Fall 2015

Comparative Study of Terrestrial Arthropod Diversity in Primary and Re-planted Pine Forest in a Community Forest at Andasibe, Madagascar

Tyler George
SIT Graduate Institute - Study Abroad

Mira Kelly-Fair
SIT Graduate Institute - Study Abroad

Andrea Wade
SIT Graduate Institute - Study Abroad

Comparative Study of Terrestrial Arthropod Diversity in Primary and Re-planted Pine Forest in a Community Forest at Andasibe, Madagascar

Tyler George
Mira Kelly-Fair
Andrea Wade
Advisor: Victor Razafindranaivo Academic Director: Nat Quansah
SIT: Zanzibar Coastal Ecology and Natural Resource Management

Fall 2015

Table of Contents

Acknowledgements

We would like to thank Dr. Nat Quansah and our field guide Claude for their efforts in helping us complete this study. We would also like to thank Said and the rest of the SIT staff in Zanzibar for helping us throughout the semester. We would also like to thank the students of the University of Antananarivo for their help in the field and for the SIT Madagascar staff for receiving us with open arms. What about the Staff in Zanzibar for help during the semester, your Malagasy peers, the AD of the SIT Urban and Rural Development Program, for office space and the staff of SIT Madagascar Traditional Medicine and Health Care Program, especially Dr Patricia Randrianavony, for helping organize your relocation from Zanzibar to Madagascar?

Abstract

This study is a comparison of tree and terrestrial arthropod diversity along native andre-planted pine transects.Transects were laid in a primary and re-planted pine forest in Andasibe Community Forest Park. Data was collected over six days, taking measurements of trees, inspecting and collecting specimens from pitfall traps once a day. Terrestrial arthropods were identified to morphospecies and measures of diversity were calculated. To understand the health of the trees, information was collected that included trees diameter at breast height, canopy cover and soil cover. Terrestrial arthropod communities and diversity were found to be significantly different in the native and replanted pine transects, likely due to the difference in non-native trees.

Introduction

Forests affected by human use and invasive species, like forests in Andasibe, are at high risk of degradation and decline. It is important that forest and ecosystem health are monitored to ensure that the forest is conserved for both current and future use and enjoyment. Biodiversity is a commonly used tool to measure ecosystem health. Insects are ideal candidates for biodiversity monitoring to measure ecosystem health because of their short life cycles, low resilience, high diversity, large spectrum of niches, and large population sizes. This makes them very responsive to ecosystem changes and good early warning indicators (Brown, 1997). Inventories of terrestrial arthropods can be helpful in designing nature reserves and guiding decisions on forest use. Many terrestrial arthropods are endemic and highly specialized to microhabitats. Terrestrial arthropod populations often can persist in smaller forest areas that cannot support populations of large vertebrates. This makes terrestrial arthropods potential candidates for flagship species used to make a case for forest reserves and parks (Kremen, 1993).

Tropical Africa, particularly Madagascar, holds great biological diversity, but there is relatively little formal knowledge on tropical African insects. According to Miller (2001), much of the existing information and collections of tropical African insects dates back to the colonial era and is held in various museums and private collections throughout Europe. This poses a problem for those researching insects in this area. There are few specialists who can identify members of any insect family to species in tropical Africa (Miller, 2001). Species counts are needed to calculate measures of species richness and diversity, tools in monitoring ecosystem health. In cases like this, the use of morphospecies classification can create accurate species counts. Measuring insect diversity with morphospecies takes less time, fewer resources, and does not need specialists that can identify insects to species. A Rapid Assessment of Biodiversity (RAB) uses arthropod morphospecies classification to generate data that can then be used to get accurate measures of biodiversity such as alpha and beta diversity. RAB are proposed as comprehensive, accurate, and inexpensive means of monitoring ecosystem health. Morphospecies classifications done by non-specialists and actual species counts done by specialists have proven to be relatively close, making morphospecies classification viable sources for data that do not compromise scientific accuracy (Oliver 1993). "In fact, in poorly surveyed regions such as many tropical moist forests, sorting to morphospecies for some arthropod taxa may be quicker and more reliable than for many plants and some vertebrates, a real advantage for inventory studies" (Kremen, 1993). Terrestrial arthropod morphospecies classification and RAB have been used in the past to measure species richness and measure ecosystem health (Goehring, 2002; Hughes, 2002; Obrist, 2010, Oliver, 1996). RAB and morphospecies classification are valuable tools to conservation biology, where the fate of species depends on our applied knowledge and protection of them and their habitats (Hughes, 2000).

Forest fauna are closely connected to the trees in a forest. Fish and other amphibious organisms rely on clean water and balanced nutrients for a productive life cycle. Trees also act on river and stream health, preventing soil from eroding along the banks and creating shade to keep temperatures low for the organisms using the water. Fertile soil is also an important quality that trees contribute to forest. As they grow, mainly in broadleaf trees, decaying leaves leave nutrients that are returned to the soil in time.Trees also benefit wildlife in amplitude of circuitous ways by providing shelter and food to a community of organisms.With deforestation comes loss of biodiversity and loss of precious resources. Although forests are a renewable resource,education enabling replanting and harvesting is very sparse in rural countries where the most deforestation occurs.

It has been estimated that about 50% of Madagascar's forests have been destroyed and converted to other uses in the past 50 years (McConnell, 2014). Madagascar's deforestation is a result of three main activities, slash and burn agriculture, logging, and firewood and charcoal production (Wild Madagascar, 2012). Slash and burn agriculture is most prevalent in remote areas where it is hard for authorities to control. This lack of enforcement has led to the annual loss of thousands of hectares of protected forest (WWF, 2015). Deforestation not only destroys valuable habitat for wildlife, but it leads to erosion, leaving land barren and unsuitable for wildlife or human use. The Madagascar Forestry Service and private organizations such as World Wildlife Fund (WWF) have led programs replanting trees in deforested areas. In 2011, the WWF planted 900,000 trees as part of its SEESO (Energy Environment Synergy in the South West) project. 500,000 of these trees were eucalyptus and 300,000 were acacia, neither of which are native to Madagascar (WWF, 2011). In the early 1900's, the Madagascar Forestry Service began planting eucalyptus trees on the eastern slopes of the Central Highlands in the Périnet region along the Tananarive-Tamatave railway (Aubreville, 2015). The reasoning behind planting non-native trees such as eucalyptus and acacia is that native Madagascar trees are slow growing. Fast growing trees can provide a quick fix to erosion and can keep up with the Malagasy people's high demand for firewood and charcoal. Eucalyptus in particular has the advantage of producing many fast growing stump shoots after being felled. This means that eucalyptus trees provide a regenerative source of wood. Eucalyptus have also been successfully grown on plantations on in Morocco and Ethiopia, meaning there is a lot of experience and information on planting and cultivating eucalyptus (Aubreville, 2015). Pines, especially *Pinus* *khasya* and *Pinus patula*, along with eucalyptus and acacia are the most common replanted trees east of the Central Highlands (Kull, 2007).

