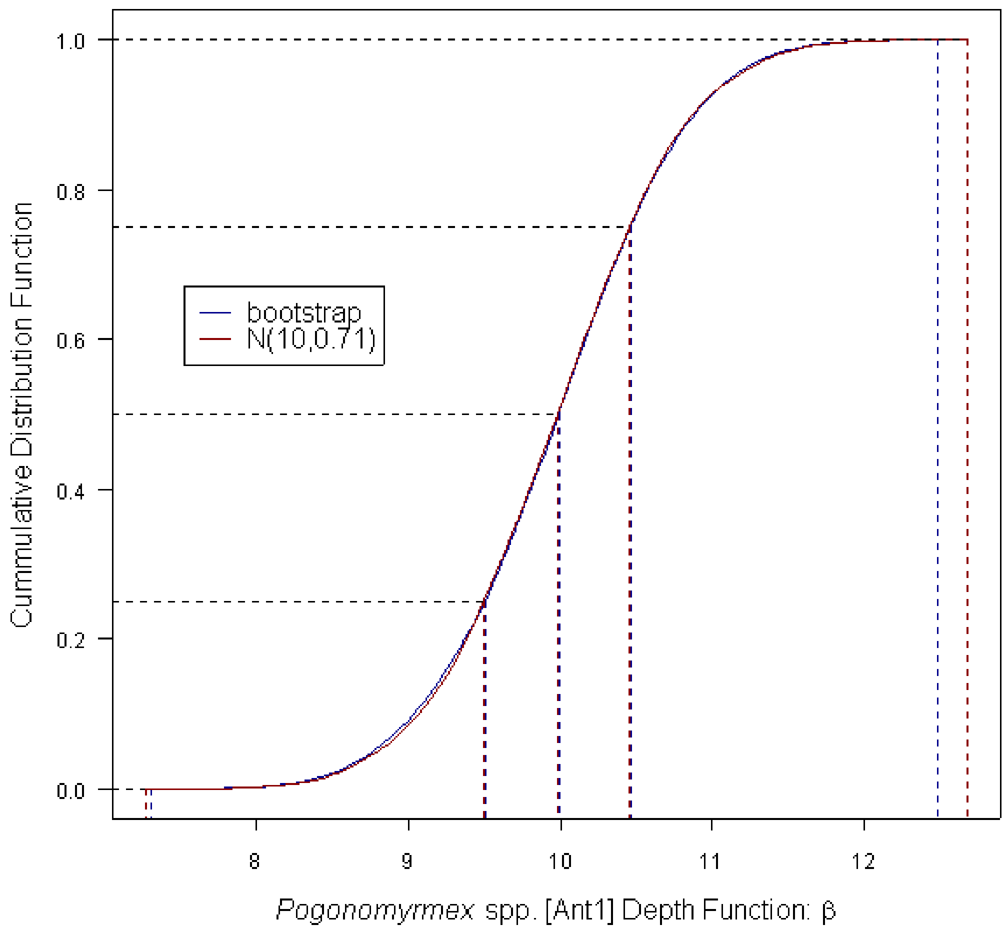

Figure 11. Comparison of the bootstrapped and a normal distribution for the average *b* parameter for *Pogonomyrmex* spp. nest volume with depth.

