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Seed Dispersal by Ants in Jarrah Forest Restorations of Western Australia

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Introduction

The jarrah forests in Western Australia cover approximately 1.75 million ha in the southwestern corner of the state (Figure 1). Jarrah, otherwise known as *Eucalyptus marginata*, is only one species among many that inhabit a region with considerable physical and biological diversity. 1200 species of plants, 29 mammalian species, 45 reptile species, 17 frog species, 4 fish species and 150 bird species live in this system which also has highly adverse conditions for survival. These may include infertile, often salt-laden soils, drought, and the occasional wildfire (Western Australia Forest Alliance, 2003). Considerable deposits of bauxite, which is the primary material involved in the production of aluminum, are scattered throughout the region. Since 1963, Alcoa of Australia Ltd. has cleared these jarrah forests to make way for mining of this ore. It is estimated that these deposits cover 7-8% of the forested area although only 3-4% will ever be mined due to environmental and economic constraints (Majer, 1989). These mined areas create a scattering of patches throughout the forest that are essentially stripped of any kind of biodiversity that was once there (Figure 2). Restoration efforts on these previously mined patches focus on many aspects of the jarrah forest ecosystem. Specifically interesting is the role that ants play in seed dispersal. This paper will focus on the topic of seed dispersal by ants in the northern jarrah forests of Western Australia while paying particular attention to myrmecochory.

Figure 1. Location of jarrah forest in Australia

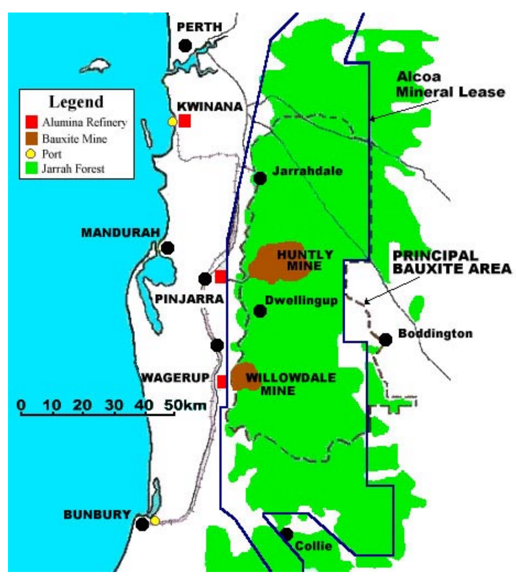

Figure 2. Mining locations within jarrah forest.


Figure 3. Bauxite mining locations in jarrah forest.

Ant-Seed Relationships

Invertebrates such as ants are involved in many important processes in forest ecosystems. They influence aeration, drainage and nutrient availability of the soil through bioturbation and many are involved in seed dispersal. These activities are variable throughout the year, being influenced by temperature and moisture levels. Thus, in the jarrah forest where there is a wide range of climatic conditions, the influence of these invertebrates is not consistent throughout (Dell, 1989). Sernander (1906) introduced the term 'myrmecochore' for any plant whose diaspores (seeds, fruits, etc.) are sought out and disseminated by ants owing to the presence of particular ant-attracting tissues or structures which he termed 'elaiosomes' (Berg, 1975). On another level, the term "myrmecochory" is revealed in this way: myrmeco- from *myrmex*, meaning "ants"; and -chory from *chorein*, meaning "to wander" (Abrahamson, 1997). Many Australian plants possess diaspores that are myrmecochorous. The structure of the elaiosome nearly always occurs in the form of a white or light-colored smooth appendage on the diaspore and most Australian elaiosomes are relatively dry and hard and, because of their firm structure, quite permanent (Berg, 1975). There is a relationship between the size of the ant and the size of the seed taken. The likelihood of seeds being taken by ants or vertebrates is related to the dimensions and weight of the seed (Abbott & van Heurck 1985a in Majer & Abbott, 1989). Jarrah seeds, for example, are quite small and are removed quite frequently by ants while heavier seeds are taken more often by vertebrates (Abbott & van Heurck, 1985). This relationship is not, however, completely indicative of the types of seeds taken by ants. Particularly intriguing, and in need of much detailed study, is the relationship between ants and *Eucalyptus* seeds. These seeds are hard and dry with no apparent elaiosome, yet they are still collected regularly and in great quantity by ants that are generally not regarded as harvester ants (Berg, 1975).

