Independent peer review of the Koolyanobbing Range F Deposit mining proposal: Assessment of potential impacts on *Tetratheca erubescens*

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1. Scope of this Review

The EPA has invited me to provide an independent expert review of information provided regarding the impacts of a mining proposal at Koolyanobbing Range F on the threatened plant species *Tetratheca erubescens*.

The specific questions which the EPA sought my opinion on were:

1. Would the proposed total impact of 22% to the known extent of *T. erubescens* significantly reduce the viability of the species in the long-term?

2. Is the use of monitoring data gathered at the proponent's Windarling mine of another Tetratheca species (*T. paynterae* subsp. *paynterae*) an appropriate surrogate to support the proponent's conclusions regarding its impact predictions on *T. erubescens* for the Koolyanobbing F Deposit proposal?

3. Would the ongoing indirect impacts associated with mining, be likely to have an adverse impact on the viability of the *T. erubescens* species?

4. Is the use of the translocation and seeding management measures a feasible mitigation strategy that would ensure the long-term viability of the *T. erubescens* species?

2. Background

2.1 The Species

Tetratheca erubescens is a woody, predominately leafless shrub from the Elaeocarpaceae family discovered in 2002 and formerly named and described in 2007 (Bull, 2007).

Through thorough field surveys (Maia, 2013, Cliffs Asia Pacific Iron Ore, 2015a), the proponent has located and accurately geo-referenced 6333 individuals in four major 'groups' or sub-populations. The extent of occurrence has been estimated at around 0.64 km^2 and the area of occupancy only 0.035 km^2 as it is restricted almost completely to cliff faces of the southern-most portion of the Koolyanobbing Range (Miller, 2015). Because of its highly restricted distribution and looming threats posed by mining, it was listed as a Threatened (Declared Rare) flora species and given the threat ranking, based on ICUN criteria, of "Vulnerable" (VU) in 2006.

2.2 The Proposal

The proponent (Cliffs Asia Pacific Iron Ore Pty Ltd, hereafter referred to as 'Cliffs') proposes expansion of its mining operations in the southern Yilgarn area to include the Koolyanobbing Range F Deposit, located in the southern Koolyanobbing Range. Cliffs propose to mine around 9 million tonnes of iron ore from the Deposit (Cliffs Asia Pacific Iron Ore. 2015a).

The EPA identified the importance of *Tetratheca erubescens* in their Environmental Scoping Document for the proposal, and specifically requested that the proponent:

> "Provide information on the implications of the proposal (direct and indirect) impacts on the genetic diversity and structuring of *T. erubescens*. Consideration of the implications of the proposal on population functionality (connectivity etc) should be provided."

2.3 Predicted Impacts

The proponent predicted the following impacts on *Tetratheca erubescens* in the PER for the proposal (Cliffs Asia Pacific Iron Ore Pty Ltd, 2015a):

1. 20% of the *Tetratheca erubescens* population (1235 individuals) are in the proposed mine pit areas and will be cleared, with another 2% of plants which may be cleared as they occur within a 10 m set-back around the outer edge of the mine pits.
2. No change in IUCN threat category of "Vulnerable"
3. No significant indirect environmental impact based on results of genetic studies of *Tetratheca erubescens* and monitoring of the related plant taxon (*Tetratheca paynterae* ssp. *paynterae*) at a nearby minesite.