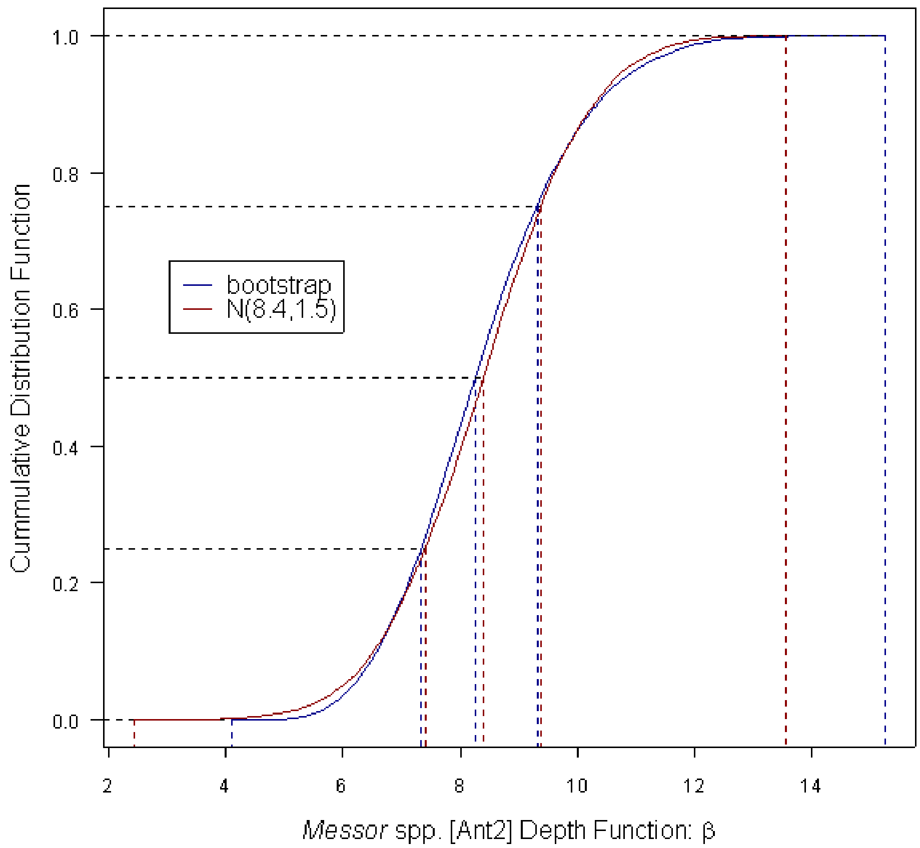

Figure 12. Comparison of the bootstrapped and a normal distribution for the average *b* parameter for *Messor pergandei* nest volume with depth.