Although planting these non-native, pine, eucalyptus, and acacia trees have short term benefits of erosion control and use as firewood, charcoal, and timber, there is much controversy over their effects on Madagascar's native ecosystem. On the Global Invasive Species Database, *Acacia mearnsii* is listed as invasive in Madagascar. Like the pine and eucalyptus, acacia is fast growing and outcompetes native trees. In addition to displacing native flora, these non-nativespecies could be detrimental to ecosystem health as a whole. This study aimed to characterize the difference between terrestrial arthropod diversity in plots of native treesand trees. This study looked at the communities of arthropods in each site, to determine whether the non-native trees have an effect on the forest fauna.

Study Area

Andasibe-Mantadia National Park (Figure 1) located at 18°49′36″S 48°26′52″E is also known as Analamazaotra Special Reserve (ASR). The National Park is 150 km east of the capital Antananarivo. Andasibe has an average annual precipitation is 1700 mm, with rainfall on 210 days of each year. This park is recognized as an IUCN Category II National Park. Andasibe was once part of the larger national park of Mantadia but was separated due to logging and deforestation. Established in 1989, Andasibe National Park is known for its 11 species of lemurs and vast biodiversity of insects and reptiles (Brandt, 2002). This study was located in a section of adjoining forest managed by the local community, (VO.I.M.MA managed community forest). Two transects were laid in this Andasibe Community Park. Located in Andasibe Community Forest, one transect was established in an area with native trees at 18°55’47” S, 48°25’4”E and one in an area with non-native trees at 18°55’53” S, 48°24’53” E.

Figure 1. Location of the Andasibe-Mantadia National Park

Methods

Tree Methods

Transects of a hundred meters long with a two meter width were laid in both the primary and replanted pine-forests. The species of tree, Diameter at Breast Height (DBH), percent canopy cover, and type of ground substrate were recorded to determine forest health. DBH was not measured on trees with a DBH of less than 5 centimeters. DBH was determined by wrapping a tape measure around the tree at breast height. The tree's location along the transect was also noted. Individual tree health was determined by looking at the trunk. A guide assisted in identifying tree species.

Insect Collection:

Terrestrial arthropod data was collected over a six day time scale in over November 9-14 2015. Insects were collected using pitfall traps (Figure 2) set up along the 100 meter transect. Ten traps were installed along each transect, spaced 10m apart. Traps were made out of 1.5 liter plastic water bottles cut in half. Traps were dug into the ground so that the lip of the trap was level with the ground. Traps were filled half way with water with a small amount of soap in it to break surface tension. Traps were checked, emptied and reset once a day for 6 days.

Insects were identified to order. Members of Coleoptera were identified to family. Some beetles that were too small to identify to family were categorized as unidentified beetles. Spiders, order Araneae, were also included in the study. Some non-insect classes of terrestrial arthropods such as Chilopoda and Diplopoda were also included in the study and were not identified past class. Bees, flies, wasps, and other flying insects were excluded from the study because the collection method of pitfall traps is targeted at collecting primarily ground dwelling insects and is not effective means to collect a representative sample of flying insects. All terrestrial arthropods were then sorted into morphospecies.

Statistics

The morphospecies were combined into order. A Shapiro-Wilks test was used to determine if the data of each sample was normally distributed. If it was, a paired t-test was used. If it was not normally distributed, a Mann-Whitney U test was used. This comparison was not completed for centipedes, millipedes, scorpions, pseudoscorpions, and earwigs since they were only found in one plot. Additionally, if data was not normally distributed but the order was not sighted every single day, then a Mann Whitney U test could not be performed. This process was also followed to compare Coleoptera morphospecies.

A Shannon Weiner Index was also used and the gamma, beta, and alpha diversity was calculated using both Andasibe Community Park and the individual transects as regional scales. These tests were conducted for both terrestrial arthropods morphospecies and Coleoptera morphospecies.

Figure 2. Pitfall Trap installed in theprimary forest.

Results:

Terrestrial Arthropods

The mean number of Hymenoptera along the native tree transect was 41.167 ± 5.868. A Shapiro Wilks test showed a p-value of 0.013. The mean number of Hymenoptera along the non-native forest -transect was 19.167 ± 3.453. A Shapiro Wilks test showed a p-value of 0.963. Because Hymenoptera on the native foresttransect did not have a normal distribution according to the Shapiro Wilks test, a Mann-Whitney U test was used. The p-value was 0.063.

The mean number of Coleoptera along the native forest transect was 3.167 ± 1.522. A Shapiro Wilks test showed a p-value of 0.801. The mean number of Coleoptera along the non-native tree transect was 18 ± 2.921. A Shapiro Wilks test showed a p-value of 0.456. Because there was a normal distribution according to the Shapiro Wilks test, a paired t-test was used. The p-value was 0.005.

The mean number of Blattaria along the native tree transect was 1 ± 0.946. A Shapiro Wilks test showed a p-value of 0.167. The mean number of Blattaria along the non-native tree transect was 1.5 ± 1.174. A Shapiro Wilks test showed a p-value of 0.191. Because there was a normal distribution according to the Shapiro Wilks test, a paired t-test was used. The p-value was 0.597.

The mean number of Orthoptera along the native tree transect was 5.833 ± 2.217. A Shapiro Wilks test showed a p-value of 0.834. The mean number of Orthoptera along the non-native tree transect was 6 ± 2.166. A Shapiro Wilks test showed a p-value of 0.614. Because there was a normal distribution according to the Shapiro Wilks test, a paired t-test was used. The p-value was 0.944.

The mean number of Araneae along the native tree transect was 16.667 ± 2.763. A Shapiro Wilks test showed a p-value of 0.533. The mean number of Araneae along the non-native tree transect was 14.500 ± 2.858. A Shapiro Wilks test showed a p-value of 0.235. Because there was a normal distribution according to the Shapiro Wilks test, a paired t-test was used. The p-value was 0.576.