Fundamentally, the central disagreement between the Western Australian Department of Parks & Wildlife (hereafter referred to as 'Parks & Wildlife') and the proponent (Cliffs) is over IUCN threat rankings. The proponent argues that the current VU ('Vulnerable'; based on Criterion D2) rank should remain (Cliffs Asia Pacific Iron Ore Pty Ltd, 2014a), whereas Parks & Wildlife argue (in their submission to the PER) the rank should move up two levels to CR ('Critically Endangered'; based on criterion B1[ab(ii)(iii)(iv)] and B2[ab(ii)(iii)(v)]), a listing which denotes an 'extremely high risk of extinction in the wild' (IUCN, 2012). The species clearly meets most of the criteria for CR (i.e. it is unquestionably restricted to single location with the extent of occurrence <100km^2 and area of occupancy <10km^2). However the CR rank (at least for the B1 & B2 criteria) also requires evidence or projection of 'continuing decline' in the area occupancy, area/quality of habitat and/or number of mature individuals (IUCN, 2012) – this is a more contentious issue and more difficult to assess. Parks and Wildlife argue there are palpable risks of ongoing declines amongst the remaining *Tetratheca erubescens* plants, especially those in close proximity to mining operations, from indirect impacts such as dust exposure, increased exposure, altered hydrology and microclimate, and increased landform instability. Conversely, the proponent argues such indirect impacts are unlikely due to specific management actions to be implemented and point to the low to nil impact of mining on the related taxon *T. paynterae* subsp. *paynterae* at a nearby mine site as evidence that remaining *T. erubescens* will not significantly decline (Cliffs Asia Pacific Iron Ore Pty Ltd, 2014a; 2015a).

Continual decline is defined by the IUCN (2012) as "a recent, current or projected future decline (which may be smooth, irregular or sporadic) which is liable to continue unless remedial measures are taken." Although this definition is open to interpretation in places, the key terms in applying the definition to this proposal are 'projected future decline' and 'liable to continue'. This suggests: 1) the 22% reduction in numbers due to clearing, although a significant impact in itself, does necessarily constitute a continual decline; and 2) that a reasonable likelihood of ongoing indirect impacts of mining is also required. However the onus is really on the proponent in this instance to present a strong case that the risks of plant deaths through future indirect impacts are likely to be nil to minimal.

It is important to note that geographically restricted plant taxa with small populations (often known as narrow- or short-range endemics) are a natural and relatively common feature of the biodiversity of south-west Australia, particularly in the transitional rainfall zone, and reflects the geological history and evolutionary processes which have occurred in the region, especially during the Quaternary period (Yates & Ladd, 2014; Hopper et al., 2004). Presumably most of these species have survived for millennia as such small restricted populations and would be expected to be strongly adapted to local conditions and variability in resource availability through specific reproductive, ecological and physiological traits (eg localised gene exchange, longevity, vegetative persistence etc.) *T. erubescens* is one of several species restricted to a specific range or narrow area of banded ironstones (Gibson et al., 2012) and there at least five other localised *Tetratheca* taxa in the Koolyanobbing region which have generally similar ecological requirement and strategies (Yates et al., 2013).

Although the evidence for and against a change in threat ranking, or otherwise, is a core issue in the impact assessment of the proposal, it should be recognised that rankings can be a somewhat imperfect and uncertain classification process. What is probably of greater importance is an evaluation of generic threats associated with the development - or more pointedly – to what degree is the proposal likely to increase the risk of extinction for *T. erubescens*.

3. Specific Issues (as per scope of this review)

3.1 Impact of clearing on species viability

Between 20-22% of the *T. erubescens* population (by numbers of known individual plants) will be directly lost through mining operations; however, there appears to be no or little information given by the proponent on the reduction in the area of occupancy or the extent of occurrence (as defined by IUCN). Nor has the reduction in the area of most suitable habitat been presented. These parameters are central to IUCN rankings, although it is noted that such areas are already well below thresholds used by the IUCN. For instance, the extent of occurrence and area of occupancy both appear to be less than 1 km^2 (Miller, 2015), much lower than the thresholds by the IUCN used for the CR rank (IUCN, 2012). *T. erubescens* appears to be restricted to a very precise habitat (cracks in banded ironstones on cliff faces; Miller, 2015), so understanding where this habitat occurs and how much will be directly lost with mining is of considerable importance to the conservation of the species and the potential for its translocation to sites outside its current distribution.