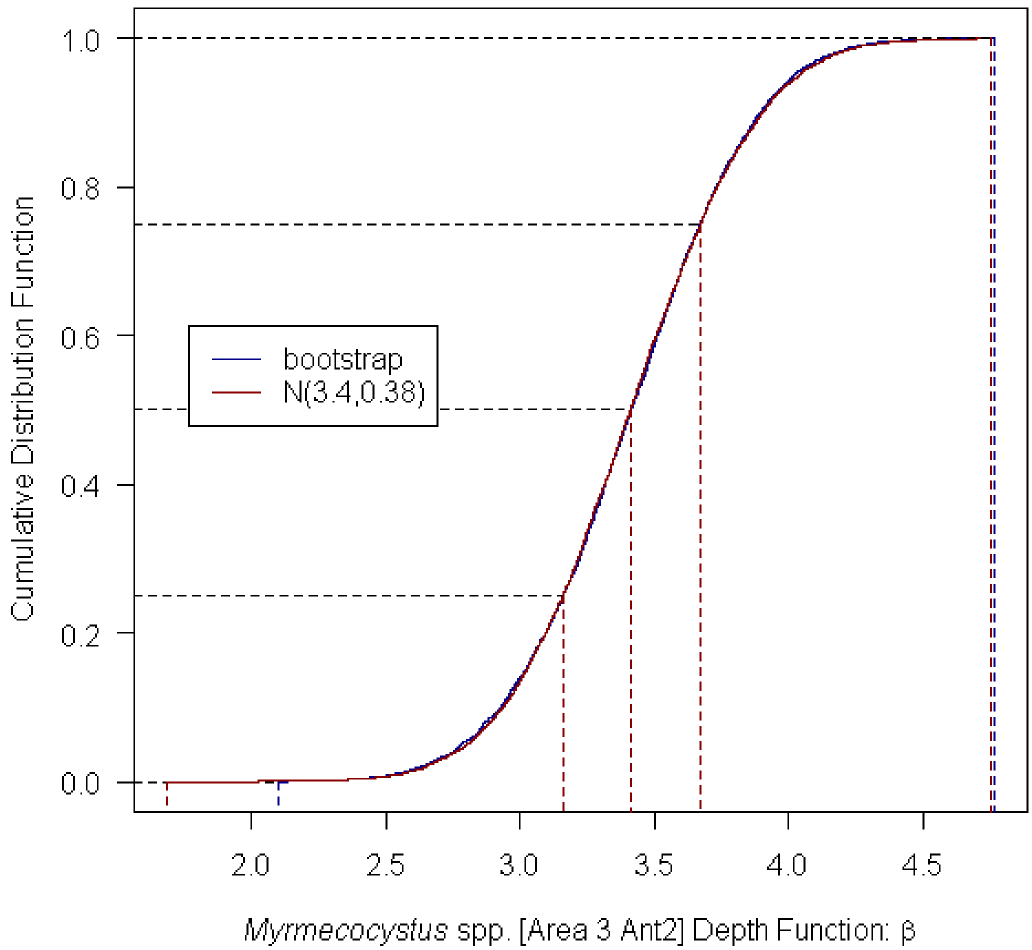

Figure 13. Comparison of the bootstrapped and a normal distribution for the average *b* parameter for *Myrmecocystus mexicanus* nest volume with depth.

Table 4. Ant species of the NTS, associated biomes, and relative abundance (from Cole [1966] and Wheeler and Wheeler [1986]). Subspecies are only listed for the purpose of cross-reference to taxa identified in Cole (1966).

Species [1]	Hot desert biome	Transition Zone [2]	Cool desert biome	Piñon-juniper biome	Relative abundance [3]
Myrmica emeryana Forel *ssp. tahoensis* Wheeler				X	Rare
Pogonomyrmex rugosus Emery	X	X	X		Uncommon (see text)
P. occidentalis (Cresson)			X	X	V. abundant
P. salinus (Olsen)			X	X	V. abundant
P. californicus (Buckley)	X	X	X		V. abundant
P. imberbiculus Wheeler	X				Rare
Aphaenogaster boulderensis M.R. Smith	X				Rare
A. megommata M.R. Smith	X	X	X		Rare
Messor (=Veromessor) lariversi M.R. Smith	X	X	X		Uncommon
M. lobognathus (Andrews)			X	X	Rare
M. pergandei Emery	X				Rare (see text)
M. smithi Cole			X	X	Rare
Pheidole desertorum Wheeler	X	X	X [2]	X	Uncommon
P. inquilina (Wheeler)				X	Rare
P. bicarinata Mayr (=*P. paiute* Mayr) [4] *ssp. paiute* Gregg *ssp. vinelandica* Forel	X	X	X	X	Common [5]
P. pilifera (Roger) *ssp. coloradensis* Emery	X	X	X	X	Rare
Crematogaster coarctata Mayr *ssp. vermiculata* Emery			X	X	Rare
C. depilis Wheeler	X				Rare
Monomorium minimum Mayr	X	X	X	X	Uncommon
Solenopsis aurea Wheeler	X				Rare
S. xyloni McCook [6]	X [5]				Rare [5]
S. salina Wheeler [7] (probably = *S. molesta*)				X [5]	Uncommon [5]
S. molesta (Say) *ssp. validuscula* (Emery)	X	X	X	X	Uncommon
Leptothorax andrei Emery			X	X	Rare
L. neveadensis Wheeler *ssp. rudis* Wheeler			X	X	Rare
Liometopum luctuosum Wheeler (=*L. occidentale luctuosum* Wheeler)				X	Rare
Iridomyrmex humilis (Mayr) (=*I. pruinosum analis* (Andre′))	X [5]		X [5]	X [5]	Common [5]
Conomyrma (=Dorymyrmex) bicolor	X	X	X		Rare