The myrmecochorous relationship between ants and plants in Australia is theorized to have developed because of several needs of the plants. They include: (1) an evolving response to dispersal requirements, (2) the need to escape seed predators, (3) the need to escape the extreme heat of wildfires and (4) the possibility to enhance the longevity of seeds. The last three of these needs may be assisted by the burial of the seed beneath the soil surface in ant nests (Majer, 1980). Seed dispersal provides a number of benefits that are not mutually exclusive to one particular plant species. In addition to those previously mentioned, dispersal allows for colonization of distant habitats, improves survival if herbivory is more prevalent where the seed was produced and allows for less competition between the parent plant and the sibling (Abrahamson, 1989).

Ants have had a particularly good mutualistic relationship with plants because they rarely eat plants or destroy living plant tissue (Abrahamson, 1989). Many plants have adapted their seed presentation characteristics to favor dispersal by ants. Elaiosomes are present on some seeds and are utilized as an attractive food source, some have stalks that bend to the ground to present the seed at ground level, some release seeds at times of the day when ants rather than seed predators are more prevalent and some plants shape the seed and elaiosome to facilitate carrying by ants (Abrahamson, 1989). Another reason ants are particularly advantageous over other seed dispersers, such as vertebrates, is because they generally plant the seed in nutrient enriched areas. This deposition of the seed in a protected or nutrient-rich microsite is called inhumation (Abrahamson, 1997).

Figure 4 An ant carrying a seed with an eliasome.

Ants are among the most diverse and abundant species on the jarrah forest floor. Their activity is strongly seasonal with their maximum foraging occurring between late December and March. These months are the warmest and driest of the year and are the times when prey, nectar and seed sources are most abundant (Dell, 1989). Ants can be classified into three groups with reference to their seed-collecting characteristics. These are non-collectors, general collectors and elaiosome collectors. Non-collectors show little interest in diaspores under test conditions and tend not to collect seeds no matter the seed type. As such, they are of little importance in the ant-plant seed dispersal relationship. The other two classes are of importance. General seed collectors are those ant species that collect diaspores with and without elaiosomes, but they seem to prefer the diaspores of elaiosome-bearing seeds. Elaiosome collectors are selective and will collect predominantly or only those seeds that have elaiosomes. There are intermediates between these types as well as the potential that one species might behave differently at different times or in different places in response to changes in environmental conditions (Berg, 1975). Within these groups defining collector types, there are three classifications defining their ant-seed relationship. The first is seed predation or granivory, where ants remove the diaspore and consume the embryo. Second is nest decoration. In this case the ant removes the diaspore and incorporates it into the structure of the nest. The third is myrmecochory. In this case, the seed possesses an elaiosome which is an oil or fat-bearing body that is attractive to ants. The ants eat the elaiosome appendage but leave the kernel intact. These activities are particularly important in bauxite mine reseeding operations and also in the encouragement of leguminous plant growth in the understory of the forest which potentially may suppress jarrah dieback. (Dell, 1989).

Ants in Bauxite Mine Rehabilitation

Disturbances in the northern jarrah forest mostly include prescribed burning, degradation of the forest canopy and understory due to jarrah dieback disease and bauxite mining. There are many factors that play into the goals for rehabilitation of bauxite mine sites in Western Australia. A statement issued by the Western Australian State Government calls for rehabilitating bauxite-mined sites by establishing stable biological systems which satisfy the long term land use objectives of the State Government (Tacey, 1979). It is important to realize, however, that if the proper components of a restoration are not installed, the desired result may not be reached. In order to further understand the process of mine site rehabilitation, it is necessary to be aware of how these sites are created.

Forest initially identified as a significant bauxite ore deposit will first have to be cleared. Often the jarrah trees in these forests are part of an old-growth stand, with some trees being 200-300 years old. Following clearing, the soil is removed in two steps. First, the top 5 cm of topsoil, which contains the seed and other biota, is removed. Then the next meter of soil, called overburden, is removed to make way for blasting of the caprock. Once the ore is exposed it is mined to an average depth of 2-5m. What remains after mining is a compacted clay pit (Majer, 1980).

To initiate rehabilitation, the overburden is replaced, followed by the top 5 cm of topsoil from another minesite which has just been cleared. This affords the mining company the flexibility of not having to store the topsoil on-site or at some other location. The compacted pallid zone, which is lower in organic content, is then ripped to a depth of approximately 2 m to allow for enhanced root penetration. The return of the topsoil is a critical component to the rehabilitation. Research has shown that direct return of the top 5 cm of soil from areas being cleared before mining can lead to a twelve fold increase in number of emergent seedlings after 18 months (Tacey, 1979). Though the benefit of this topsoil return may be great, often times it is not enough to restore the native vegetation that previously existed on the site. Initial success in a restoration may sometimes be short-lived. Fertilizer applications often accompany broadcast seeding in revegetation efforts. Some plants such as *Acacia* species, however, may die and certain trees may have slowed growth once these initial fertilizer treatments have worn off. Also influencing success in the revegetation of a site is pollination and seed dispersal. Lack of these two actions, along with weed and pest invasion, may provide for one or several species to end up dominating the site (Majer, 1997).