3.1.2 Genetic Impacts

Genetic studies (BGPA 2014; Anthony et al. 2016) predict very minor to no impact from the 22% loss of plants on overall genetic variability in the species and genetic differentiation between sub-populations. These studies and analyses were thorough and rigorous, and followed accepted protocols and methodology, in my opinion. It is noted however that there is strong genetic differentiation between the northern and southern sub-populations with some clinal (i.e. gradual) variation between these two groups. Although much more of the northern subpopulations will be directly cleared by mining, there appears to be enough individuals in the remaining sub-populations to not significantly reduce overall levels of genetic variability. Two of the sub-populations in the northern group (A and B) which won't be cleared are separated from the other northern populations by a major ridge and a distance of several hundred metres; however, the genetic data supports them as not being genetically distinct from the sub-populations to be cleared, and thus integral to the maintenance of overall genetic diversity.

The breeding system of the species is largely unknown but has been reasonably inferred from floral morphology and studies of close relatives nearby as being insect pollinated, most likely via buzz pollination by native bees. Seed dispersal vectors area also unknown, but the presence of a seed aril suggests it is very likely to be ant dispersed (Bull, 2007). These pollination and dispersal mechanisms would both tend to promote outcrossing but only across relatively short distances, thus explaining the positive correlations between genetic differentiation and spatial distance, and the genetic differences between northern and southern subpopulations (BPGA, 2015).

Although the species is likely to be strongly outcrossing, some of the remaining subpopulations (specifically subpopulations G and E in BPGA, 2015) will become smaller in number and/or more isolated from other subpopulations. Therefore there is some potential for enhanced inbreeding depression, especially as the numbers in these subpopulations approach thresholds where such effects become more likely (Frankham et al., 2014). However the potential for and effects of inbreeding depression in this species remains unknown.

Although the overall genetic impacts appear likely to be minor, BGPA (2014) outline ways to further minimise genetic impacts of clearing, such as keeping some sub-populations in each geographic group (largely done) and *in situ* collection of seed and plant material for long-term storage and propagation.

3.1.2 Population Viability

A common approach to assessing the long-term viability of rare species is Population Viability Analysis (PVA), which appears not to have been done for *T. erubescens*. Although it is accepted that many of the parameters required for the PVA may need to be estimated at this stage, and that error rates could be high (Beissinger & Westphal, 1998), there are merits in attempting such analysis, especially as there is some reliable data on population structure, phenology and reproductive rates already available. PVAs can not only indicate overall extinction risks, they can also be used to compare relative extinction risks across various scenarios in terms of impacts (e.g. different areas cleared) and remedial responses (e.g. comparing different transplanting or restoration options). Also PVAs can help elucidate the key unknown parameters in assessing species extinction risk and therefore help prioritise research projects (Beissinger & Westphal, 1998). Note a PVA was done successfully by Yates et al (2008) for *Tetratheca paynterae* ssp. *paynterae* which showed, amongst other findings, that viability was particularly sensitive to any increased mortality of adult plants.

It is likely *T. erubescens* has survived for a long period as a small and isolated population, perhaps for millennia (although the population may well have waxed and waned in response major climatic fluctuations). It is therefore reasonable to assume the species is capable of persisting with moderately lower numbers in the future, although the means by which it does so remains unclear. Although it is restricted to a very particular habitat, it may persist via considerable longevity (of adult and seed), high tolerance of drought and other environmental extremes, and/or maintaining high reproductive output and dispersal. The actual traits it uses to survive are worthy of further research and could contribute to a better understanding of rare species and their ecological requirements more generally.

Conclusions & Recommendations. I accept that the *c.*22% loss of the population (as described in the PER) will unlikely have ongoing deleterious genetic effects. Therefore, although the clearing for mining is unlikely to result in significant direct impacts on species viability from a genetic perspective, I recommend a PVA to provide an alternative approach (using demographic data) to better understand extinction risks with various clearing and mitigation scenarios.