Species [1]	Hot desert biome	Transition Zone [2]	Cool desert biome	Piñon-juniper biome	Relative abundance [3]
(Wheeler)					
C. insana (Buckley) (=*C. pyramicus* (Buckley))	X	X	X	X	Uncommon
Camponotus hyatti Emery			X	X	Rare
C. ocreatus Emery			X	X	Rare
C. semitestaceus Emery (=*C. maccooki* Forel)			X	X	Uncommon
C. vicinus Mayr			X	X	Abundant
Lasius crypticus Wilson			X	X	Rare
L. sitiens Wilson			X	X	Rare
Acanthomyops latipes (Walsh)			X	X	Rare
Myrmecocystus mimicus Wheeler			X		Rare
M. lugubris Wheeler	X				Rare
M. mexicanus Wesmael	X	X	X		Rare
M. testaceus Emery (=*M. mojave* Wheeler)			X	X	Common
M. comatus Wheeler [7] (probably = *M. mimicus*)			X [5]	X [5]	Rare to Uncommon [5]
Formica lasioides Emery			X	X	Uncommon
F. limata Wheeler				X [5]	Rare
F. neogagates Emery			X	X	Uncommon
F. integroides Emery *ssp. planipilis* Creighton				X [5]	Rare
F. microgyna Wheeler			X		Rare
F. obscuripes Forel			X	X	Uncommon
F. fusca Linnaeus			X	X	Common
F. moki Wheeler				X	Rare
F. neorufibarbis Emery				X [5]	Common
F. subpolita Mayr *ssp. camponoticeps* Wheeler			X	X	Very abundant
F. obtusipilosa Emery			X	X	Rare

1 Species are listed phylogenetically (according to Wheeler and Wheeler 1986) with author.

2 The occurrence of the ant species in the transition zone is based upon the inference that if they occur in both the cool and hot desert biomes, they likely occur in regions between.

3 Wheeler and Wheeler (1986) consider the number of statewide collection records per species as an index of relative abundance. Unfortunately, this form of measure, based on literature records and museum specimens, is biased (Magurran 1988) and poorly represents actual abundances of species in nature. Additionally, Wheeler and Wheeler's categories of abundance (used for qualitative reference only) are obscurely defined (1–53 rare; 60–137 moderately abundant; 197–261 very abundant) and not well supported. For convenience and clarity, we modify their scale of measure and nomenclature, deriving the following categories: 1–50 rare; 51–100 uncommon; 101–150 common; 151–200 abundant; >200 very abundant. Abundances on the NTS, in truth, are likely quite different than this relative index implies

4 There is some confusion regarding *Pheidole bicarinata*: Cole (1966), for example, recognizes *P. bicarinata* as a valid species, although Wheeler and Wheeler (1986) do not. Cole recognizes two subspecies, however there is little agreement regarding these taxa. Wheeler and Wheeler recognize *P. paiute* Gregg as a single valid taxon synonymous with *P. bicarinata*.

[5] After description by Cole (1966).

[6] Wheeler and Wheeler do not validate this finding.

[7] Wheeler and Wheeler (1986) do not recognize these taxa as valid species.

Table 5. Ant-plant affiliations of the NTS (Cole 1966) with cross reference to plant alliances of Ostler et al. (2000). Reproduced from Table 15 in Hooten et al. 2004.

