ROSEMONT COPPER PROJECT

BIOLOGY AND LIFE HISTORY OF COLEMAN’S CORALROOT (H. COLEMANII) AND SURVEYS FOR H. COLEMANII IN 2011

Prepared for:

ROSEMONT COPPER COMPANY
2450 W. Ruthrauff Road #180
Tucson, Arizona 85705

Prepared by:

WestLand Resources, Inc.
Engineering and Environmental Consultants
4001 E. Paradise Falls Drive
Tucson, Arizona 85712

September 2012
Project No. 1049.24
Memorandum

To: Jim Upchurch
Cc: Chris Garrett
From: Kathy Arnold
Doc #: 060/12-15.3.2
Subject: Transmittal of WestLand Reports
Date: September 25, 2012

Rosemont Copper Company is having delivered by courier service the following materials in hard copy and cd format:

- *Habitat Characteristics of Two Hexalectris Species in Southern Arizona*, by WestLand Resources, Inc. dated September 2012 **Hard Copies Only**
- *Biology and Life History of Coleman’s Coralrood (Hexalectris colemanii) and Surveys for Hexalectris in 2011*, by WestLand Resources, Inc. dated September 2012
- *Forest Sensitive Plant Species on the Rosemont Project Area 2011*, by WestLand Resources, Inc. dated August 2012

Three (3) hard copies and two (2) cds each to the Forest Service and two (2) hard copies and one (1) cd to SWCA.

Please do not hesitate to contact me should you require anything further.
TABLE OF CONTENTS

EXECUTIVE SUMMARY........................................................................................................................... 1
1. INTRODUCTION ................................................................................................................................ 1
2. LITERATURE REVIEW ........................................................................................................................ 1
   2.1. Taxonomy ..................................................................................................................................... 1
   2.2. Biology .......................................................................................................................................... 2
   2.3. Reproductive Constraints .............................................................................................................. 4
3. SPECIES DESCRIPTIONS ..................................................................................................................... 5
   3.1. Hexalectris colemanii, Coleman’s coralroot ................................................................................. 5
   3.2. Hexalectris arizonica, Arizona crested coralroot .......................................................................... 5
4. SURVEY METHODS .......................................................................................................................... 6
5. RESULTS ............................................................................................................................................. 9
   5.1. Survey Effort ................................................................................................................................. 9
   5.2. Hexalectris colemanii, Coleman’s coralroot ................................................................................. 9
   5.3. Hexalectris arizonica, Arizona crested coralroot .......................................................................... 9
   5.4. Annual Variation in Inflorescence Number and Rainfall Amount ............................................. 10
6. DISCUSSION ..................................................................................................................................... 10
7. REFERENCES ................................................................................................................................... 13

TABLES

Table 1. Summary of WestLand’s survey effort for 2011 Hexalectris colemanii and H. arizonica.......7
Table 2. Summary of survey findings of Hexalectris colemanii, Coleman’s coralroot, and H. arizonica, Arizona crested coralroot, inventories conducted in 2010 and 2011............8

FIGURES

(1-4 follow text)

Figure 1. Rosemont Project Area and Location of Hexalectris
Figure 2. Illustration of Hexalectris Structure and its Relationship of White Oak
Figure 3. Illustration of Hexalectris Life History
Figure 4. Map of Location where Hexalectris Species were Located in 2010 and 2011
Figure 5. Number of spikes of Hexalectris colemanii in two canyons between 1996 and 2011........... 11
EXECUTIVE SUMMARY

WestLand Resources, Inc. (WestLand) conducted a review of the scientific literature on the biology of myco-heterotrophic orchids. Species in the genus *Hexalectris* are fully myco-heterotrophic, meaning that they rely on their interaction with an endosymbiotic fungus (an ectomycorrhizal root associate of oaks) for all of their energy for growth and reproduction. Review of the literature on *Hexalectris* species and the more extensive literature on similarly fully and partially myco-heterotrophic orchids suggests that *Hexalectris* has a long life cycle with a prolonged pre-reproductive period during which the developing orchid lives entirely underground. Flowering most likely begins at least 10-20 years after seeds germinate. After flowering, individuals may require one or more years of dormancy during which the orchid obtains energy from its symbiotic fungus that is necessary for subsequent flowering. The number of flowering stems does not indicate population size and there may be many undetected individuals within a known population, and populations in locations where no plants have reached reproductive maturity.

In 2011, WestLand conducted surveys for the orchid species *Hexalectris colemanii* and *H. arizonica* in the Rosemont Area (areas within the Rosemont Mine Plan of Operations and the alternatives developed by Coronado National Forest as part of their National Environmental Policy Act review of the Plans of Operations) and additional canyons outside the Rosemont Area. These surveys were conducted during May and July 2011 when inflorescences (aboveground flowering stalks) of these orchids emerge or are in flower. Survey efforts were focused on the portions of the Rosemont Area that have Arizona white oak (Quercus arizonica) and Emory oak (Q. emoryi) stands with contiguous, closed or nearly closed canopies, and where orchids were detected during field surveys in 2010. In 2011, six individual *H. colemanii* inflorescences were detected in upper McCleary Canyon in the Rosemont Area, six inflorescences in Sawmill Canyon in the Santa Rita Mountains south of the Rosemont Area, and one inflorescence in West Cochise Stronghold Canyon in the Big Dragoon Mountains that is distant from the Rosemont Area.

