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# MUTINY ON THE BOUNTY OR BOUNTIFUL MUTANTS? DIVERSITY AND COMPOSITION OF WOOD-DECAYING MACROFUNGI ON HIBISCUS TILIACEUS WOOD IN FRENCH POLYNESIA

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**Abstract.** Wood-decaying macrofungi are an important component of forest ecosystems because they are the major decomposers of dead woody debris and are crucial for nutrient cycling. This is especially true in the tropics where biomass is high. However, most studies to date have focused on temperate forests in the northern hemisphere. Little is known about wood-inhabiting fungi in French Polynesia. In fact, no identification materials exist. The following study seeks to fill this gap in knowledge. First, a general survey was done of the wood-fungi occurring in the mountains of Moorea. Next, in a pilot study, all *Hibiscus tiliaceus* dead wood (>1cm) was measured and surveyed for fungi using 10, 25-meter line transects. The aim of this phase was to determine if wood with fungi has different characteristics than wood without. Fungi were found on 61% of wood surveyed, but larger logs, and wood of intermediate decay were more likely to have at least one species. An additional 20 transects focused only on wood with fungi. A total of 114 species were found on 644 pieces of *Hibiscus tiliaceus* wood. However, 36.8% species were found only once and most wood had only 1 or 2 species. There were a few very abundant species, and the others were rare. When common species were examined individually, it was evident that many had preferences for certain wood sizes and decomposition. Species richness was found to positively correlate with average diameter, and wood of intermediate decay was also found to have greater species richness. In general, the results of this study were found to support much of the research conducted in temperate forests. Although the details differ, the underlying trends of diversity and succession are surprisingly similar.

*Key words: fungi, species richness, diversity, succession, species composition, decomposition, tropical forest.*

## INTRODUCTION

Wood-decaying macrofungi are an important, but often overlooked and understudied component of forest ecosystems. They play a major role in decomposition and nutrient cycling (Boddy and Watkinson 1995; Cromack and Caldwell 1992). Yet not all “wood-decaying macrofungi” are created equal. Instead, this umbrella term disguises the diversity of different morphologies, decay capabilities and niches exhibited by this group. Urcelay and Robledo (2004) have proposed to divide species into **functional guilds. Many fungi decay wood of a certain**

**size and level of decomposition** (Renvall 1995).

The extent of decomposition has been demonstrated to be one of the most important factors determining fungi species presence and diversity (Kuffer and Senn-Irlet 2005; Tofts and Orton 1998). Wood in intermediate to advanced stages of decay has the highest species richness (Niemala et al. 1995; Bader et al. 1995; Renvall 1995; Crites and Dale 1998). Wood is not only a substrate upon which fungi live, but it is also an energy/nutrient source that is transformed by the fungi (Allen et al. 2000; Stewart and Burrows 1994; Boddy and Watkinson 1995). Colonizing fungi can alter the moisture, physical structure, acidity,

and nutrient content of the wood, making way for other species. For example, dead wood often contains resins, alkaloids, and phenols that are toxic to fungi (Holmer et al. 1997). Several studies have shown that there are patterns of species succession; as wood decays, initial colonizers are replaced by other species (Niemela et al. 1995; Renvall 1995; Holmer et al. 1997, etc). This is not deterministic however, and there may be many alternative pathways for succession, even when other factors are the same (Boddy 1992).

Species composition and diversity are also correlated to wood size. To date, the majority of studies on wood-decaying fungi have focused on coarse woody debris (CWD) (Edman et al. 2004) that is defined as wood with diameters of >10cm, such as fallen trees, downed branches, etc (Waddell 2002). Species richness tends to be higher on larger logs, which is partially due to greater surface area and volume (Edman et al. 2004; Bader et al. 1995; Kruys et al. 1999). Additionally, the decay rate varies even on the same log, resulting in heterogeneous microhabitats (Crites and Dale 1998). Several studies have been carried out in northern Europe in disturbed or managed forests where CWD is unnaturally scarce (Lindhe et al. 2004; Heilmann-Claussen and Christensen 2003; Kuffer and Senn-Irlet 2005, etc). They emphasize the threat this poses to fungi biodiversity. Recently, fine woody debris (FWD, diam 5-9cm) and very fine woody debris (VFWD, diam <5cm) have also been found to contribute to overall species richness and should not be overlooked (Kuffer and Senn-Irlet 2005). If the same surface areas are examined, FWD has the same diversity as CWD, and diversity is greater on FWD when equal volumes are compared (Kruys and Jonsson 1999). Branches and twigs have a greater surface-area-to-volume ratio and smaller wood pieces are likely to harbor different species. However very little research has been done to determine if these patterns hold true in tropical forest ecosystems.