3.2 Monitoring of T. paynterae subsp. *paynterae as a suitable surrogate*

Tetratheca paynterae subsp. *paynterae* is very similar to *T. erubescens* in terms of taxonomy, biology, ecology, biogeography and habitat (Yates et al. 2008). This doesn't necessarily mean they have same physiological strategies for surviving in this harsh environment, but the two species would be generally regarded as ecological analogues. Both species are also rare and restricted in distribution, grow in the same general area and habitat (BIF cliff faces), and both will be ultimately impacted directly, and potentially indirectly, by the same type of mining. Therefore it is acceptable and logical in my opinion to use the *T. paynterae* subsp. *paynterae* as a surrogate species to help assess impacts of mining on *T. erubescens.*

Although the dictionary definition of a surrogate is along the lines of something that functions as a substitute for another, there is no claim by the proponent or others that any impacts or otherwise of mining on *T. paynterae* subsp. *paynterae* will definitively and conclusively point to the same occurring on *T. erubescens*. Rather they are using *T. paynterae* subsp. *paynterae* as a model species to aid in the prediction and evaluation of impacts on a similar, nearby species, and I support this approach. In other words, any impacts or otherwise on *T. paynterae* subsp. *paynterae* provides important support for similar impacts (or not) on *T. erubescens*, but shouldn't be relied on as the only line of evidence*.*

Monitoring is an essential component of environmental impact assessment and ongoing mine site management to detect (and hopefully prevent or minimise) impacts before they become significant, test predictions of impacts and guard against unforeseen impacts. It is important however for the design of monitoring programs to be able to not only detect changes in key environmental features (or indicators thereof), but also be able to attribute the cause of any detrimental changes to the development or otherwise.

The standard and proven best approach to detect impacts on a population is via an adequately-replicated BACI monitoring design (Underwood 1992). In this approach, changes are compared before (B) and after (A) development in both impacted (I) areas and areas which are sufficiently distant or separated from potential impacts (control sites; C). Otherwise any impacts on the population (such as increased deaths or a decline in condition) cannot be confidently attributed to mining - i.e. they could be just natural fluctuations or be caused by something else. The monitoring program for *T. paynterae* subsp. *paynterae* is large and comprehensive, but the design does not satisfy BACI principles strictly speaking, although it has element of this. Only one year of baseline monitoring seemingly exists (2003) which is not enough to establish natural variability before mining; additionally, control and impact sites or zones are not clearly defined.

The first seven or so years of monitoring *T. paynterae* subsp. *paynterae* was deemed to be deficient and replaced with new design starting in 2011. The reasons given for the change were to improve statistical power (and hence ability to detect change) and to focus more on demographics (i.e. changes in number of individuals at different life stages). Although the change in monitoring design is unfortunate, I found it to be justified and acceptable in these circumstances, although the transitional arrangements and compatibility of data across the two monitoring periods could have been made more explicit. It should be possible to combine and compare some of the data from the two periods, such as Cliffs Asia Pacific Iron Ore (2015b) did for overall health scores from 2004-14.

The report summarising monitoring & research into *T. paynterae* subsp. *paynterae* (Cliffs Asia Pacific Iron Ore 2015b) doesn't mention the 2003 pre-mine baseline conditions, although I accept including only one year of data could be misinterpreted as it does not capture natural or typical fluctuations in baseline conditions. The baseline data are available in consultant reports (eg Western Botanical 2013) and indicate that the plants were generally healthy in 2003 and then declined in 2004-5 when mining started. In fact 2003, had the highest overall health rating of all years 2003-2010 (Western Botanical 2013). However such changes in condition from year to year were correlated with rainfall and cannot be necessarily attributed to mining.

The latest monitoring report (Cliffs Asia Pacific Iron Ore, 2015c) based on monitoring in October 2014 shows a ~9% (precisely 8.78%) decline in number of live plants recorded in monitoring blocks from the previous year (ie 923 in 2013 to 842 in 2014) together with a statistically significant decline in plant condition. Although the decline seems to be within the natural range of fluctuations (and did not exceed stated trigger values, although close), the declines are concerning given 2014 was an above-average rain year and previous declines have all been linked to relatively dry years. However it is difficult to apportion this decline to mining or anything else given deficiencies in design and analysis. However I note that blocks with highest 2014 decline are spread spatially and are not necessarily closer to mining activities, but this has not been tested statistically.