There were six areas where orchids were detected in 2010 that did not have any emerged inflorescences in 2011. The much lower numbers of *H. colemanii* seen in locations surveyed in 2011 versus 2010 (13 vs. 289) is most likely due to a combination of three factors. First, a severe drought from December 2010 thru March 2011 resulted in roughly a 90 percent reduction in cumulative rainfall in the Tucson Area compared to the same four months the previous season. Second, during the winter of 2010/2011, there were some of the coldest days on record for southern Arizona, which might have affected orchid reproduction. Third, similar species of orchid have mandatory dormancy periods following flowering, which could have contributed to reduced inflorescence production in 2011. While the numbers of inflorescences seen in 2011 are lower than in 2010, they are within the range of variation seen in long-term observations in some of these populations.
1. INTRODUCTION

WestLand Resources, Inc. (WestLand) was retained by Rosemont Copper Company to conduct surveys for *Hexalectris colemani*, Coleman’s coralroot; and *H. arizonica*, Arizona crested coralroot (Orchidaceae) in the Rosemont Area and at other occupied locations in southern Arizona as part of a series of baseline resource studies to support mine permitting efforts. In Arizona, *H. colemani* and *H. arizonica* are found in mountain ranges of Cochise, Pima, and Santa Cruz counties (AGFD 2005 and 2004). Coleman’s coralroot is known to be present in the northern portion of the Santa Rita Mountains within the footprint of the proposed Rosemont Copper Mine (Figure 1). This species is a Forest Sensitive species in the Coronado National Forest (US Forest Service 2007).

*H. revoluta*, of which *H. colemani* was formerly considered a subspecies [*H. revoluta* spp. *colemani*] was petitioned for federal listing on June 25, 2007 (WildEarth Guardians 2007). On December 16, 2009 (Federal Register Vol. 74 Number 240 Page 66866), federal listing of *H. revoluta* was considered warranted by the US Fish & Wildlife Service (USFWS), but no final rulings have been made as of this report. After full species status was recommended by Kennedy and Watson (2010), *H. colemani* was also petitioned for listing on December 14, 2010 by the Center for Biological Diversity (2010) (Federal Register Vol. 75 Number 239 Page 78061) and is currently undergoing a 90-day review by the USFWS. No findings or a final rule have been published to date.

The goals of this project were: 1) to conduct surveys for *H. colemani* and *H. arizonica* in areas where these species were observed in 2010 (WestLand 2010); 2) to survey other potentially suitable habitats in several mountain ranges in southern Arizona; and 3) to review the available scientific literature on the biology and demography of *Hexalectris* and other myco-heterotrophic species. Due to extremely low numbers of plants producing flower stalks in 2011, there was a very low probability that other *Hexalectris* populations would be found, so “survey other potentially suitable habitats” was not pursued. Therefore, this report focuses on the results of the 2011 survey, analyzes patterns in the numbers of flower stalks seen at sites visited by Coleman from 1997 to 2009 (and subsequently by WestLand in 2010 and 2011), and provides a review of the scientific literature that covers relevant biological and demographic issues related to these species.

2. LITERATURE REVIEW

2.1. TAXONOMY

Orchid specimens later assigned to *H. colemani* were first collected in Baboquivari Canyon, Baboquivari Mountains in 1981 and in McCleary Canyon, Santa Rita Mountains, in 1986 by Steve McLaughlin (SEINet 2011). Both of these specimens from Pima County were initially identified as *H. spicata*. Ronald A. Coleman (Coleman), a Tucson orchid specialist, has studied orchids of Arizona extensively (Coleman 1999, 2001, 2002), photographed flowers of *H. revoluta* collected from the same location as McLaughlin, and sent the photographs to Paul Catling, who identified these plants as *H. revoluta*. Catling (2004) named the specimens from McCleary Canyon *H. revoluta* var. *colemani*, in honor of Coleman.
Kennedy and Watson (2010) undertook a phylogenetic analysis of the genus *Hexalectris*, a New World genus consisting of eight described species. Among their objectives was the resolution of the taxonomic relationships among the taxa and to determine if interspecific hybridization might be responsible for intermediate flower structures seen among some of the taxa. They analyzed DNA sequences of six plastid DNA markers, extracted from chloroplast DNA, and nuclear ribosomal ITS (internal transcribed spacers) that are highly variable and are useful in determining phylogenetic differences among species. They conducted their analyses on collections of specimens representing the geographic range and morphological variation of all known species of *Hexalectris*. They were able to show that four *Hexalectris* species were clearly distinct from each other and confirmed their current taxonomy. However, other specimens were more difficult to separate using the ITS sequence analysis and they concluded that ITS sequence analysis was not useful in resolving the taxonomy of these species. Relying on the consensus phylogeny based on plastid DNA, they were able to resolve the remaining relationships. Their results showed that the eastern *H. spicata* populations and the western *H. spicata* populations were only distantly related and they renamed the western *spicata* group *H. arizonica* (previously named *H. spicata* var. *arizonica*). Their results also indicated that the taxon *H. revoluta* var. *colemanii* was more closely related to *H. arizonica* than to *H. revoluta*. Thus, they formally recognized *H. revoluta* var. *colemanii* as a new species named *H. colemanii* (Kennedy and Watson 2010).