The purpose of this study was to see if these trends found in temperate forests in the Northern hemisphere could also predict species richness and composition the tropical

environment of Moorea, French Polynesia. It is known that wood biomass is far greater in tropical forests, and both the rate of decomposition and activity of wood-decaying fungi are higher (Ferrer and Gilbert 2002). Specifically I investigated the following questions: 1) How much/what type of wood is available and what percentage of has fungi? 2) Is species richness correlated to the physical characteristics of the wood (i.e. size or decomposition)? 3) Does species composition vary depending on the physical properties of the wood? I chose to examine only *Hibiscus tiliaceus* woody debris because I wanted to compare the physical variables of the wood and not differences that could be due to the tree specie or possible host specificity of certain fungi. Thus, they are not included in the scope of this study.

## METHODS

### Study site

Moorea is a tropical oceanic island in the Society Islands. The average temperature is 26° C, although it is warmer and wetter during the winter rainy season (Meyer 1996). The Belvedere trail on Moorea, French Polynesia was the primary field site for this study (FIG. 1). It is located at 17°32'29.0" S, 149°49'25.6W and the elevation is approximately 250m (Ranker et al. 2005). The forest is composed of primarily *Hibiscus tiliaceus*, *Metrosideros polymorpha*, *Angiopteris evecta*, and *Inocarpus fagifer*.



FIG. 2. Map of Moorea, French Polynesia. The Belvedere field site is indicated by the star

## Survey of Moorea fungi

Initially, it was necessary to conduct a general survey of fungi that occur in Moorea. This was necessitated by the absence of any identification materials. Thus, the period from October 3, 2006 through October 19, 2006 was spent collecting various species at the Belvedere and at the Gump Station (Cooks Bay). Each sample was assigned a species number and was photographed, described and dried. Spore prints and permanent spore slides were made when possible. This datum was used to create a field key for the second phase of the study. Additional new species of fungi encountered during the sampling phase were also added. Each specimen was identified to the most specific taxonomic level possible. Specimens will be deposited in the Jepson Herbarium at the University of California, Berkeley.

### Sampling methods

Field sampling began October 23, 2006 and ended on November 11, 2006. A total of thirty, 25-meter line transects were laid out at 200 pace intervals (0 paces corresponded to the Belvedere lookout/parking lot). At each interval, a transect was placed 10 paces from either side of the trail and parallel to it due to the dense vegetation and often steep incline. Every piece of dead *Hibiscus tiliaceus* wood greater than 1cm intercepting the line was examined including stumps, logs, branches and twigs. This tree species was chosen because it is common at this site, fallen wood is abundant on the forest floor, and it is fairly easy to identify. Each qualifying piece was examined for presence or absence of fungal fruiting bodies. Although this method leads to an underestimate of fungi, it has been widely used in comparable studies (Norden and Paltto 2001). Searching for mycelia would have been impractical because it requires destroying the wood, a huge amount of wood was examined, and not enough is known about the species occurring in the area to identify species from the mycelium alone. Physical data was taken on length, large and small end diameters, % cover (visually

estimated), and decomposition stage. The decomposition stage was measured using a qualitative scale ranging from 1-5 (Renvall 1995; Waddell 2002) that was modified for *Hibiscus* wood (Table 1; Appendix A). If fungi were present, each species was noted as present or absent. If the identity of a fungus was questionable, a sample was taken back to the lab and compared to previously collected vouchers to either confirm its identity or to give it a unique species number.