The mean number of Collembola along the native tree transect was 5.167 ± 2.109. A Shapiro Wilks test showed a p-value of 0.726. The mean number of Collembola along the non-native tree transect was 9 ± 2.166. A Shapiro Wilks test showed a p-value of 0.212. Because there was a normal distribution according to the Shapiro Wilks test, a paired t-test was used. The p-value was 0.050.

Coleoptera

The mean number of Staphylinidae along the native tree transect was 1.833 ± 1.213. A Shapiro Wilks test showed a p-value of 0.804. The mean number of Staphylinidae along the non-native tree transect was 14.667 ± 2.500. A Shapiro Wilks test showed a p-value of 0.107. Because there was a normal distribution according to the Shapiro Wilks test, a paired t-test was used. The p-value was 0.003.

Shannon Weiner

The terrestrial arthropods in the native tree transect had a score of 2.603 according to the Shannon Weiner Index. The terrestrial arthropods in the non-native tree transect had a score of 3.125 according to the Shannon Weiner Index (Figure 3).

The Beetles along the primary forest transect had a score of 2.205 according to the Shannon Weiner Index and the beetles along the re-planted pine forest transect had a score of 1.749.

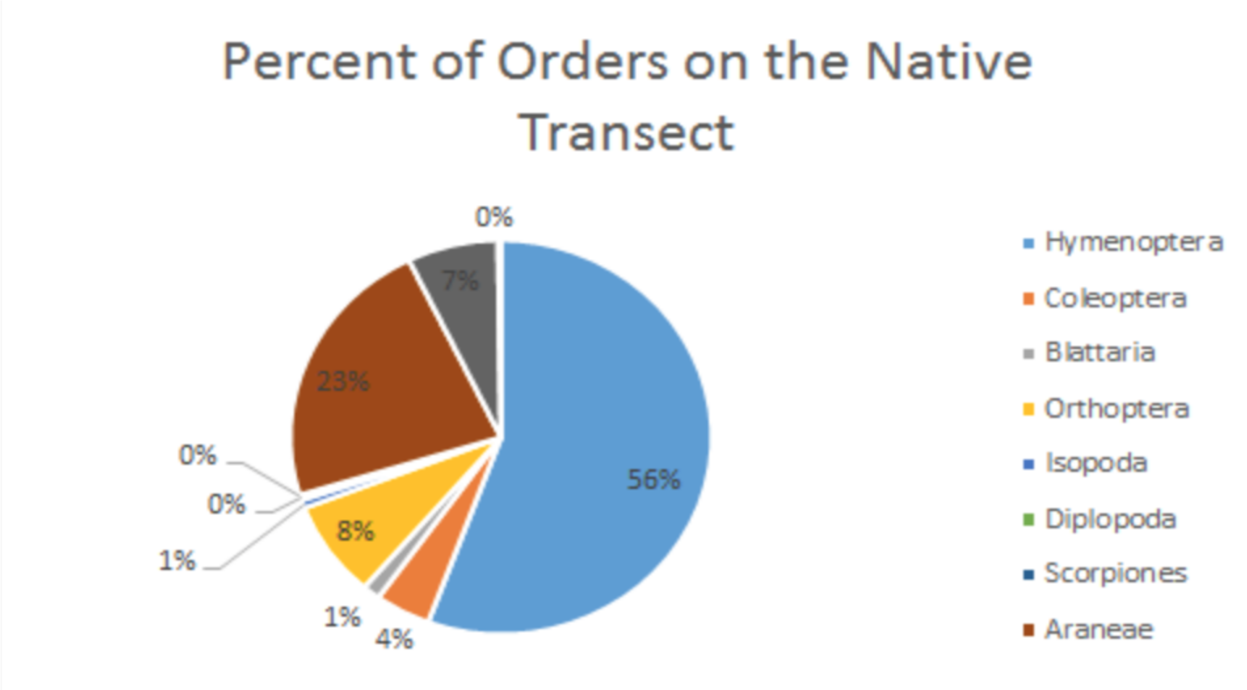
Alpha, Beta, Gamma Diversity

Using the transects as a local scale and Andasibe Community Forest as a regional scale, the alpha diversity of terrestrial arthropods is 56.5, the beta diversity is 76, and the gamma diversity is 1.345.

With the transects as a regional scale and the individual pitfall traps as a local scale, the alpha diversity of terrestrial arthropods along the native transect is 15.7, the beta diversity is 57, and the gamma diversity is 3.631. Along the non-native transect, the alpha diversity is 17, the beta diversity is 56, and the gamma diversity is 3.294.

Using the transects as a local scale and Andasibe Community Forest as a regional scale, the alpha diversity of Coleoptera is 14.5, the beta diversity is 21, and the gamma diversity is 1.448.

With the transects as a regional scale and the individual pitfall traps as a local scale, the alpha diversity of Coleoptera along the primary forest transect is 1.6, the beta diversity is 12, and the gamma diversity is 7.5. Along the re-planted pine forest transect, the alpha diversity is 4, the beta diversity is 17, and the gamma diversity is 4.250.