Species*	Plant affiliations of Cole (1966)	Plant alliances and associations of Ostler et al. (2000)
Myrmeca emeryana Forel	Piñon-juniper	*Pinus monophylla-Artemisia spp.* Woodland
Pogonomyrmex rugosus Emery	Grayia-Lycium, Salsola, Atriplex-Kochia, Coleogyne, Larrea-Krascheninnikovia (Franseria)	*Larrea tridentata-Ambrosia dumosa* Shrubland, *Atriplex confertifolia-Ambrosia dumosa* Shrubland, *Hymenoclea-Lycium* Shrubland, *Ephedra nevadensis* Shrubland, *Coleogyne ramosissima* Shrubland, *Atriplex spp.* Shrubland
P. occidentalis (Cresson)	Artemisia	*Artemisia spp.* Shrubland
P. salinus (Olsen)	Piñon-juniper	*Pinus monophylla-Artemisia spp.* Woodland
P. californicus (Buckley)	Grayia-Lycium, Salsola, Atriplex-Kochia, Coleogyne	*Hymenoclea-Lycium* Shrubland, *Atriplex spp.* Shrubland, *Coleogyne ramosissima* Shrubland
P. imberbiculus Wheeler	Grayia-Lycium	*Hymenoclea-Lycium* Shrubland
Aphaenogaster boulderensis M.R. Smith	Listed in Cole (1966) but not found at the NTS at that time. Only probable in *Larrea*-dominated communities.	*Larrea tridentata-Ambrosia dumosa* Shrubland
A. megommata M.R. Smith	Listed in Cole (1966) but not found at the NTS at that time. Probable in *Larrea, Larrea-Krascheninnikovia, Grayia-Lycium*.	*Larrea tridentata-Ambrosia dumosa* Shrubland, *Hymenoclea-Lycium* Shrubland
Messor lariversi M.R. Smith	Grayia-Lycium, Salsola, Coleogyne	*Hymenoclea-Lycium* Shrubland, *Atriplex spp.* Shrubland, *Coleogyne ramosissima* Shrubland
M. lobognathus (Andrews)	Piñon-juniper	*Pinus monophylla-Artemisia spp.* Woodland
M. pergandei Emery	Larrea	*Larrea tridentata-Ambrosia dumosa* Shrubland
M. smithi Cole	Coleogyne	*Coleogyne ramosissima* Shrubland
Pheidole desertorum Wheeler	Grayia-Lycium, Coleogyne, Larrea-Krascheninnikovia, Salsola	*Hymenoclea-Lycium* Shrubland, *Coleogyne ramosissima* Shrubland, *Larrea tridentata-Ambrosia dumosa* Shrubland
P. inquilina (Wheeler)	Piñon-juniper	*Pinus monophylla-Artemisia spp.* Woodland
P. pilifera Emery	Piñon-juniper	*Pinus monophylla-Artemisia spp.* Woodland
P. bicarinata Mayr (=*P. paiute* Gregg)	Grayia-Lycium, Larrea-Krascheninnikovia, Coleogyne, Atriplex-Kochia	*Hymenoclea-Lycium* Shrubland, *Larrea tridentata-Ambrosia dumosa* Shrubland, *Atriplex spp.* Shrubland
Crematogaster coarctata Mayr	Piñon-juniper, Grayia-Lycium, Atriplex-	*Pinus monophylla-Artemisia spp.* Woodland, *Hymenoclea-Lycium* Shrubland, *Atriplex spp.*

Species*	**Plant affiliations of Cole (1966)**	**Plant alliances and associations of Ostler et al. (2000)**
	Kochia, Larrea-Krascheninnikovia	Shrubland, *Larrea tridentata-Ambrosia dumosa* Shrubland
C. depilis Wheeler	Larrea-Krascheninnikovia	*Larrea tridentata-Ambrosia dumosa* Shrubland
Monomorium minimum Mayr	Coleogyne, piñon-juniper	*Coleogyne ramosissima* Shrubland, *Pinus monophylla-Artemisia spp.* Woodland
Solenopsis aurea Wheeler	Coleogyne, Grayia-Lycium	*Coleogyne ramosissima* Shrubland, *Hymenoclea-Lycium* Shrubland
S. xyloni McCook	Larrea-Krascheninnikovia	*Larrea tridentata-Ambrosia dumosa* Shrubland
S. molesta (Say) (including *S. salina* Wheeler)	Piñon-juniper, *Grayia-Lycium, Larrea-Krascheninnikovia*	*Pinus monophylla-Artemisia spp.* Woodland
Leptothorax andrei Emery	Piñon-juniper	*Pinus monophylla-Artemisia spp.* Woodland
L. neveadensis Wheeler	Piñon-juniper	*Pinus monophylla-Artemisia spp.* Woodland
Liometopum luctuosum Wheeler *(=L. occidentale luctuosum)*	Piñon-juniper	*Pinus monophylla-Artemisia spp.* Woodland
Iridomyrmex humilis (Mayr) (=*I. pruinosum analis* (Andre′))	"Present in all plant communities…" (Cole 1966)	All plant alliances.
Conomyrma (=Dorymyrmex) bicolor (Wheeler)	Larrea-Krascheninnikovia	*Larrea tridentata-Ambrosia dumosa* Shrubland
C. insana (Buckley) *(=C. pyramicus)*	Larrea-Krascheninnikovia, Coleogyne	*Larrea tridentata-Ambrosia dumosa* Shrubland, *Coleogyne ramosissima* Shrubland
Camponotus hyatti Emery	Juniper	*Pinus monophylla-Artemisia spp.* Woodland
C. ocreatus Emery	"Mixed community" (Cole 1966, probably *Coleogyne, Grayia-Lycium*), *Larrea-Krascheninnikovia*	*Coleogyne ramosissima* Shrubland, *Hymenoclea-Lycium* Shrubland, *Larrea tridentata-Ambrosia dumosa* Shrubland
C. semitestaceus Emery *(= C. maccooki)*	*Grayia-Lycium,* piñon-juniper	*Hymenoclea-Lycium* Shrubland, *Pinus monophylla-Artemisia spp.* Woodland
C. vicinus Mayr	Piñon-juniper	*Pinus monophylla-Artemisia spp.* Woodland
Lasius crypticus Wilson	Piñon-juniper	*Pinus monophylla-Artemisia spp.* Woodland
L. sitiens Wilson	Piñon-juniper	*Pinus monophylla-Artemisia spp.* Woodland
Acanthomyops latipes (Walsh)	Piñon-juniper	*Pinus monophylla-Artemisia spp.* Woodland