Pilot study  
For 10 out of 30 transects, every qualifying piece of dead *Hibiscus* wood intercepting the line was

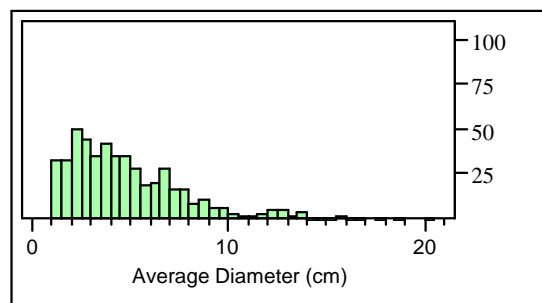


FIG. 2. Distribution of all 505 pieces of wood with and without fungi in the pilot study by average diameter (cm).

recorded and measured whether or not fungi were observed. All dead wood was recorded in this step to quantify distribution of potential substrates. Another aim was to see what percentage of wood harbored fungi, and if there were certain features that correlated to fungi presence. First, the distribution of all wood was examined by average diameter and decomposition. The frequencies of fungi occurrence were calculated for the five decomposition categories using Microsoft Excel. Diameters and decay were compared graphically for wood with and without fungi using JMP univariate histograms.

### Species richness and composition

For the remaining 20 transects, only *Hibiscus* wood with fungi was measured and recorded. This was to acquire additional data on species diversity and species composition on logs of various sizes and states of decomposition. The percentage of wood with different numbers of species was graphed to determine how diversity was distributed. To assess species richness trends, the average

number of species was graphed for average diameter and decomposition stage. The Wilcoxon test in JMP was used to analyze species richness by average diameter and decay stage because the wood did not display a normal distribution. To analyze species composition, the abundances of all species found were graphed, as well as the % of species with a given abundance. Then, species found at least 5 times were examined. For each, the diameter and decay of the wood was averaged and the standard deviation was calculated to determine if it had a substrate preference.

## RESULTS

### Pilot study

A total of 505 pieces of dead Hibiscus wood were found in the pilot study: 197 without fungi, and 308 with one or more species. Average diameter was not normally distributed, but was positively skewed so that smaller units outnumbered larger logs (FIG. 2). However, wood with fungi had a slightly larger average diameter of 5.33cm, whereas the mean was 4.01cm for wood lacking fungi.

FIG. 3. Distribution of all 505 pieces of wood with and without fungi in the pilot study by decay stage. Values given are % of total wood.

Also, the decomposition stages were not normally distributed, but were negatively skewed so that more decayed wood was found more frequently (FIG. 3).

Overall, fungi were found on 61% of wood encountered, but this rate was different for each decay stage. No fungi were found on wood in the first stage, but fungi were found on 70% of wood in decomposition category 4. However, the frequency of fungi was found to taper off for the 5<sup>th</sup> stage of decomposition. Decomposition stages 2 and 5 were less likely to have fungi than the average, and stages 3 and 4 had fungi more frequently (FIG. 4)

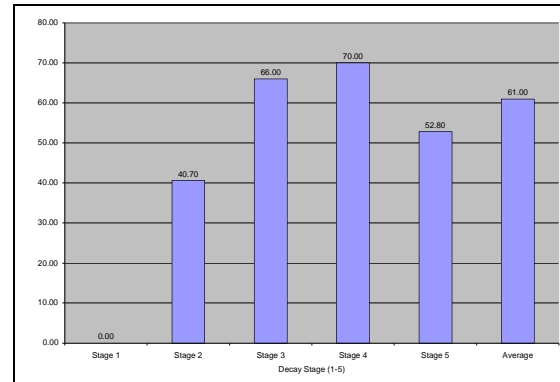
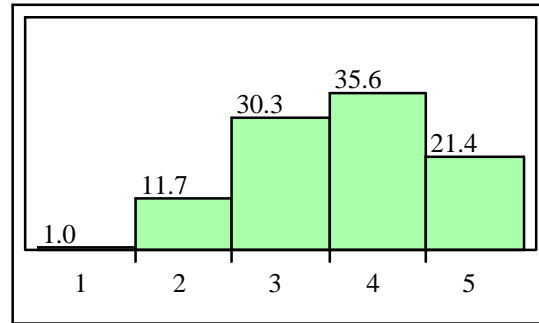


FIG. 4. Percentage of wood surveyed in the pilot study with fungi for each decay stage compared to the average overall.