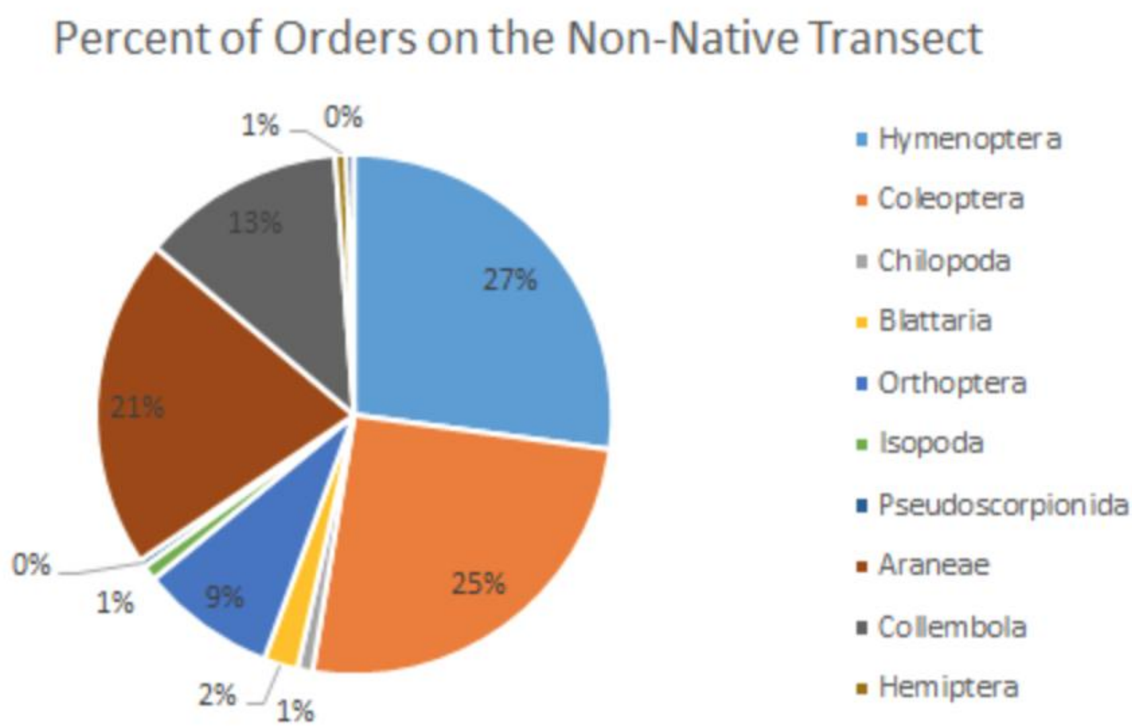


Figure 3. Comparison of Distribution of Terrestrial Arthropods

Tree plots

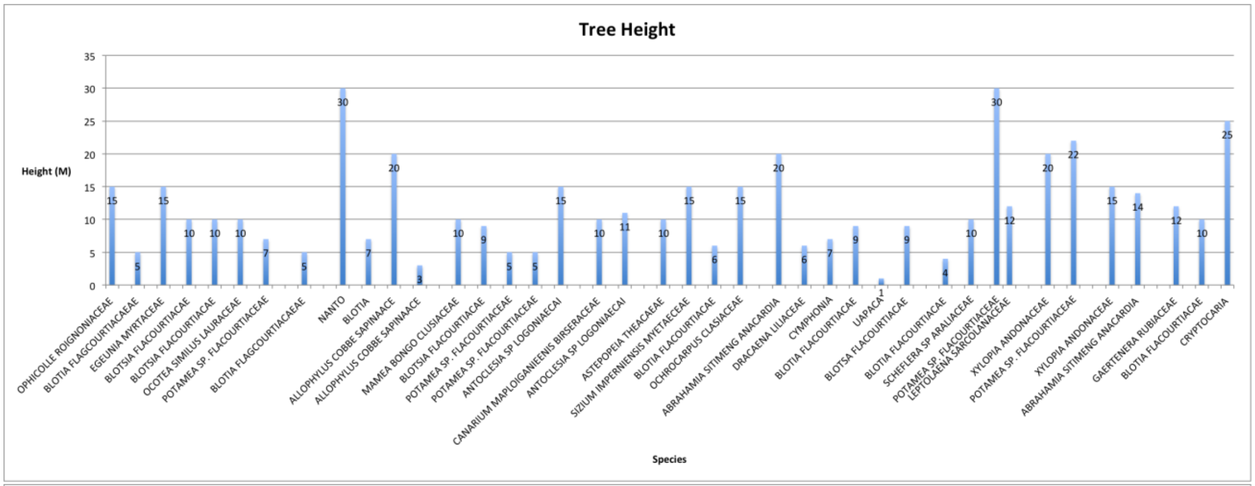
Over the span of 100 meters 40 trees were observed within the primary forest included a total of 23 tree species (Table 1). The average height of the trees in the primary forest was 11.85 meters, with the highest tree measuring 30 meters tall (Figure 3). At an elevation of 9420 meters, primary forest’s trees were 1150 meters higher than the forest and they were not as prone to traffic. Within the primary fores, the canopy cover was much lower than that of the -planted pine forest. While the primary foresthad a 50% canopy cover, it was observed to be 13% less than the re-planted Pine forest, which had a canopy cover of 63(Figure 4). The re-planted Pine forest included a range of only 10 species (Table 2) and plot of only 24 trees within the same measure of 100 meters. The re-planted Pine forest had a greater DBH than the primary forest averaging a DBH of 15.4 while the primary forest had an average DBH of 10.8 (Figure 5). The Re-planted Pine forest towered over the Primary Forest with an average of 18.7 meters and the highest measured height at 55 meters (Figure 6). Within the re-planted pine forest plot the trees the plot distribution was less dense than the primary forest trees. The re-planted pine forest’s trees had a measureable tree on average every 3.8 meters while the primary forest’s trees were able to be measured every 2.6 meters (Figure 7)

Table 1. Primary ForestTree Species

1 *Ophiocollea sp.* Bignoniaceae
2. *Blotia sp.* Euphorbiaceae
3. Eugenia *sp.* Myrtaceae
4. Blotsia *sp.* Flacourtiaceae
5. *Ocotea similis* Lauraceae
6. *Potameia sp.* Lauraceae
7. *Chrysophyllum sp.* Sapotaceae
8. Allophylus cobbe Sapindaceae
9. Mammea *sp.* Clusiaceae
10. *Potameia sp.* Lauraceae
11. Anthocleista *sp.* Loganiaceae
12. Canarium *madagascariense* Burseraceae
13.unidentified species Theaceae
14. *Syzygium sp.* Myrtaceae
15. *Ochrocarpus sp.* Clusiaceae
16. *Abrahamia sitimeng* Anacardiaceae
17. *Dracaena sp.* Liliaceae
18. *Symphonia sp.* Clusiaceae
19. *Uapaca sp.* Euphorbiaceae or (Phyllanthaceae)
20. *Schefflera sp.* Araliaceae
21. Lepilaena sp. Zanichelliaceae
22. Xylopia sp. Annonaceae
23.Gaertnera sp. Rubiaceae
24. Cryptocarya sp. Lauraceae

Table 2 . Non-Primay (Re-planted Pine) FOREST Species

1. *Harungana madagascariensis*
2. *Pinus ponderosa*
3. *Weinmannia*
4. *Dypsis palm*
5. *Erythroxylum*
6. *Cryptocarya*
7. *Bridelea*
8. *Ocotea*
9. *Haruongana madagascariensis*
10. *Campylospermum sp. Ochnaceae*