There have been several techniques in bauxite mine revegetation. One technique utilized is the broadcasting of seed of native species over prepared topsoil. This method was compared with two other revegetation practices: (1) planting seedlings of a single tree species to create a monoculture and (2) simply not planting the site and allowing the existing seed bank in the soil to germinate as mentioned before. The results of the two methods are quite different. The planted mine pits initially have the appearance of a plantation, whereas the direct seeding produces a regrowth of high structural and species diversity (Majer, 1998). It was also noted that the seeded plot was, rapidly colonized by a rich and abundant invertebrate fauna while the area planted to monoculture and the un-rehabilitated area were colonized by relatively few invertebrates (Dell, 1989). Part of this situation involves the probability that the return of a rich ant fauna was enhanced by the provision of a dense litter cover, large logs and also a dense and diverse plant cover (Majer, 1984). There was however some concern in the seeded plot where the broadcast seeding effort resulted in severe seed removal (2/3 of seeds) in the 25 m from the edge of the adjacent undisturbed forest habitat. It was found that ants had colonized the edges of the mines prior to seeding and that seed removal was a slight problem (Majer, 1989). It should also be noted that the seeds of *Acacia extensa* (Wiry Wattle), which possess an elaiosome, were removed by ants 7.5 times faster than *Eucalyptus marginata* (Jarrah) seeds which do not possess an elaiosome (Majer, 1989).
In newly rehabilitated areas involving the broadcast of native seed, the removal of seeds does not mean that they are destroyed. Many are taken for the elaiosome attached to them and are likely to germinate on the site of the nest to which they were taken. Many seeds are also taken below the soil surface into tunnels and chambers. Here the seeds remained buried because once the

appendage was removed the small ants were unable to move the now handleless, stone-hard, smooth and heavy seeds (Berg, 1975). This may be disadvantageous with respect to early bauxite mine rehabilitation. The newly rehabilitated areas have seed that is sown into fertilized soils; seeds have usually been pre-treated by heat or smoke to enhance germination. Once collected by ants and stored in or around the nest, the germinated seeds will come up in clumps and cause an uneven array of vegetative structure. In a study of two ant species, *Rhytidoponera inornata* and *Melorphus* sp., infrared heat lamps were placed over the nests of the two species as well as over land directly adjacent to their nests. Large clusters of seedlings germinated over these nests, indicating the ants' responsibility in the clumped distribution of seedlings following disturbance (Dell, 1989). In contrast, this process of seed collection by ants in maturing rehabilitated mines is most likely beneficial. It is here where myrmecochory takes its place. This transition from new growth to more mature growth reveals that floral species diversity declines after about 5-7 years as the short-lived fire ephemerals die, leaving only soil-stored seed (Bell, 1987). This is important because these areas are more often subjected to prescribed burns or accidental fires and it is the insulating benefit from the seed being buried in an ant nest that is utilized (Majer, 1997).

Conclusion

The rehabilitation of bauxite mine sites within the jarrah forest of Western Australia is heavily influenced by ant-plant relationships. Reestablishment of this relationship is important for the long-term survival of many plant species. The benefit the ants provide through seed dispersal ensures that a viable seed bank is created for future growth following disturbance. It was noted that the removal of seeds by ants in newer restoration efforts hampered seed germination, but this was only a concern within 25m of the edge of the site. As areas of jarrah forest continue to be removed, it will be important to continue the rehabilitation of these areas. Understanding the role ants play in restoration is critical, but further study needs to be done that highlights the characteristics of the seeds that ants are attracted to. We know that ants are attracted to elaiosomes, but what of the seeds which have no elaiosomes and are still collected? Do these seeds possess other characteristics that make them attractive or are the ants that collect these seeds simply the unbiased generalists that don't care whether the seed has an elaiosome or not? This understanding may aid in the establishment of certain species, such as jarrah, which are currently threatened due to the amount of forest clearing and jarrah dieback disease.

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Image Sources:

Figure 1, Location of jarrah forest in Western Australia
http://www.ea.gov.au/erin/ert/epbc/imap/map.html

Figure 2, Map showing mining locations within jarrah forest
http://wafa.org.au/articles/alcoa/leasemap.html

Figure 3, Bauxite mining locations in jarrah forest
http://wafa.org.au/articles/alcoa/

Figure 4, An ant carrying a seed with an elaiosome
http://www.ento.csiro.au/science/ants/feeding.htm