### Species richness

In all 30 transects, a total of 644 pieces of dead Hibiscus wood were found with at least 1 fungi species. Of these, 406 pieces had 1 species (63.04%), 149 had 2 species (23.14%), 56 had 3 species (8.7%), 24 had 4 species (3.73%), 5 had 5 species (0.78%), 4 had 6 species (0.62%), and only 1 piece of wood had 7 species (0.16%). When these percentages were natural log transformed, there was a strong negative relationship between species richness and the percentage of wood found with that number of species [ $\ln(\% \text{ of wood}) = 5.1122884 - 0.9850012(\text{species richness})$ ,  $R^2 = .99$ ,  $P < 0.0001$ ] (FIG. 5).

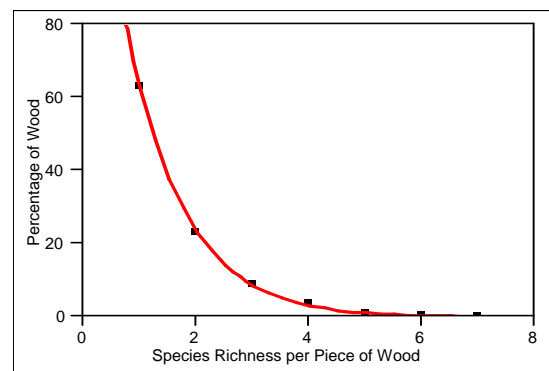


FIG. 5. The percentage of wood found for each species richness. The chance (%) of

finding a given species richness on wood with fungi= $e^{(5.112-0.99(\text{species richness}))}$

A Wilcoxon non-parametric analysis was done to determine if there were significant differences between the average diameters of wood with different species richness. Then the Tukey-Kramer honestly significant difference test was used to compare means ( $q^*=2.96$ ,  $\text{Alpha}=0.05$ ). There were significant differences between species richness 5 and 1, between 4 and both 1 and 2, and between species richness 3 and 1 (FIG. 6; Appendix B). When the average number of species per piece of wood was plotted against the average diameter, there was a strong positive linear correlation (FIG. 7).

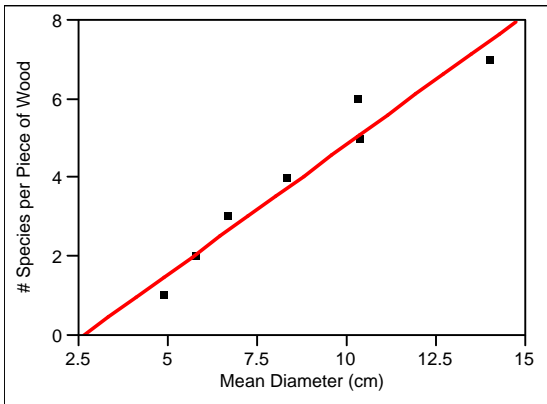


FIG. 7. Linear regression of # species per wood piece as a function of mean diameter (cm). [ $\text{\# species} = -1.68 + 0.66(\text{mean diameter})$ ,  $R^2=0.95$ ,  $P>0.0002$ ].

The Wilcoxon non-parametric test was used to determine if each decomposition stage was significantly different in terms of species richness. When pairs were compared using the Tukey-Kramer HSD test, statistically significant differences were found between decay stage 3 and both decay stages 2 and 5 ( $q^*=2.58$ ,  $\text{Alpha}=0.05$ ). Decay stage 3 also had the highest mean species richness value of 1.75 species per unit (FIG. 8; Appendix B). The average number of species per piece of wood was graphed against decomposition stages 2-5 (no fungi were found on logs of decay stage 1). Species richness was found to be a quadratic function [ $\text{\#Species} = 0.74 + 0.32(\text{decomposition stage}) - 0.25(\text{decomposition stage})^2$ ,  $R^2=0.97$ ,  $P>0.035$ ] with a peak between stages 3 and 4 (FIG. 9).

stage)<sup>2</sup>,  $R^2=0.97$ ,  $P>0.035$ ] with a peak between stages 3 and 4 (FIG. 9)