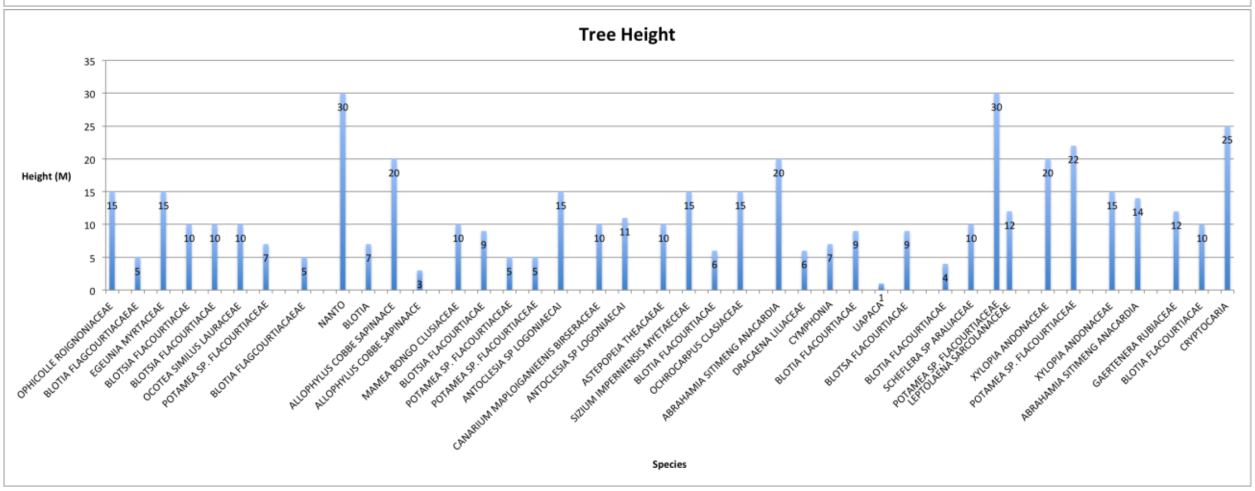
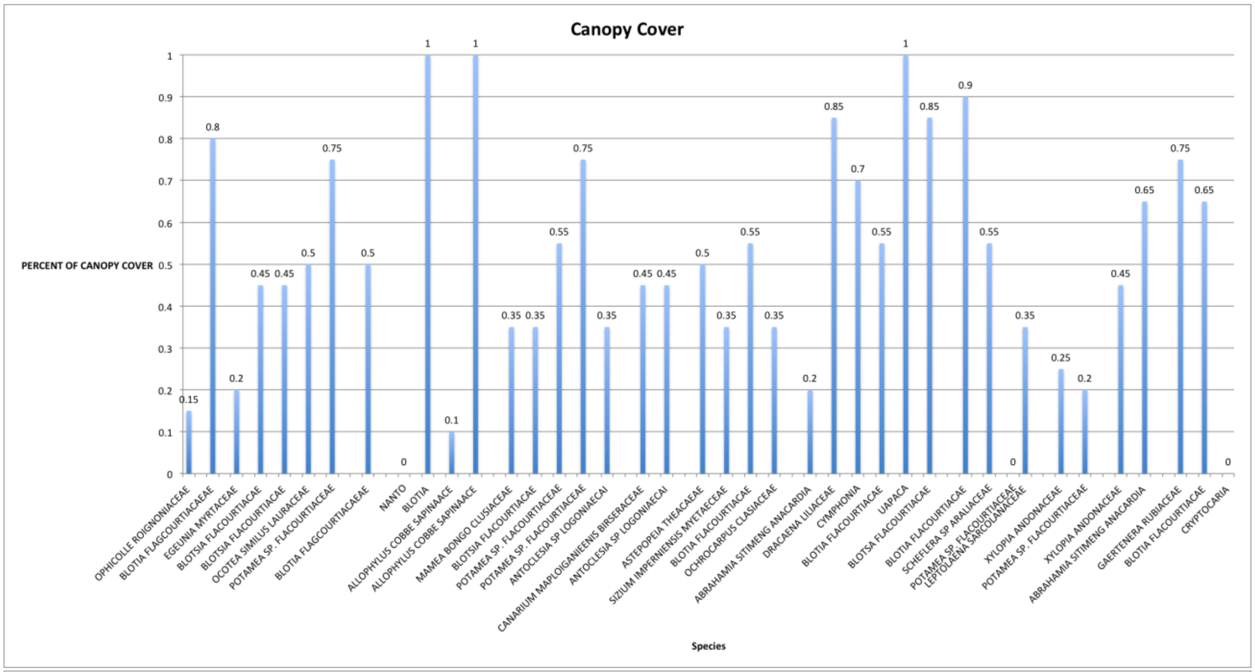