Species*	Plant affiliations of Cole (1966)	Plant alliances and associations of Ostler et al. (2000)
Myrmecocystus mimicus Wheeler (including *M. comatus* Wheeler)	Grayia-Lycium, Larrea-Krascheninnikovia, Atriplex-Kochia, Coleogyne, Salsola	*Hymenoclea-Lycium* Shrubland, *Larrea tridentata-Ambrosia dumosa* Shrubland, *Atriplex spp.* Shrubland, *Coleogyne ramosissima* Shrubland
M. lugubris Wheeler	Atriplex-Kochia	*Atriplex spp.* Shrubland
M. mexicanus Wesmael	Grayia-Lycium, Salsola, Coleogyne, Larrea-Krascheninnikovia	*Hymenoclea-Lycium* Shrubland, *Coleogyne ramosissima* Shrubland, *Larrea tridentata-Ambrosia dumosa* Shrubland
M. testaceus Wheeler (=*M. mojave* Wheeler)	Piñon-juniper	*Pinus monophylla-Artemisia spp.* Woodland
Formica lasioides Emery	Piñon-juniper	*Pinus monophylla-Artemisia spp.* Woodland
F. limata Wheeler	Piñon-juniper	*Pinus monophylla-Artemisia spp.* Woodland
F. neogagates Emery	Piñon-juniper	*Pinus monophylla-Artemisia spp.* Woodland
F. integroides Emery	Piñon-juniper	*Pinus monophylla-Artemisia spp.* Woodland
F. microgyna Wheeler	Piñon-juniper	*Pinus monophylla-Artemisia spp.* Woodland
F. obscuripes Forel	Listed in Cole (1966) but not found at the NTS at that time. Probable in piñon-juniper	*Pinus monophylla-Artemisia spp.* Woodland
F. fusca Linnaeus	Piñon-juniper	*Pinus monophylla-Artemisia spp.* Woodland
F. moki Wheeler	Piñon-juniper	*Pinus monophylla-Artemisia spp.* Woodland
F. neorufibarbis Emery	Piñon-juniper	*Pinus monophylla-Artemisia spp.* Woodland
F. subpolita Mayr	Piñon-juniper	*Pinus monophylla-Artemisia spp.* Woodland
F. obtusipilosa Emery	"…found in a mixed plant community…" (Cole 1966, probably *Atriplex-Kochia*), juniper, *Artemisia*	*Atriplex spp.* Shrubland, *Pinus monophylla-Artemisia spp.* Woodland

* Species with author are listed phylogenetically (according to Wheeler and Wheeler 1986).