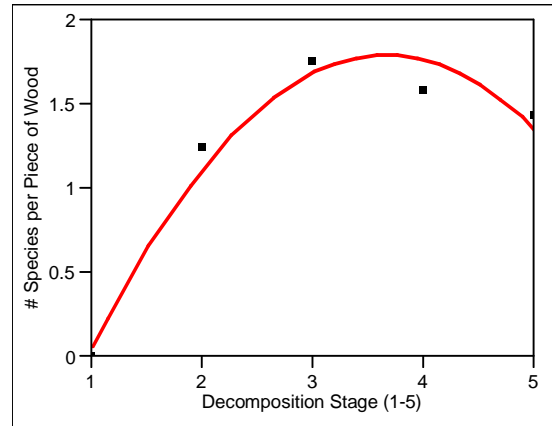


FIG. 9. Species richness per piece of wood as a function of decay stage.

### Species composition

A total of 114 species were found, but 36.8% were found only once. 72 species were found 2 or more times, and 56 species were found 3 or more times. The distribution of abundances of each species and analysis with the Shapiro-Wilk W Test revealed that species abundance was not normally distributed. Then, species abundance was graphed against the % of species found at a given abundance. The datum for species abundance was transformed to fit the reciprocal [ $\% \text{ species by abundance} = -0.86 + 34.69(\text{abundance})^{-1}$ ,  $R^2=0.96$ ,  $P<0.0001$ ]

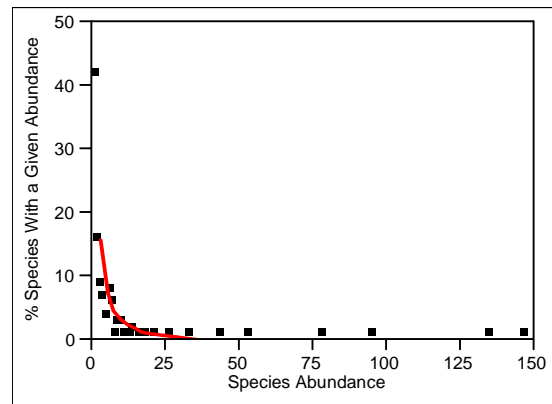




FIG. 10. Percentage of species with a given abundance as a function of species abundance.

Only species found 5 or more times were used to examine fungal communities. The average diameter and decay stage on which each was found and standard deviation were calculated and graphed (FIG. 11 and FIG. 12; Appendix C).

## DISCUSSION

### Pilot study

The results of the pilot study show general trends in the features of wood with and without fungi. Few studies report datum for wood without fungi, so it is difficult to compare the occurrence of fungi in the tropical island forest ecosystem of Moorea to other studies. Overall, more than half of the wood surveyed had fungi, but the frequency of fungal presence varied depending on the average diameter and decomposition stage of the wood. The likelihood of encountering fungi increased with the average diameter, and was greater for wood of intermediate decay. One striking observation was that no fungi were found on newly fallen wood. This could in part be due to the fact that this category was rarely found overall, which might be attributed to fast rates of decay in the moist, tropical environment. Also, I observed that many Hibiscus limbs began decaying while still attached to the tree, so they may be more decomposed when they do fall (this may explain the high amount of Hibiscus dead woody matter).

Interestingly, there were few significant differences between wood with and without fungi. I was unable to determine why certain wood that appeared suitable lacked fungi. This may have been due to chance and the inability for spores to either reach the wood or to survive on it. Edman et al. (2004) found that local spore sources play a key role in the presence of fungi species. They also point out that establishing mycelium and a fruiting body is a complex process that can be hindered at many points. Another possible explanation is that mycelia were present, but did not exhibit fruiting bodies.

### Species richness

Although many species of fungi were surveyed and encountered along the transects, most wood had one species. Some had 2 species, but the chance of finding each additional species decreased exponentially. Thus, most individual logs display little species diversity.

When richness was examined in closer detail, it was found that it increased linearly with average diameter. This is similar to the pattern found in northern temperate forests (Bader et al. 1995; Renvall 1995; Kruys et al. 1999). Edman et al. (2004) found that in Sweden, the size of a log is an important factor in colonization and species diversity over time. This is somewhat intuitive because CWD has larger volume and surface area. As well as providing more substrate, larger wood may also contain more moisture and be more stable (Edman et al. 2004). In addition, larger units of wood may decay at different rates, providing heterogeneous microhabitats (Boddy and Watkinson 1995).