### 2.2 Biology

*Hexalectris* is an obligately myco-heterotrophic (MH), non-photosynthetic genus of orchids, meaning that it derives all of its energy for growth by being a parasite on the mycorrhizae of oaks or pines and has no functioning photosynthetic structures (e.g., green leaves or stems) although it does have chloroplasts. Myco-heterotrophy is a common life history trait that has evolved independently more than 20 times in orchids (Orchidaceae) (Molvray et al. 2000) and in at least 10 other plant families (Leake 1994). The degree of dependence of an orchid on its fungal relationship varies among species. All known species of orchids require fungi for seed germination and early development, but species vary widely in their dependence on fungi as they mature (Taylor 2004). Many orchids are partially MH as adults, in that they retain a relationship with fungi at early stages of development, but they do produce green leaves and can produce a portion of their energy needs through photosynthesis (e.g., lady slipper, *Cypripedium*). Other orchid species become primarily photosynthetic as they mature (Leake 1994).

Most terrestrial plants have mutualistic mycorrhizal relationships, where the plant obtains nutrients and water from the fungus, which fungal mycelia are able to extract from the soil, while the mycorrhizal fungi obtain carbohydrates from the plant. In contrast, for obligate MH orchid species, the orchid extracts carbohydrates and nutrients from the mycorrhizal fungus without providing any apparent reciprocal benefits to the fungus. Thus, the orchid is parasitic on the fungus, and because the fungus obtains its carbohydrates from its host (oaks in the case of *H. colemanii*); the orchid is an indirect parasite of the oak host (Shefferson et al. 2011). Recent studies using $^{13}$CO$_2$ labeling and stable isotope techniques demonstrate that carbohydrates found in obligate myco-heterotrophs are derived from the host plant (e.g., oaks) via mycorrhizal fungi (Rasmussen and Whigham 2002, Bougoure et al. 2010).

The relationships between some orchid species and their fungal associates have been shown to be highly specific. Taylor et al. (2003) were able to identify the fungi colonizing 25 specimens of three species of
Hexalectris. They showed that *H. spicata* var. *arizonica* (now *H. arizonica*) was associated with one genetic morph of fungus, and *H. revoluta* var. *colemanii* (now *H. colemanii*) was associated with a different genetic morph of fungus. The third species, *H. spicata* var. *spicata* was associated with four genetic morphs of fungus. These genetic morphs were all related, putatively distinct, species in the family Sebacinaeae. Recently, Kennedy et al. (2011) have shown that among the nine species of *Hexalectris* sampled from 42 populations, there is a high level of association of a number of *H. spicata* species-complex with Sebacinaeae subgroup of ectomycorrhizal fungi. Other studies have demonstrated highly specific relationships of other MH orchids and their fungal hosts (Taylor et al. 2003, Roy et al. 2009, Barrett et al. 2010), further illustrating the complex life cycle of MH plants.

The establishment of an MH relationship between the orchid, fungus, and host plant is a complex process that is difficult to observe since it takes place in the soil. Orchids have very large numbers of miniscule seeds that are dispersed by wind and water, and have little energy stores with which to develop. For orchid seeds to germinate they must become associated with a species of mycorrhizal fungus (Leake 1994). If seeds land where the correct species of fungi are located, germination will occur in response to interaction with the mycorrhizal host, which begins to degrade the cellulose surface of the seed. Mycorrhizal hyphae grow into the seed and the seed breaks down fungal cells and digests them as energy for growth. The seed/fungal structure begins to grow and develops into a protocorm, which is a teardrop-shaped structure consisting of plant cells and the mycorrhizae in the first few layers of cortical cells. A considerable amount of time is needed, possibly several years, for the protocorm to grow to the point where buds begin to develop the orchid rhizome (Leake 1994). Buds eventually develop from the protocorm and initiate early development of the rhizome.

Because of the highly specific associations that need to develop between orchids and their fungal hosts and the small amount of energy obtained by the protocorm from fungal mycelia, initial orchid growth is slow and it may take many years for a reproductive structure to appear. For *Corallorhiza odontorhiza*, a widespread forest dwelling MH orchid in the eastern United States, it takes four years for orchid seeds to reach reproductive maturity (Shefferson et al. 2011). In the partially photosynthetic, partially MH orchid *Cypripedium*, it takes 10-16 years from seed germination before plants become reproductive (Curtis 1943, Kull 1995, Gill 1989). For an obligately MH orchid living in less favorable environmental conditions, such as *H. colemanii*; reproductive maturity could plausibly exceed 20 years.