Table 6. Parameters for the estimation of soil turnover rates by ants in valleys and bajadas in the area of the NTS. Information more broadly applicable to each genus is provided before species. Note: only the 12 genera and 27 known species that occur in plant alliances other than the *Pinus monophylla-Artemisia spp.* Woodland are included. Units are reported with standard deviation of the mean. Reproduced from Table 16 of Hooten et al. 2004.

Genera and species [1]	Max nest (n) or queen (q) longevity (years)	Nest depth (cm)	Nest width (cm)	Nest density (per ha)	Number of obs.	Authors
Pogonomyrmex	17–30 (q)					Hölldobler and Wilson 1990 [2]
	2–17 (n)					Hölldobler and Wilson 1990 [2]
				33.4 ± 32.5 (6−82)	11	MacKay 1981 [3]
	20.2 ± 8.1				5	Porter and Jorgensen 1988
				56.3 ± 23.9	3	Sneva 1979 [4]
				ca. 8–40		Whitford 1999a [5]
P. rugosus Emery				ca. 253		Whitford 1999a
				1–25		MacKay 1981
P. salinus (Olsen)				21.1 ± 27.8	40	Blom et al. 1991 [7]
		200				Gaglio et al. 1998
				42.6 ± 97.5 (12109)	12 plots over 3 years	Sharp and Barr 1960 [8]
			69			Wheeler and Wheeler 1986
Pogonomyrmex occidentalis (Cresson)		230–300				Fitzner et al. 1979, references
	>7 (n)					Hölldobler and Wilson 1990 [2]
		191 ± 30.7 (127−277)	58.3 ± 22.8 (25−112)		33 and 32, respectively	Lavigne 1969
			7295	ca. 40		Mandel and Sorenson 1982
				3–31		MacKay 1981
				23 ± 16	10	Rogers et al. 1972 [6]
		140–200	o			Rogers and Lavigne 1974
			30–180,			Wheeler and Wheeler 1986

Genera and species [1]	**Max nest (n) or queen (q) longevity (years)**	**Nest depth (cm)**	**Nest width (cm)**	**Nest density (per ha)**	**Number of obs.**	**Authors**
			mean = 79			
P. californicus (Buckley)				4–6		MacKay 1981
		15				Winkel et al. 1995
P. imberbiculus Wheeler			5			Wheeler and Wheeler 1986
Aphaenogaster			15			Cowan et al. 1985
	>3–13 (q)					Hölldobler and Wilson 1990 [2]
				ca. 656		Whitford 1999a
			1–5			Wheeler and Wheeler 1986
Aphaenogaster boulderensis M.R. Smith	N/A[9]					
A. megommata M.R. Smith			7–22			Wheeler and Wheeler 1986
Messor	9 (q)					Hölldobler and Wilson 1990 [2]
		>335				Tevis 1958
Messor lariversi M.R. Smith		56	5–10			Wheeler and Wheeler 1986
M. pergandei (Mayr)		ca. 400				Tevis 1958
			100–200			Wheeler and Wheeler 1986
		340				Winkel et al. 1995
M. smithi Cole		60	5–13			Wheeler and Wheeler 1986
Pheidole				ca. 340-675		Whitford 1999a
Pheidole desertorum Wheeler	0.08 (n) [10]					Hölldobler and Wilson 1990 [2]
			narrow slit			Wheeler and Wheeler 1986
P. inquilina (Wheeler)	N/A					
P. bicarinata Mayr (=*P. paiute* Gregg)			2.5			Wheeler and Wheeler 1986
Crematogaster				ca. 100-1250		Whitford 1999a
Crematogaster coarctata Mayr			5			Wheeler and Wheeler 1986
C. depilis						