Also, fungi richness was higher on logs in intermediate stages of decay. No fungi were found on newly fallen logs and the frequency of fungi tapered off for very decomposed logs. This is also similar to findings from research done in other parts of the world (Renvall 1995; Linde et al. 2004). It may take some time for fungi to become established and develop fruiting bodies, and older wood may provide fewer energy and nutrients.

### *Species composition*

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#### APPENDIX A

Decomposition Stage	Description
1	Sound wood, bark completely intact, original color
2	Sapwood slightly decayed, heartwood sound, bark mostly intact
3	Sapwood somewhat decayed, heartwood mostly sound, bark starting to come off in patches
4	Sapwood decayed and pitted, bark mostly gone, wood is soft, but maintains shape
5	Bark absent, heartwood is very decayed and crumbling, breaks apart when touched

Table 1: Decomposition scale modified from Renvall (1995) and Waddell (2002)

#### APPENDIX B

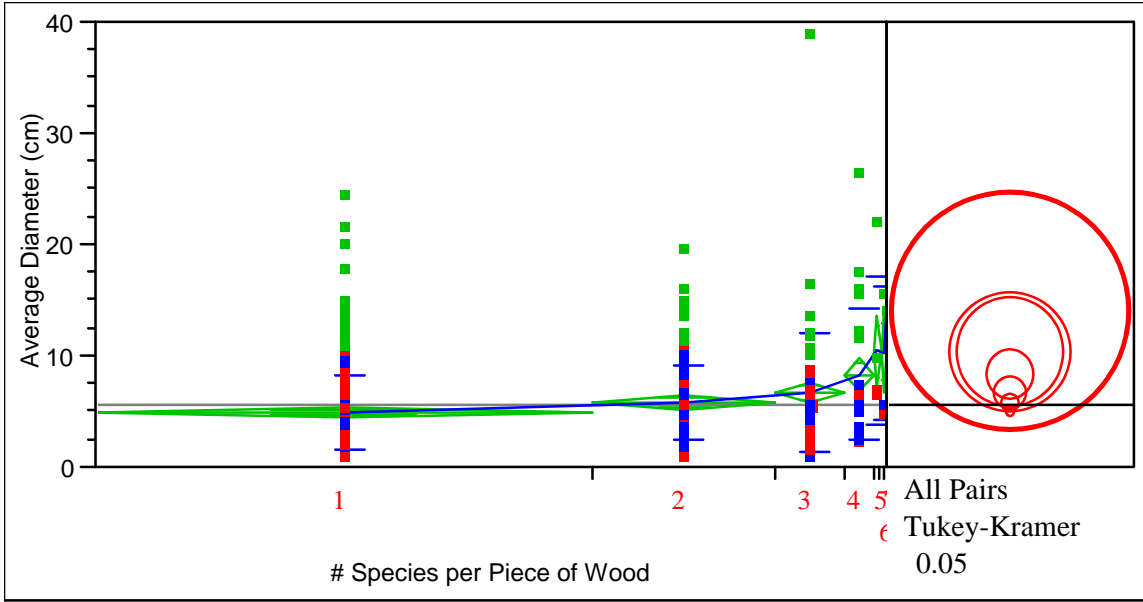


FIG. 9. Results for Wilcoxon Test for differences between species richness if the datum does not display normal distribution. A Tukey-Kramer test was used to compare means (average diameter in cm). The middle of the green diamond represents the mean diameter. Non-overlapping circles are statistically different from each other.