As the rhizome grows, it develops a vertical orientation in the soil. Fungal mycelia become restricted to lateral branches emanating from the base of the rhizome, which can be thought of as equivalent to roots (Taylor et al. 2003). The rhizome increases in thickness and may initiate lateral extensions near the soil surface before it begins to flower. When it has reached a sufficient size, the rhizome will send up its first flower stalk. In reproductively mature plants, lateral branches from the main rhizome may give rise to other reproductive stalks or to new plants should they become detached from the main rhizome (*Figure 2*).

Flowering in *Hexalectris* species can be very irregular (Hill 2007). Vegetative dormancy, a non-reproductive period that occurs after flowering, is a shared phenomenon among MH plants and appears to be a requirement for these plants to regain enough energy to reproduce again (Shefferson 2009). Additionally, climatic conditions can stimulate or prevent flowering (Coleman 2002). These periods of
vegetative dormancy between flowering events can last several years (Shefferson 2009). *Figure 3* illustrates this point with an interval of two years before a plant flowers again; however, there are no data that have documented the dormancy period for *Hexalectris* species. Estimation of the lifespan of *Hexalectris* is also difficult given the infrequent and sporadic flowering events and the current lack of long-term demographic studies, but the lifespan of *Hexalectris* is likely to be many years. Jacquemyn et al. (2010) estimated the life span for a partially MH orchid was from 44-60 years.

2.3. **REPRODUCTIVE CONSTRAINTS**

Life history theory considers how the combinations of life history traits of a species interact to optimize survival and reproduction. Energy is usually the limiting factor for a species such that survival, growth, and reproduction cannot simultaneously be maximized (e.g., energy for growth cannot be used for reproduction). Thus, there is an intrinsic trade-off in energy commitment to survival, growth, and reproduction. For a perennial plant, this means that reproduction begins when a plant reaches a size that will support flowering and fruit production without excessively decreasing the probability of survival. This does not occur at a fixed age but rather depends on size, which itself depends on growing conditions, such as nutrients, light, and moisture (Shefferson 2009). Thus, often there is a delay in reproduction (the pre-reproductive period) when a plant commits energy to growth and survival, but not to reproduction (Shefferson 2006, Jacquemyn et al. 2010). The age at which reproduction begins is called the *age of first reproduction*, which is an important life history attribute.

In *Hexalectris*, as suggested above, the age of first reproduction may be 20 years or more. Once an individual *Hexalectris* begins to reproduce, reproduction from year to year is irregular (Hill 2007), which could occur for at least two reasons; response to external environmental factors and internal energetic constraints. Climatic factors, such as moisture availability, that could affect the host plant and the mycorrhizal fungus or the degree of solar radiation, that could affect the photosynthesis of the host plant, could limit energy transfer to the orchid and thus reduce the chance of flowering (Jacquemyn et al. 2010). Moreover, energy committed to reproduction one year could prevent reproduction in subsequent years. When current reproduction decreases the probability of survival or delays future reproduction it is termed a “cost of reproduction”.

Costs of reproduction are common in perennial plants (Obeso 2002). Some photosynthetic plants can largely support reproduction from current photosynthesis or may recover energy after reproduction has occurred (Obeso 2002). Plants that incur a cost of reproduction have committed a large amount of energy to producing reproductive structures and seeds, and this energy must be replaced before a plant can reproduce again. Plants may have a year or more of reduced reproduction or may not reproduce at all (vegetative dormancy); a trait that has been well studied primarily in the Orchidaceae, but is known from 52 species in 10 plant families (Shefferson et al. 2003, Shefferson 2009). Vegetative dormancy is a clear demonstration of the cost of reproduction for plants expressing this trait and varies among species, specifically the length of time and the proportion of the population in which plants remain vegetatively dormant. Shefferson (2009) found that numerous studies showed 1-4 years of dormancy; additionally, 10-85 percent of the population can be dormant in a particular year. Shefferson (2009) points out that vegetative dormancy often occurs in MH species and that it may be an adaptation to cope with stressful environmental conditions and a reduced ability to replace energy via its fungal associate.
In MH orchids, where the flow of energy is from the host plant via the mycorrhizal fungus species that it parasitizes, the flow of energy does not appear to support annual reproduction. *Hexalectris* plants may enter a period of dormancy where energy continues to be acquired from the fungal host to replace energy previously committed to reproduction. Reproductive dormancy in *Hexalectris* species may last several years depending on the effects of environmental factors such as rainfall, but no specific studies have studied this in the genus. Furthermore, *Hexalectris colemanii* grows lateral branches from the upper portion of the rhizome close to the soil surface (*Figure 2*). Commitment to vegetative growth involves an intrinsic trade-off with reproduction that may also explain intervals of non-flowering, which is different from the costs of reproduction described above.