Genera and species [1]	**Max nest (n) or queen (q) longevity (years)**	**Nest depth (cm)**	**Nest width (cm)**	**Nest density (per ha)**	**Number of obs.**	**Authors**
Wheeler						
Monomorium	0.75 (q)					Hölldobler and Wilson 1990 [2]
Monomorium minimum Mayr			2.5–5			Wheeler and Wheeler 1986
Solenopsis	1.9–18 (q)					Hölldobler and Wilson 1990 [2]
Solenopsis aurea Wheeler	N/A					
S. xyloni McCook	N/A					
S. molesta (Say) (including *S. salina* Wheeler)		13				Wheeler and Wheeler 1963
		5–15	5			Wheeler and Wheeler 1986
Iridomyrmex			115–150			Cowan et al. 1985 (Table 5)
		≤300	150–200			Ettershank 1968
Iridomyrmex humilis (Mayr) (=*I. pruinosum analis* (Andre′))	N/A					
Conomyrma see *Conomyrma bicolor* (Wheeler)						
Conomyrma (=Dorymyrmex) bicolor (Wheeler)			8–20			Wheeler and Wheeler 1986
C. insana (Buckley) *(=C. pyramicus)*				ca. 250-335		Whitford 1999a
			2–15			Wheeler and Wheeler 1986
Camponotus ***Note:***			47 ± 16.5			Cowan et al. 1985 [11]
Camponotus spp. are wood nesters.	>7 (q), >10 (n)					Hölldobler and Wilson 1990 [2]
Camponotus ocreatus Emery						
C. semitestaceus Emery *(= C. maccooki)*						
Myrmecocystus	11–40 (n)					Hölldobler and Wilson

Genera and species [1]	Max nest (n) or queen (q) longevity (years)	Nest depth (cm)	Nest width (cm)	Nest density (per ha)	Number of obs.	Authors
						1990 [2]
		≈ 488				Creighton and Crandall 1954 as in Tevis 1958
				ca. 10-350		Whitford 1999a [13]
Myrmecocystus mimicus Wheeler (including *M. comatus* Wheeler)	N/A					
M. lugubris Wheeler	N/A					
M. mexicanus Wesmael	40 (n)					Hölldobler and Wilson 1990 [2]
			4–30			Wheeler and Wheeler 1986
Formica	14–20 (q)					Hölldobler and Wilson 1990 [2]
Formica obscuripes Forel	3.1–7.8 (n) [12]		43–150 mean = 88			Hölldobler and Wilson 1990 [2] Wheeler and Wheeler 1986
F. obtusipilosa Emery			5–19 mean = 14			Wheeler and Wheeler 1986

1 Species are listed phylogenetically (according to Wheeler and Wheeler 1986) with author.

2 From Tables 3-3 and 3-4 of Hölldobler and Wilson (1990); consult Hölldobler and Wilson for original authors.

3 Calculated as the mean and standard deviation of the maximum reported value across 8 species of *Pogonomyrmex* (MacKay [1981], Table 3; see MacKay for reported authors).

4 Calculated for the same plot of *Pogonomyrmex owyheei* in eastern Oregon for the following years: 1938, 1962, 1974 (Sneva [1979], Table 1).

5 Range of reported values for *Pogonomyrmex apache and P. desertorum*.

6 Reporting only the value for ungrazed plots.

7 Calculated across all vegetation types rounding reported densities (column 2, Table 2) to the nearest integer.

8 Calculated across all vegetation types and across years.

9 N/A = not available.

10 *P. desertorum* is a nomadic species.

11 Calculated from the sum of the means for reported length and width of *C. intrepidus* (Kirby) nests (Australia).

12 Mean nest residence times reported by Hölldobler and Wilson (1990), Table 3-4.

[13]Reported range for *Myrmecocystus depilis* in three habitats. Reported nest density in creosote bush *(Larrea tridentate)* was ca. 10 on each of five plots.

Table 7. Porter and Jorgensen (1988) provide what may be the best picture of *P. occidentalis* nest life, since they studied this phenomenon more directly than other authors. We used their estimation of the mean plus/minus 2 standard deviations for the minimum and maximum of the distribution.

Species	**maximum nest longevity (mean years ± s.d.)**	**Reference**
Pogonomyrmex spp.	2-17	Hölldobler and Wilson 1990
Pogonomyrmex spp.	20.2 ± 8.1	Porter and Jorgensen 1988
Pogonomyrmex occidentalis	> 7	Hölldobler and Wilson 1990

8.0 References

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