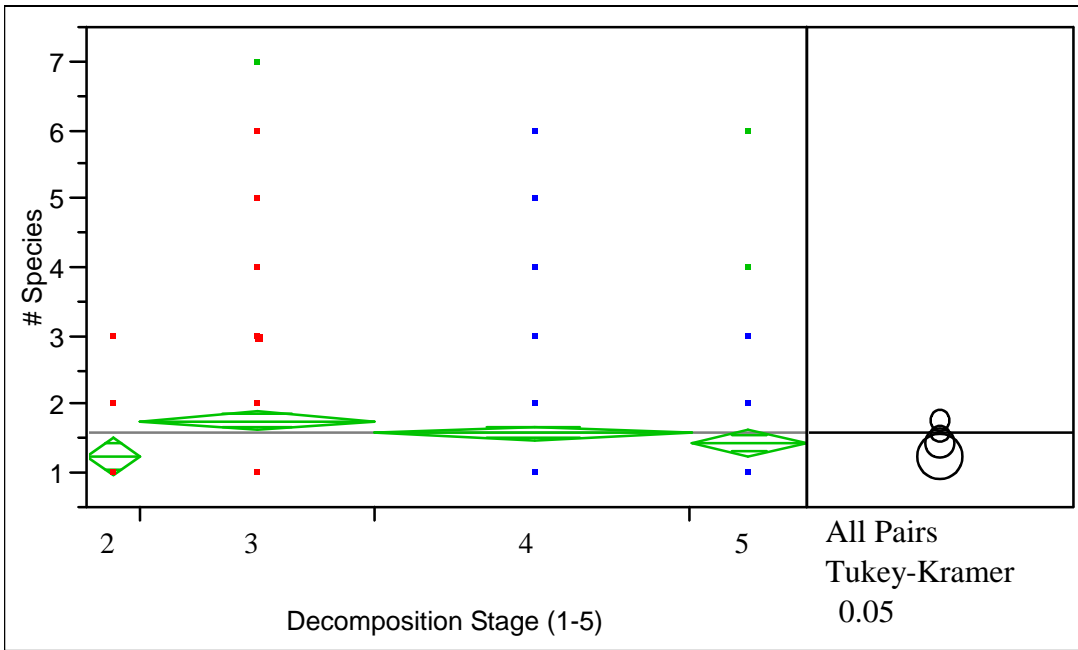


FIG. 8. Results from Wilcoxon Test for differences between decay stage (the datum does not display normal distribution). A Tukey-Kramer test was used to compare means (average number of species). The middle of the green diamond represents the mean species richness. Non-overlapping circles are statistically different from each other.