Given the lack of baseline data, an alternative approach to detect impacts could employ a control chart approach where every year of monitoring data contributes to an improved measure and understanding of inter-annual variability. Then years where a measured parameter is well outside the typical variation (typically more than two standard deviations) are flagged as 'out of control' or non-random events (Nelson 1984) which require further investigation and action as required. For instance values from the monitoring summary by Cliffs Asia Pacific Iron Ore (2015b) indicate an overall 10% fluctuation in *T. paynterae* subsp. *paynterae* condition levels from 2004 to 2014. The decline in overall health score from 41% to 30% between 2013 and 2014 is relatively large, however it appears to be within two standard deviations from the 2004-14 mean. There are similarities in this approach with the thresholds adopted in the monitoring plan for both *T. paynterae* subsp. *paynterae* and *T. erubescens*, although the thresholds adopted are not always well justified.

It is acknowledged that establishing valid control sites to satisfy a BACI design may be difficult in these circumstances mainly as impacts may not necessarily be related to distance from mining. However there appear to be sub-populations which are not only several hundred metres from mining operations, they are also protected from dust and prevailing winds etc. However, it is important that control and impacts sites are well replicated and not spatially biased or structured (Underwood, 1984).

Conclusions & Recommendations. Although it is a suitable surrogate species to aid in impact predictions, the data available on *T. paynterae* subsp. *paynterae* is unfortunately lacking to make definite conclusions on the impacts of mining on this species. In particular, the design of the current monitoring and analyses prevents apportioning any detected changes to a particular cause. However, on the evidence presented at least, changes detected in the monitored *T. paynterae* subsp. *paynterae* plants seem to be within natural fluctuations for this species, however more analysis and monitoring is required to confirm this.

3.3 Indirect impacts on species viability

3.3.1 Coverage of Indirect Impacts in the PER

Despite some claims to the contrary, the PER did assess indirect impacts such as potential effects of dust deposition on plant leaves and altered hydrology and concluded that significant indirect impacts were unlikely in these areas. Indirect impacts were also further addressed incidentally in the PER under additional management controls (Table 3-3 in the PER; Cliffs Asia Pacific Iron Ore, 2015a), where potential impacts such as dust, trampling, grazing and fire were covered, with proposed management actions generally appropriate to minimise these indirect impacts.

3.3.2 Monitoring as Impact Management Strategy

It is mentioned several times in the PER that a detailed monitoring plan will be established and put in place to detect indirect impacts. This is key component of the proponent's plans to minimise indirect impacts with the strategy here to detect and deal with such impacts before they become significant. Although the specific details of the monitoring plan are yet to be developed, the PER did detail trigger criteria and actions based on level of detected changes in the monitored individuals of *T. erubescens*. The main trigger for action given is 10% average or greater decline in health (or 15% if drought year) from previous year combined with evidence of decline over the longer term and greater decline in areas proximate to mining – this is reasonable and acceptable in my opinion as will tend to separate mining impacts from fluctuations due to annual and seasonal climate variation. However it would be perhaps better to assess impacts relative to pre-mining variation in plant condition (i.e. baseline status, which would require at least several years of pre-mining monitoring) and compare this to any changes post mining in both areas close to (impact) and distant (control) from mining. This would be classic BACI design, although defining impact and control zones would need to be done carefully. Alternatively, but less desirably, a control chart approach could be adopted as described above.

Although the triggers given appear to be appropriate, actions (when changes exceed trigger) are reporting/referral and further investigations to establish the cause and develop contingency plans if required, which can potentially include alterations to mine operations. However substantial changes to mine plans would be unlikely once mining has commenced and there are not necessarily any commitments given in this area. However, I accept that there needs to be some evaluation of data to develop the most appropriate actions.

3.3.3 Indirect Impacts of Concern

Although a number of indirect impacts have been raised by Parks & Wildlife and others in their response to the PER, many of them are unlikely to pose a problem in my opinion as impacts are either of low probability of occurrence or are easily mitigated via the proposed management prescriptions or otherwise. These include altered fire regimes (most of the habitat is not fire prone), grazing (easy to control) and microclimate (wind, sun exposure, heat and evaporative demand can already be extreme and are unlikely to change considerably with mining). However, I remain concerned about: 1) stability of cliff faces and microhabitat features; 2) inadvertent physical damage due to proximity of mining; and 3) dust impacts.