Figure 3. Height of Primary Forest trees and Replanted Trees



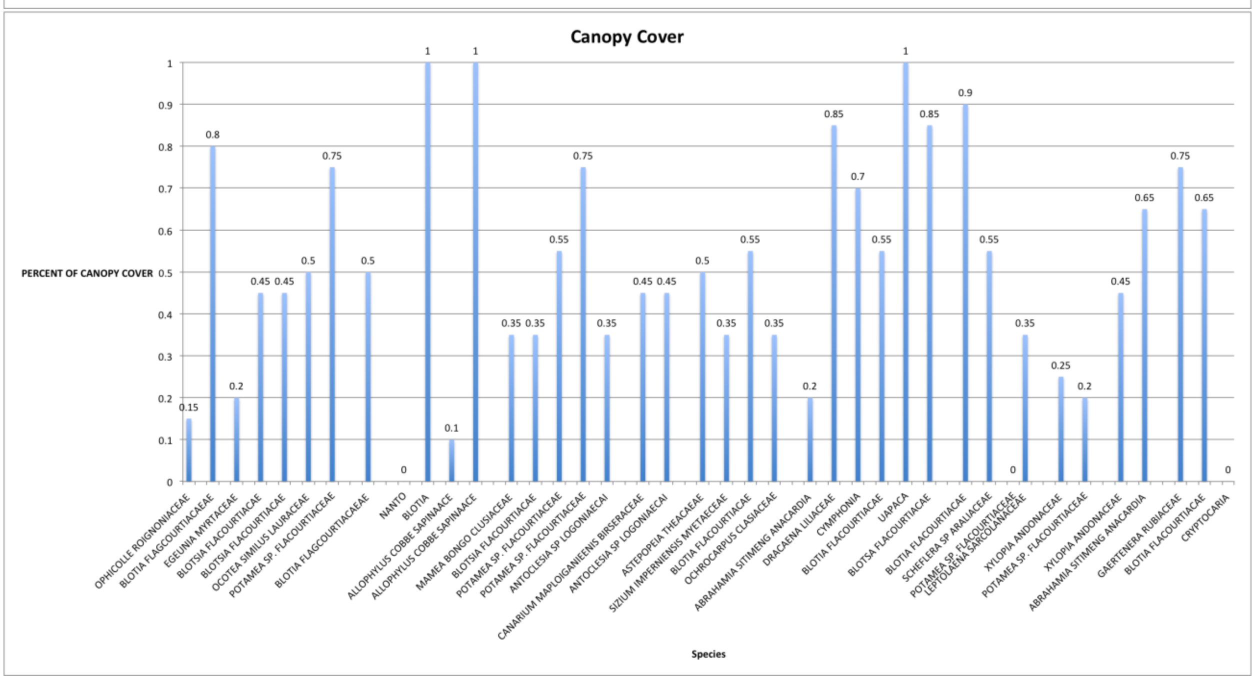


Figure 4. Canopy Cover Primary Forest Trees.and Replanted Trees

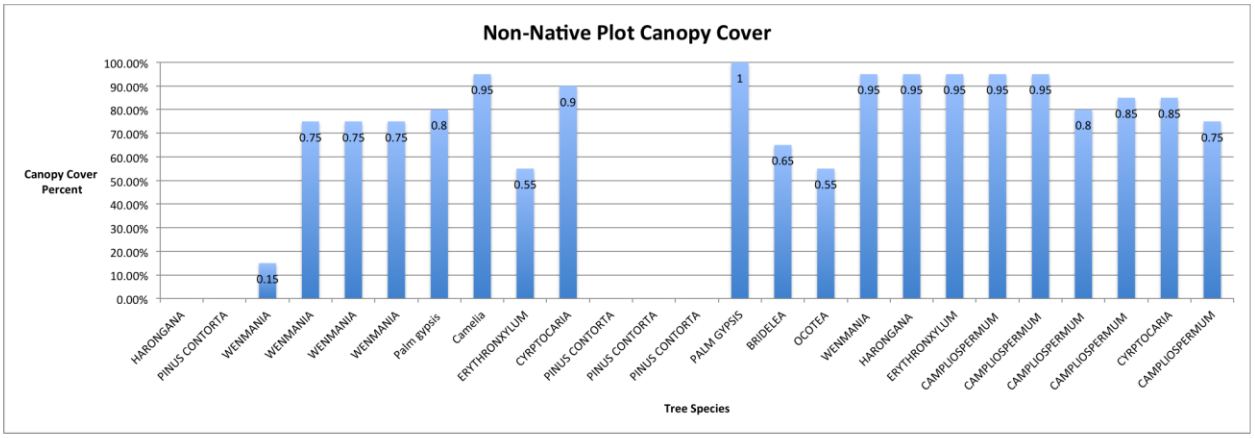


Figure 5. Re-planted Pine Forest Canopy Cover Percent

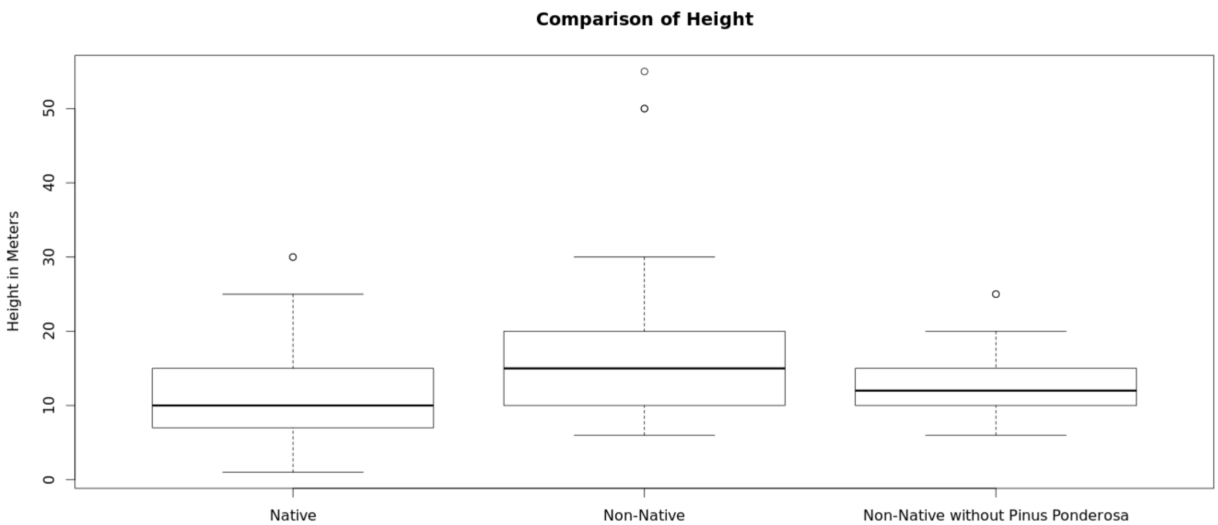


Figure 6a: A comparison of height between the Primary and Replanted Transects and the Replanted Transect with the *P. Ponderosa* outlier removed