3. **SPECIES DESCRIPTIONS**

In Arizona, species of *Hexalectris* are associated with mixed oak woodlands found in the sky islands of the southeastern portions of the state, although *H. arizonica* may also be found in the lower reaches of mixed and coniferous forests (Coleman 2002). The only visible portion of the orchid is the inflorescence; as the approximately 19 in (50 cm) spike that emerges above ground to flower. The inflorescence arises from a rhizome when plants reach a size at which reproduction can be supported. The time during which the inflorescence can be seen is brief, extending from end of April to the end of blooming in mid- to late June for *H. colemanii* and mid to late May to end of blooming in late-August for *H. arizonica*. The cryptic life history of these species has contributed to its rather recent inclusion as part of the Arizona flora in 1981.

3.1. **HEXALECTRIS COLEMANII, COLEMAN’S CORALROOT**

*H. colemanii* has been identified and collected in four localities within Arizona. These sites include McCleary and Sawmill Canyons in the Santa Rita Mountains, West Cochise Stronghold Canyon in the Big Dragoon Mountains, and Baboquivari Canyon in the Baboquivari Mountains (*Figure 4*). Twelve inflorescences were documented and one was collected in Baboquivari Canyon, nearly 30 years ago (Coleman 2001). WestLand (2010) discovered two new populations in McCleary Canyon and a new population in Wasp Canyon just south of McCleary Canyon. Coleman has monitored the number of inflorescences in McCleary, Sawmill and Cochise Stronghold canyon populations since the late 1990’s (WestLand 2010).

3.2. **HEXALECTRIS ARIZONICA, ARIZONA CRESTED CORALROOT**

*H. arizonica* has a larger known range than *H. colemanii* and tends to be found at scattered locations with populations consisting of a small number of inflorescences (AGFD 2005). AGFD Heritage Data Management System (HDMS) records place this orchid in the Chiricahua, Huachuca, Santa Rita, and Whetstone mountains of southeastern Arizona (AGFD 2005). This species also occurs in New Mexico and Texas. Coleman (pers. comm.) found *H. arizonica* in at least three canyons in each of the larger mountain ranges in southeastern Arizona. Herbarium collections show one specimen collected in the Rincon Mountains (Catling and Engel 1993) and two specimens in Yavapai County (Baker 9909, Baker 9931; ASU). *H. arizonica* is not known to occur within the Rosemont Area.
4. SURVEY METHODS

Surveys were conducted in 2011 at four known locations within the Rosemont Area, including Upper, Middle, and Lower McCleary Canyon and Wasp Canyon. The Rosemont Area is defined as the location of the preferred Barrel Canyon Alternative and adjacent lands (Figure 1).

Surveys of the Rosemont Area occurred during the peak *H. colemanii* flowering time (mid-May to mid-June) and at a time when inflorescences have emerged for both species (beginning in late April for *H. colemanii* and mid-May for *H. arizonica*). *H. arizonica* and *H. colemanii* can be distinguished in their early stages. *H. arizonica* inflorescences have a darker pinkish-brown cast while *H. colemanii* are typically pale pink in color. Inflorescences of both species are above ground during similar time period, but flower morphology and reproductive biology differ markedly. *H. colemanii* flowers open in April and display deeply rolled petals that curl to create a full circle when they bloom. *H. arizonica* flowers enlarge in mid-May but flowers seldom open as this is a self-pollinating species (Coleman 2002).

The majority of survey efforts focused on areas known to be occupied from prior surveys (WestLand 2010). Surveys were focused along riparian zones between 4,500 and 6,500 ft (1372 and 1981 m), the elevation range that spans the distribution of both *H. colemanii* and *H. arizonica* (Coleman 2002). The Rosemont Area was surveyed, including the larger drainages of Barrel, McCleary, Sycamore, Scholefield, and Wasp canyons where white oaks occur. In addition to the Rosemont Area, five canyons in the Santa Rita Mountains, one canyon in the Big Dragoon Mountains, and one canyon each in the Santa Catalina Mountains and Patagonia Mountains were surveyed. (Table 1). Survey protocols followed those utilized in 2010 with efforts targeting oak-dominated habitats of larger drainages, as well as previously occupied habitats (WestLand 2010). WestLand biologists returned to areas of known *H. arizonica* occurrence to document the presence of orchid flowering during peak blooming periods (May-Aug). A summary of WestLand’s survey efforts is provided in Table 1 below.
WestLand biologists surveyed the Rosemont Area in 10-hour days over a 12-day field survey period (Table 1). Field survey crews consisted of 2 to 6 WestLand personnel carefully inspecting the ground surface under the canopies of oak stands in canyons in and outside the Rosemont Area. Surveys were conducted May 6, 10, 13, 17-20, 23-24, 26-27 to encompass the time of *H. colemanii* and *H. arizonica* inflorescences emergence and flowering (Table 2). A subsequent visit to a known *H. arizonica* location was performed on July 21, 2011.