The southern sub-populations are mostly located on the cliff faces on the upper part of a ridgeline which will experience mining on the opposite side of the ridge to create effectively create a second cliff face. This formation of a considerably narrower ridge could lead to an overall reduction in structural integrity and greater risks of land slippage and erosion which may impact on *T. erubescens*, especially given the use of explosives and large machinery in mine pits. The dimensions and internal features of cracks seem to be important in development of suitable habitat for *T. erubescens* (Miller, 2015) and these features may change with nearby mining.

Secondly, it is clear that many plants are very close to edges of mine pits or generally close to mining operations and infrastructure (including access tracks). The risks of accidental/unintentional damage to plants in these areas are real, even allowing for a 10 m setback. For instance, through intensive mining activity and high human presence in the area, there is a risk of plant damage through such events as trampling, off-road vehicle movement, saline water application (eg to reduce dust) and accidental clearing, particularly on less steep slopes. I appreciate there will be strict rules and education programs in place to manage such impacts, but I felt the PER lacked specific details or a plan of how remaining plants of *T. erubescens*, especially those in vicinity of pit edges, will be protected. Therefore, I am not confident that there will be no ongoing decline of *T. erubescens* due to indirect mining impacts. In other words, the proponent hasn't established a strong case for protecting the remaining plants and their habitat over the long-term. I have been to many mine sites across WA where I have regularly observed and studied (eg Bertuch & Van Etten 2004) damage to plants and soils next to roads, pits and other infrastructure, and therefore my concern in this instance.

The last issue of concern is dust impacts and my apprehension here is based on observations by Western Botanical (2013) that dust deposition was common on *Tetratheca* plants close to mine pits. Such dust has the potential to reduce photosynthetic rates (and hence plant growth and vigour) and interfere with water/gas exchange etc. However, I note few studies which have conclusively shown impacts of mining dust on plants, and therefore agree that such impacts are speculative at present.

It is noted that Cliffs, in an email to EPA dated 25/2/16, state that they would consider shifting the boundary of pits to the east by about 10 m to reduce impacts on plant near the edge of pits, and would consider another 20 m if deemed essential. Given the indirect impacts discussed above are all linked to close proximity to mining and many plants are very close to proposed mine pits edges, shifting boundaries would greatly reduce the potential and, if realised, the magnitude of such impacts. Although this is an informal proposition at present, it should be taken as a gesture of goodwill by the company and an indication they are prepared to be proactive and flexible to some degree to find a solution to protect the remaining individuals of *T. erubescens*. With this increased setback, topographic profiles of the southern ridge would be less narrow, likely to be less vulnerable to slippage and be more stable.

3.3.4 Indirect Impacts on Habitat

It is important to note that IUCN threat rankings are also tied to changes in habitat area and/or quality (in addition to changes in population sizes and areas). For *T. erubescens* this habitat is quite specific and focussed on cliff faces where there are cracks in the banded ironstones. The area of suitable habitat would decline with construction and mining operations, but this doesn't seem to have been quantified in the PER.

The Kings Park Habitat study (Miller 2015) showed strongest correlations with elevation and slope (in other words the species tends to occur on the steepest slopes at the highest parts of the range). However, at a finer scale, rock crevices on cliff faces are clearly important with the species one of only a few in the area capable of growing in this habitat. The study by Miller (2015) also suggests that *T. erubescens* habitat is quite specific in terms of soil and rock features – therefore the species would be vulnerable to any changes in habitat conditions. However the study is ultimately correlative so it remains unclear which of the identified abiotic and biotic features of habitat are most influential for the species. For instance, is the species only present in areas where there is good moisture storage within rock crevices, or is soil moisture of secondary importance with the species displaying very strong drought tolerance or avoidance strategies to to be able to survive on cliff faces. This requires more study as identified by Miller (2015).