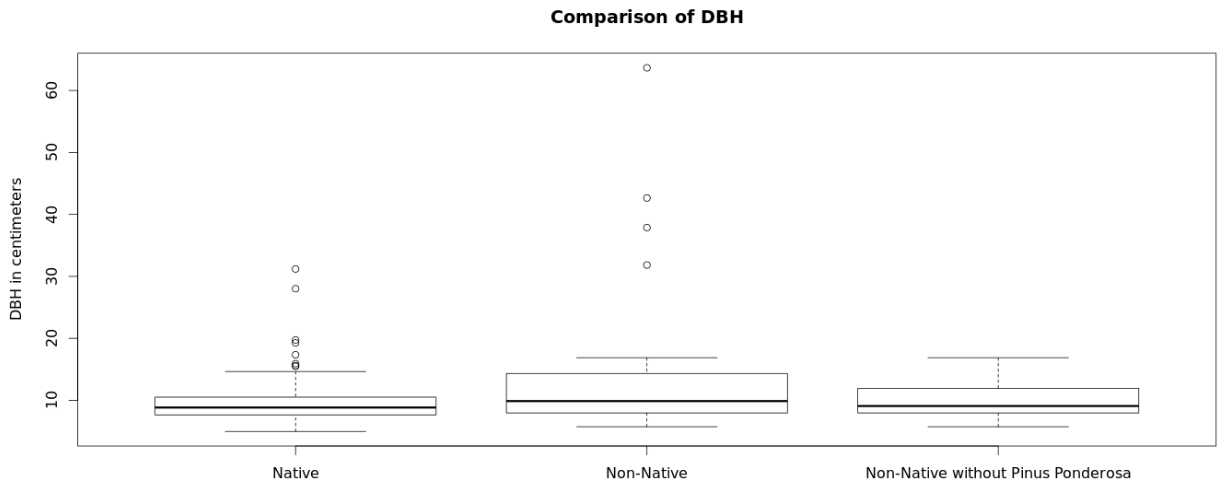
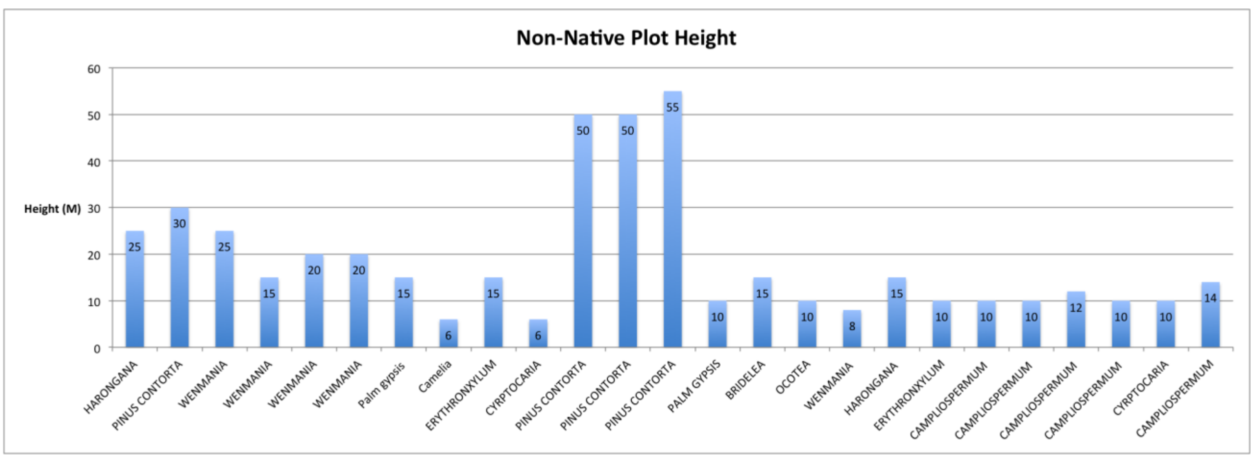


Figure 6b: A comparison of DBH between the Primary and Replanted Transects and the Replanted Transect with the *P. Ponderosa* outlier removed



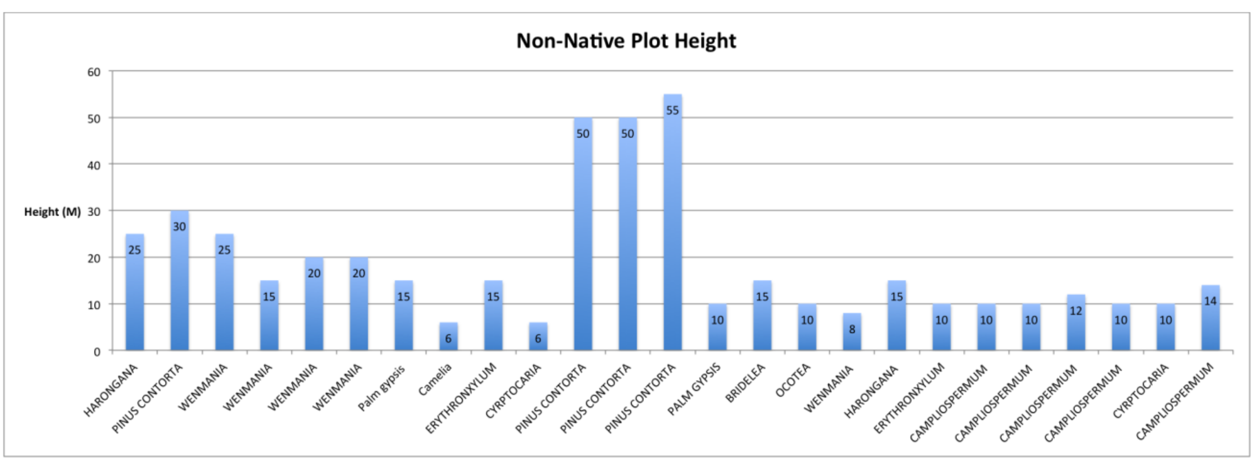


Figure 7. Re-planted Pine Forest Tree Height

Discussion

While comparing the primary forest and planted forest's trees height, there is a difference with the re-planted forests being 6.85 meters taller than the primary forest. This is because Pinus was able to grow higher than its competitors in the transect. The tallest *P. ponderosa* in the re-planted forest plot was measured at 55 meters tall, while its closest primary rival in the primary forest was Nanto, with a height of only 30 meters. Here the *P. ponderosa* is allowed to absorb a vast amount of sunlight and nutrients over the other species in the same plot. The growth and size of the Pinus p. skewed the data and threw off the average. Without the pines, the primary and re-planted forests would have had a more similar average height.

Relating to the height of the trees, canopy cover was measured to be considerably higher in the re-planted plot. At 63%, the re-planted trees managed to have 13% more cover. This is also due to the height difference of the primary and re-planted. But without the pines skewing the data, statically speaking, the primary forest should have had a greater canopy density due to their denser plot size of a tree every 2.6 meters. With 23 species located in the primary forest and only 10 species within re-planted forest, assumptions can be made about a greater biodiversity within the primary forest.

The DBH of the re-planted forest was 70% greater than that of the primary forest. With an average DBH of 15.4, the re-planted forest's trees were far larger than that of the primary forest's trees, which had a DBH of 10.8. This was due to the large pines having an average DBH of 43.45. Once again the pines skewed the data of the re-planted forest. A more accurate comparison would have been achievable without the pines in the data set.

The results were as expected. *P. ponderosa* is a huge tree that can overgrow most primary forest species. Creating canopy cover and using nutrients from the soil, you can start to see once larger trees, growing to smaller sizes under the shade of *P. ponderosa*. Invasive species typically have mass growth that occurs and trees reproduce and seed within close proximity.

More data should have been collected over a greater amount of time to receive better results. Collecting tree cores and being able to measure water density and wood density would have made the study more accurate to more precisely compare the native and non-native trees growth rates and biomass. Using a DBH tape measure would have been more reasonable. Converting circumference to DBH manually can lead to human error and further inaccurate results. Also, a tool that would have enhanced recordings would have been LIDAR.