### Table 1. Summary of WestLand’s survey effort for 2011 *Hexalectris colemanii* and *H. arizonica*.

<table>
<thead>
<tr>
<th>Location</th>
<th>Canyon Surveyed</th>
<th>Mountain Range</th>
<th>Survey Date</th>
<th>Number of Person-days*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rosemont</td>
<td>McCleary Canyon</td>
<td>Santa Rita</td>
<td>May 6, 13, 17, 20, 23</td>
<td>12.50</td>
</tr>
<tr>
<td></td>
<td>Barrel Canyon</td>
<td>Santa Rita</td>
<td>May 20</td>
<td>2.50</td>
</tr>
<tr>
<td></td>
<td>Wasp Canyon</td>
<td>Santa Rita</td>
<td>May 20</td>
<td>2.50</td>
</tr>
<tr>
<td></td>
<td>Sycamore Canyon</td>
<td>Santa Rita</td>
<td>May 23</td>
<td>2.50</td>
</tr>
<tr>
<td></td>
<td>Scholefield Canyon</td>
<td>Santa Rita</td>
<td>May 23</td>
<td>2.50</td>
</tr>
<tr>
<td></td>
<td><strong>Subtotal</strong></td>
<td></td>
<td></td>
<td><strong>22.50</strong></td>
</tr>
<tr>
<td>Offsite</td>
<td>West Cochise Stronghold Canyon</td>
<td>Big Dragoon</td>
<td>May 10, 19</td>
<td>10.00</td>
</tr>
<tr>
<td></td>
<td>Sawmill Canyon</td>
<td>Santa Rita</td>
<td>May 6, 13, 18</td>
<td>10.00</td>
</tr>
<tr>
<td></td>
<td>Montosa Canyon</td>
<td>Santa Rita</td>
<td>May 23 and July 21</td>
<td>3.75</td>
</tr>
<tr>
<td></td>
<td>Madera Canyon</td>
<td>Santa Rita</td>
<td>May 24</td>
<td>6.25</td>
</tr>
<tr>
<td></td>
<td>Molino Canyon</td>
<td>Santa Catalina</td>
<td>May 26</td>
<td>3.75</td>
</tr>
<tr>
<td></td>
<td>Corral Canyon</td>
<td>Patagonia</td>
<td>May 27</td>
<td>2.50</td>
</tr>
<tr>
<td></td>
<td>Agua Caliente Canyon</td>
<td>Santa Rita</td>
<td>July 21</td>
<td>1.25</td>
</tr>
<tr>
<td></td>
<td><strong>Subtotal</strong></td>
<td></td>
<td></td>
<td><strong>37.50</strong></td>
</tr>
<tr>
<td></td>
<td><strong>GRAND TOTAL</strong></td>
<td></td>
<td></td>
<td><strong>60.00</strong></td>
</tr>
</tbody>
</table>

* - 10 hours per survey day per person is equal to 1.25 person-days.
Table 2. Summary of survey findings of *Hexalectris colemanii*, Coleman’s coralroot, and *H. arizonica*, Arizona crested coralroot, inventories conducted in 2010 and 2011.

<table>
<thead>
<tr>
<th>Location</th>
<th>Canyon</th>
<th>2010</th>
<th>2011</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hexalectris colemanii, Coleman’s coralroot</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rosemont</td>
<td>McCleary Canyon</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Santa Rita Mountains</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Upper</td>
<td>95</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Middle</td>
<td>15</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Lower</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Wasp Canyon</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Santa Rita Mountains</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Rosemont Total</strong></td>
<td>124</td>
<td>6</td>
</tr>
<tr>
<td>Offsite</td>
<td>Sawmill Canyon</td>
<td>25</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Santa Rita Mountains</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>West Cochise Stronghold Canyon</td>
<td>140</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Big Dragoon Mountains</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Offsite Total</strong></td>
<td>165</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td><strong>Season Total Hexalectris colemanii</strong></td>
<td>289</td>
<td>13</td>
</tr>
</tbody>
</table>

| **Hexalectris arizonica, Arizona crested coralroot** |                               |      |      |
| Rosemont | Rosemont Total                 | 0    | 0    |
|          | Agua Caliente Canyon          | 15   | 0    |
|          | Santa Rita Mountains          |      |      |
|          | Montosa Canyon                | 3    | 0    |
|          | Santa Rita Mountains          |      |      |
| Offsite  | West Cochise Stronghold Canyon| 14   | 0    |
|          | Big Dragoon Mountains         |      |      |
|          | East Cochise Stronghold Canyon| 3    | Not visited |
|          | Big Dragoon Mountains         |      |      |
|          | **Offsite Total**             | 35   | 0    |
|          | **Season Total Hexalectris arizonica** | 35   | 0    |

When *Hexalectris* inflorescences were found, intensive surveys were conducted in all potentially suitable habitats in an approximately 33 ft (10 m) diameter circle centered on the plant. A photograph of the general site that included the inflorescence(s) was also taken. For each individual or cluster of inflorescences less than 10 ft (3 m) apart, its location was recorded with a Garmin Legend handheld unit. Field notes were taken of topographical and localized vegetation characteristics at each survey area.
Monthly rainfall data for 1997 - 2011 were obtained from the Santa Rita Mountain Experimental Range. The data from the “Forest” station was used because these data were the most complete of the weather stations at the Santa Rita Mountain Experimental Range and were most comparable to sites where Hexalectris grow. The relationships between monthly, seasonal, and annual rainfall data and the number of *H. colemanii* for this period were analyzed using linear and multiple regression models run in JMP 9.0 (2010).