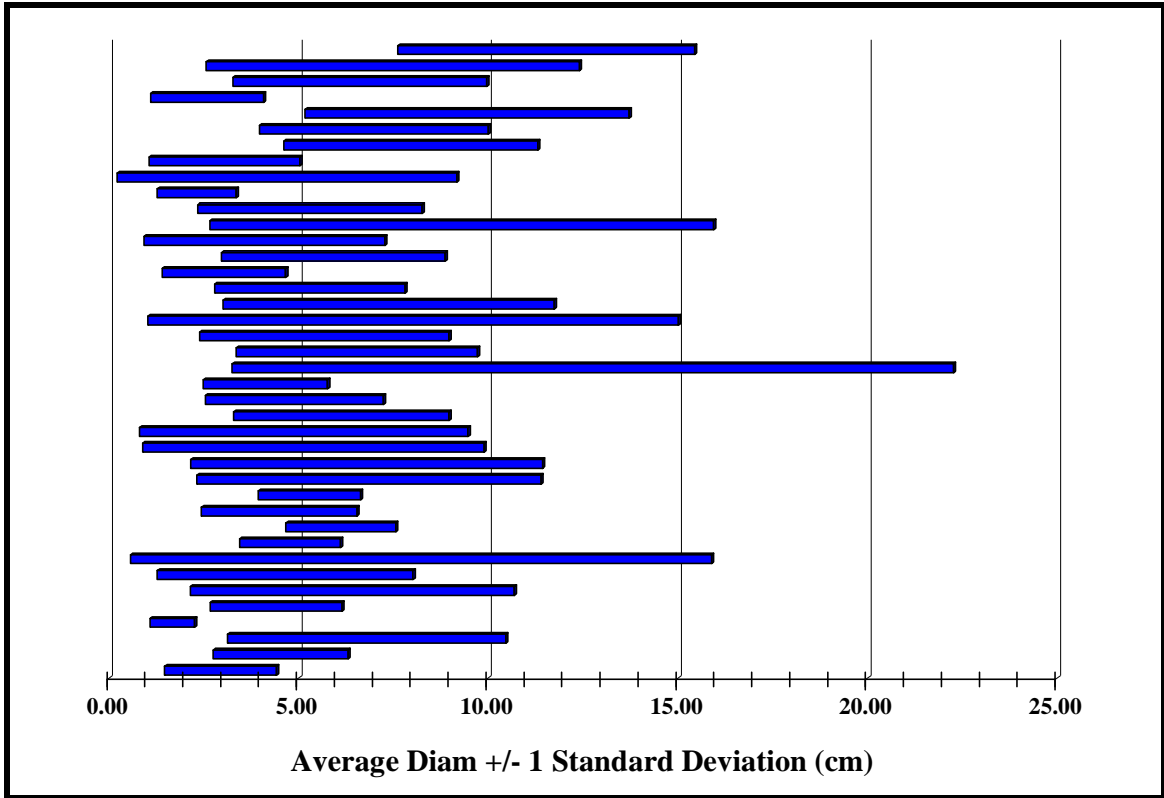


FIG. 11.

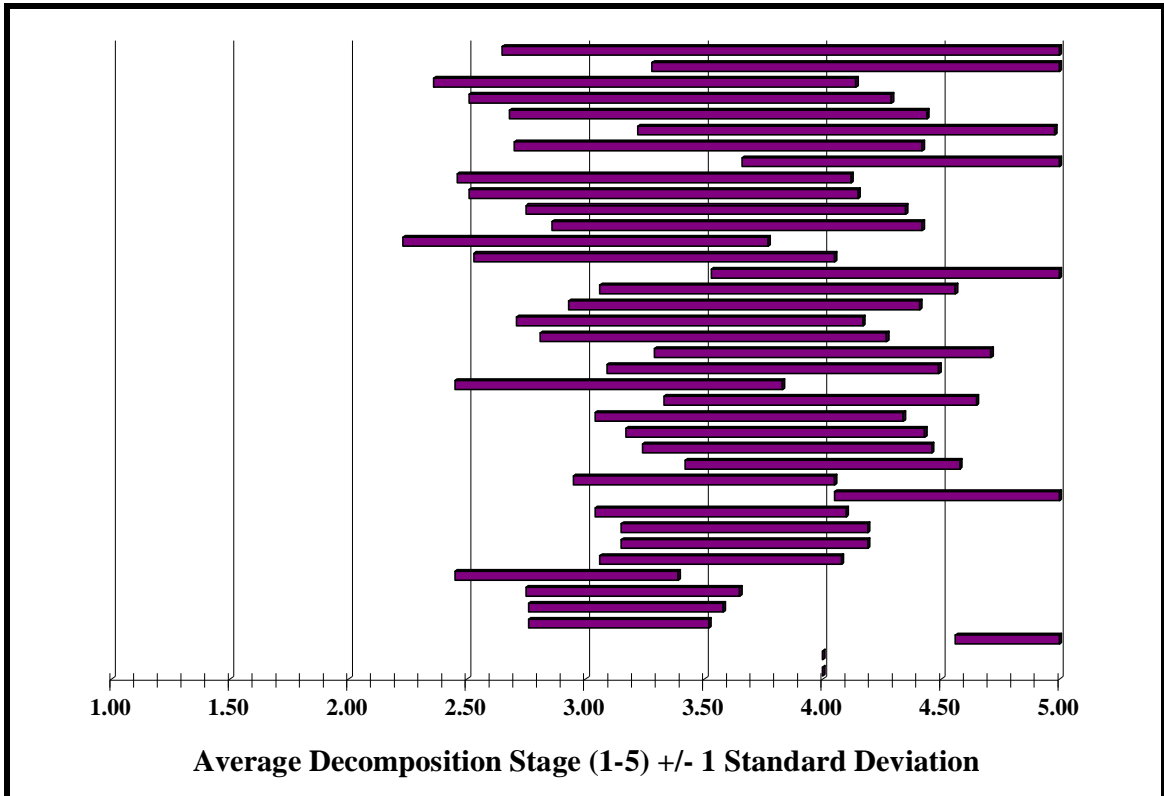


FIG. 12.