The study was limited to a small sample size. If the sample size had expanded, the results wouldn't have been so skewed by the pines. The study would have benefited from an increase previous knowledge of rainforest ecology of growth rates and species.

Terrestrial Arthropod Discussion:

There was not a significant difference between most of the orders of terrestrial arthropods along the two transects. However, there was a significant difference in the number of Coleoptera between the two transects. For this reason, calculations were completed to determine if there was a significant difference in the number of individuals of each morphospecie in Coleoptera along the two transects. It was found that there was a significant difference in the number of Staphylinidae.

According to our results, there is a higher morphospecies count in the primary transect than in the re-planted transect. However, because the gamma diversity is relatively low, this difference is probably not significant. Additionally, there is a higher Shannon Weiner Index score in the re-planted transect. This suggests that of the morphospecies that are in the re-planted plots, there is a more regular distribution of morphospecies and individuals.

However, looking just at beetles, both Shannon Weiner and the gamma diversity seem to suggest that there is a higher diversity of beetles along the primary transect. The count of morphospecies recorded along the re-planted transect is higher but the gamma diversity score for the primary transect is much higher. Like with the terrestrial arthropod's gamma diversity, when the results are put on the regional scale of Andasibe, the gamma diversity is relatively low.

Conclusion

The primary and re-planted transects appear to be two very different environments as seen by the data collected on trees and terrestrial arthropod communities and diversity. From the ground cover to the DBH and height of the trees, major differences were noted. The ground cover created by the pines also appeared to differ from that created by the native broadleaf trees. While the height of the trees created a canopy cover greater than that of the primary forest. Terrestrial arthropod communities also differed greatly between transects laid in the primary and re-planted pine forests .There were significantly more Staphylinidae in the re-planted fores.. There were also more Coleoptera morphospecies in the re-planted forest giving it higher beta diversity, but the primary forest transect had significantly higher gamma diversity for Coleoptera. This suggests a more regular distribution of Coleoptera in the primary forest transect even though there was a higher count of individuals and number of morphospecies along the re-planted forest transect. Although this is not necessarily correlated to the differences in tree species, it is likely that the re-planted forest have had an effect on the terrestrial arthropod community.

Recommendations

A more comprehensive investigation of non-native trees in the Andasibe region is still needed to determine what effect re-planted trees have on ecosystem health and fauna communities. This study looked at a plot of pine trees, but pines represent just one of the three main exotic trees being planted in reforestation efforts in Andasibe. Future work could include plots going through replanted acacia and eucalyptus areas. Transects through multiple different patches of each type of tree would also benefit future studies. This would ensure that differences in insect community and diversity is a result of the re-planted trees and not local microhabitat conditions like moisture, elevations, or temperature.

Future research should look at the growth rates of both plots. Also, researchers should take note on observable seedlings or reproductive signs of the non-native pines.

For further study, suggestions would be made in the direction of doing more than just two transects and using a width of more than 2 meters. Also, researchers should do transects through multiple terrains and types of forest instead of the same for each plot. Taking samples of each leaf for an identification guide is also be recommended for later identification.

Bibliography

Aubreville, A. (2015). No to the "eucalyptus war" in madagascar! (I. Bossanyi, Trans.). Bois Et Forets Des Tropiques, 323(1), 51-56

Bradt, H. (2002). *Madagascar*. Chalfont St. Peter, England Guilford, Conn: Bradt Globe Pequot.

Brown, K. S. (1997). Diversity, disturbance, and sustainable use of neotropical forests: insects as indicators for conservation monitoring. Journal of Insect Conservation, 1, 25-42.

Goehring, D. M. , Daily, G. C. , Sekercioglu, C. H. (2002). Distribution of ground-dwelling arthropods in tropical countryside habitats. Journal of Insect Conservation, 6, 83-91

Google earth V 6.2.2.6613. (November, 25 2015). Madagascar.
AfriGis 2015. http://www.earth.google.com [2015].

Hughes, J. B. , Daily, G. C. , Ehrlich, P. R. (2000). Conservation of insect diversity: a habitat approach. Conservation Biology, 14(6), 1788-1797

Invasive Species Specialist Group. Global invasive species database, Madagascar http://issg.org/database/species/search.asp?st=sss&sn=&rn=Madagascar&ri=19363&hci=-1&ei=-1&fr=1&sts=&lang=EN

Kremen, C. , Colwell, R. K. , Erwin, T. L. , Murphy, D. D. , Noss, R. F. , Sanjayan, M. A. (1993). Terrestrial arthropod assemblages: their use in conservation planning. Conservation Biology, 7(4), 796-808

Kull, C.A., Tassin, J., Rangan, H. (2007). Multifunctional, scrubby, and invasive forests? Wattles in the highlands of Madagascar. Mountain Research and Development, 27, 224-31. DIO:http://dx.doi.org/10.1659/mrd.0864

McConnell, W., Kull, C. (2014). Protecting lemurs: Madagascar's forests. Science (344)358. DIO:10.1126/science.344.6182.358-a

Miller, S. E. ,Rogo, L. M. (2001). Callenges and opportunities in understanding and utilisation of African insect diversity. Cimbebasia: Journal of the State Museum, Windhoek, 17, 197-218

Obrist, M. K. ,Duelli, P. (2010). Rapid biodiversity assessment of arthropods for monitoring average local species richness and related ecosystem services. Biodiversity and Conservation, 19(8), 2201-2220. DIO 10.1007/s10531-010-9832-y

Oliver, I. , Beattie, A. J. (1993). A possible method for the rapid assessment of biodiversity. Conservation Biology, 7(3), 562-568

Oliver, I. , Beattie, A. J. (1996). Invertebrate morphospecies as surrogate for species: a case study. Conservation Biology, 10(1), 99-109.

Oliver, I. , Beattie, A. J. (1996). Designing a coast-effective invertebrate survey: A Test of methods for rapid assessment of biodiversity. Ecological Applications, 6(2), 594-607 DIO: 10.2307/2269394

Wild Madagascar. (2004-2012) Threats to Madagascar's biodiversity and ecosystems. Butler, R. http://www.wildmadagascar.org/conservation/threats.html

World Wildlife Fund. (2011). 900,000 trees planted in Madagascar's dry South West http://www.wwf.mg/?202480/900000-trees

World Wildlife Fund. The problem: slash-and-burn agriculture http://wwf.panda.org/what_we_do/where_we_work/project/projects_in_depth/wwf_on_the_ground_in_madagascar/the_problem__slash_and_burn_agriculture/