5. RESULTS

5.1. SURVEY EFFORT

A total of 60 person-days were spent looking for orchids with 22.50 person-days spent on the Rosemont Area and 37.50 person-days at offsite locations. McCleary Canyon received the greatest number of survey person-days of any area surveyed (12.50 person-days) (*Table 1*).

5.2. *HEXALECTRIS COLEMANII*, COLEMAN’S CORALROOT

In 2011, a total of 13 *H. colemanii* inflorescences were found at all localities surveyed, including six within the Rosemont Area. All six of these inflorescences were found in the upper section of McCleary Canyon (*Table 2, Figure 3*). No inflorescences were found in the middle McCleary Canyon, where *H. colemanii* have been observed since 1996 or in lower McCleary Canyon, where plants were discovered in 2010 (*Figure 3*). In addition, no inflorescences were found in Wasp Canyon, an area where four inflorescences were first detected in 2010. Six inflorescences were located in Sawmill Canyon in the Santa Rita Mountains and one inflorescence was found in West Cochise Stronghold Canyon in the Big Dragoon Mountains (*Table 2*). The single inflorescence found in West Cochise Stronghold Canyon on May 10 was not present during the second visit on May 19, 2011, possibly lost due to herbivory. The low number of *Hexalectris* inflorescences seen in 2011 differs markedly from the large numbers seen in 2010 (WestLand 2010,* Table 2, Figure 4*).

5.3. *HEXALECTRIS ARIZONICA*, ARIZONA CRESTED CORALROOT

In 2011, no *H. arizonica* were found on the Rosemont Area or at areas where *H. arizonica* were found in 2010 (*Table 2*). While *H. arizonica* were not detected on the Rosemont Area, surveys were conducted in middle to late-May when both species inflorescences would have emerged. Similar to the results for *H. colemanii*, the absence of any *H. arizonica* from the areas where it was found in 2010 differs markedly from previous results (WestLand 2010, *Table 2, Figure 4*).
5.4. **ANNUAL VARIATION IN INFLORESCENCE NUMBER AND RAINFALL AMOUNT**

Coleman provided data on the number of inflorescences of *H. colemanii* that he recorded from 1996-2009 at middle McCleary Canyon and Sawmill Canyon in the Santa Rita Mountains to R. Schmalzel at WestLand in 2010 (*Figure 5*). These data show that the number of inflorescences seen at these two locations is highly variable from year to year. High numbers of inflorescences in one year are typically followed by much lower numbers the following year (e.g., 1997, 2001, 2004, and 2010) (*Figure 5*). After the high numbers recorded in 1997, there was a three-year decline in the number of inflorescences observed (*Figure 5*).

To see if there is a relationship between the variable numbers of inflorescences among years and rainfall amounts, total inflorescence number at McCleary Canyon and Sawmill Canyon were compared to fall/winter rainfall data (September-December of the previous year plus January-March of the flowering year). There was a significant positive regression \( y = 1.89x - 2.40, F = 6.91, p = 0.023, n=13, r^2\text{ adjusted} = 0.33 \) for McCleary Canyon Thus, for McCleary Canyon one third of the variation in inflorescence numbers among years is explained by fall/winter rainfall totals. The regression for Sawmill Canyon was not statistically significant.

6. **DISCUSSION**

In 2011, at total of 13 *H. colemanii* and zero *H. arizonica* were found in surveys of areas on the Rosemont Area or at other locations where these species are known to occur. These results are in contrast to the results of surveys conducted in 2010 where the largest total numbers of these species in southern Arizona were counted (289 *H. colemanii* and 35 *H. arizonica*) (WestLand 2010). However, this pattern of variation in inflorescence numbers among years is well documented by data collected by Coleman, which shows that relatively high numbers of *H. colemanii* in one year is typically followed by a decline in the number of inflorescences in the following year. This large inter-annual variation is the general pattern of flowering for this species. This pattern could be due to at least two possible causes: response to rainfall and the cost of reproduction.

Analysis of orchid data collected by Coleman and WestLand demonstrated that orchid flowering is positively related to October-March rainfall totals, with total rainfall explaining 33 percent of the variation in flowering at one of two sites. Rainfall amounts during this six-month period varied 9-fold over the period analyzed (data not shown). Hill (2007) also suggested that rainfall might affect the flowering of Crested coralroot (*H. spicata*), but no specific information was presented to support that hypothesis. Other studies show that flowering in orchids, including photosynthetic species and obligately MH species like *Hexalectris*, are affected by rainfall (Pfeifer et al. 2006a, 2006b, McCormick et al 2009, Hutchings 2010). For example, experiments with a perennial tuberous orchid (*Himantoglossum hircinum*) that grows in seasonally dry Mediterranean conditions, exhibit irregular inflorescence production that is strongly related to rainfall, accounting for 50 percent of the variability (Pfeifer et al. 2006). In the case of the obligately myco-heterotrophic *Corallorhiza odontorhiza*, population size was positively related to growing season rainfall and negatively related to mean winter temperature (McCormick et al. 2009). In February 2011, some of the coldest days on record for southern Arizona were recorded. For example, in the Empire Mountains near the Rosemont Area the low temperature in February 2011 was 6°F but
February low temperatures in 2008, 2009, 2010, and 2012 were 19ºF, 20ºF, 25ºF and 22ºF, respectively (Weather Underground 2012). Therefore both direct and indirect evidence supports the hypothesis that rainfall in particular and perhaps cold temperatures, might affect the pattern of flowering of *Hexalectris*.

Figure 5. Number of spikes of *Hexalectris colemanii* in two canyons between 1996 and 2011. Data obtained from Ronald A. Coleman for 1996-2009. No data were collected in 2008.

Variation in the number of inflorescences produced annually can also be affected by the cost of reproduction. Coleman’s observations lend correlative evidence to the possibility that energetic costs incurred during a reproductive year may preclude reproduction in subsequent years. A study of the long-lived perennial terrestrial orchid, *Cypripedium acaule*, showed that the cost of reproduction is manifested through lower probability of flowering and reduced leaf area in years following experimental manipulation of fruit production (Primack and Stacy 1998). Primack and Stacey (1998) also found that subsequent flowering of individuals in experimental plots occurred from two to three years later, and they suggest that this effect is likely a response to environmental conditions and intrinsic influences in the previous one to two years (Primack and Stacy 1998). Moreover, plant size had a significant influence on the probability of being dormant, with smaller plants being more likely to be dormant following reproduction (Primack and Stacy 1998). Shefferson (2006) found that plant size was a significant predictor for dormancy following reproduction in other species of *Cypripedium*, with smaller plants being less likely to flower than larger plants. A study of the long-lived orchid, *Gymnadenia conopsea*, demonstrated that experimentally manipulated plants rarely flowered in the second year of the study (Sletvold and Agren 2011). They suggest that intermittent flowering may be a result of costs linked to flowering and fruit production. In fact, flowering might be a rare occurrence, while reproductive dormancy is the normal reproductive status of many orchids (Shefferson et al. 2011). The fact that many orchids have the ability to survive long periods of adverse environmental conditions by remaining dormant below ground as rhizomes or tubers and to flower when conditions are favorable necessitated the
development of studies to investigate the degree of reproductive dormancy in order to more fully understand the population dynamics of these species (Primack and Stacy 1998, Coleman 2002, Pfeifer et al. 2006, Shefferson et al. 2011).

_Corallorhiza odontorhiza_ illustrates the linkage among flowering, dormancy, and the effects of climatic conditions including precipitation and winter temperatures (McCormick et al. 2009). Shefferson et al. (2011) found flowering to be a rare occurrence while vegetative dormancy was common for this orchid species (Shefferson et al. 2011). They point out the need to develop studies to evaluate underground demography and relationships with soil microbial feedbacks that are important to non-photosynthetic orchid species.

 Regardless of the factors contributing to yearly variation of inflorescence emergence, it appears that surveys by WestLand and Coleman bracket the extremes for _H. colemanii_ reproduction, with 2010 likely representing a peak of inflorescence production while 2000, 2002, and 2011 representing the low end of inflorescence production. The same may be true for _H. arizonica_, though the numbers of inflorescences detected were much lower for this species. The results of this study demonstrate that the number of orchid inflorescences varies widely over time and that inflorescence numbers are probably influenced by environmental conditions. The literature also strongly supports the hypothesis that only a fraction of the _Hexalectris_ population flowers in a given year due to dormancy, and that perhaps a large portion of the population has not yet reached a sufficient size to reproduce. Thus, counts of orchid inflorescences are not a sufficient measure of population size and are not adequate to determine population trends.
7. REFERENCES


Center for Biological Diversity (CBD). 2010. Petition to list Coleman’s coral-root Hexalectris colemanii as threatened or endangered under the Endangered Species Act.


ROSEMONT COPPER COMPANY
Biology and Survey for Hexalectris 2011
Rosemont Project Area and Locations of Hexalectris
Figure 1
ROSEMONT COPPER COMPANY
Biology and Survey for Hexalectris 2011
Illustration of Hexalectris Structure and Its Relationship of White Oak
Figure 2
PRE-REPRODUCTION

SEED

PROTOCORM

EARLY RHIZOMES

SOIL SURFACE

GROWTH AND DEVELOPMENT

TIME IN YEARS