Miller (2015) states that "the locations where plants grew were more likely to be in a locally water concentrating position in a crack within the steepest regions, on a cliff, with some small amount of local soil that was organic rather than mineral in nature, and with lower plant cover." This suggests some specific features of crevices are likely to be important to *T. erubescens* establishment and persistence, and will heavily influence if they are easily recreated in a postmine environment, or will take some time to develop. Therefore finding out these critical habitat features of crevices which support the species is an important research area.

Lastly, it could be argued because the species is not in conservation reserve or other formal protected area, it may be vulnerable to further mining interests in the future. Therefore mining itself could be seen as an ongoing threat separate or in addition to the current proposal. The IUCN rankings are based on evaluation of threats over the long term, although I agree this issue is beyond scope of the current PER.

Conclusions & Recommendations. 1) A properly designed monitoring plan is crucial in this instance to detect and minimise indirect impacts on *T. erubescens*, but it needs more detail to demonstrate it will be able to detect and apportion impacts; 2) I was not completely convinced that indirect impacts will be minimal to zero as claimed in the PER with particularly concerns over relatively large number of plants very close to edge of mine pits and other mining operations; 3) Shifting the edge of mine pits away from these plants will reduce the likelihood and magnitude of any impacts. Therefore, at present, I see a palpable case for ongoing indirect impacts of mining on *T. erubescens* and hence the justification for change in threat ranking based on IUCN criteria.

3.4 Translocation and seeding as mitigation strategies

As part of proposed offsets, the proponent has committed to the development and implementation of a recovery plan for *Tetratheca erubescens*, which will become an important component of the strategy to protect the species and mitigate against impacts, both direct and indirect. Although there are no specific details as yet, the recovery plan will include translocation and seeding of new areas (Cliffs Asia Pacific Iron Ore Pty Ltd 2014b), presumably both within its current distribution and in additional suitable habitat in close proximity. I am supportive of a recovery plan as an offset and impact mitigation strategy for this project as it should lead to strategic, direct and prompt action to improve conservation outcomes for the species, as well as the funds to do so. Recovery plans are routinely prepared for threatened species and they generally have a solid track record in delivering targeted, effective and efficient conservation actions because they typically have been well planned and involve collaboration between multiple stakeholders (Taylor et al., 2005), although sometimes there is lack of funds and staffing to see things through, and a lack of auditing and monitoring to check on success or otherwise (Lindenmeyer et al., 2013). Offsets should lead to no net loss and, ideally, a net positive benefit, and there is potential that this offset could deliver here. However a key assumption here is that: 1) there is available suitable habitat in the vicinity of the mine for translocation; and 2) translocation is a feasible option, with research on other nearby *Tetratheca* important here in making this assessment.

The *Tetratheca erubescens* Habitat Study done by Kings Park Science (Miller 2013), although a 'first pass' modelling exercise, was done using appropriate and widely accepted methodology (i.e. Maxent modelling involving a wide range of variables mapped at suitable scale). It showed that there is around 550 m of highly suitable ('highly predicted') cliff face habitat in the immediate vicinity of the sub-populations which is unoccupied by the species, as well as other such areas nearby. This suggest there are potential areas for establishment of new individuals via seeding and/or planting, if required. However the unoccupied habitat was somewhat different to areas with the species present: on average they had 'slightly lower slope angles and rock cover and greater soil depth and plant cover than occupied sites' (Miller 2013). They also were 'significantly more likely to include hillslope and talus features and less likely to be cliff features, they had more locations with soil, and that soil was more likely to be visually assessed as mineral rather than organic'. Despite these general differences, there is still likely to be many suitable areas of the right type of cliff face habitat present for transplanting or establishment of the species if this is required in the recovery plan.

The results of translocation and seeding trials for *T. paynterae* subsp. *paynterae* to date have recently been summarised by Cliffs Asia Pacific Iron Ore (2015b). The first seeding trial in 2004-6 involving 800 seed directly sown into rock crevices, found 16 (2%) germinated and 8 (1%) established. Two plants had flowered by year three and one had set seed. This is a very low rate of establishment but probably consistent with natural reproductive rates. For instance, Yates et al (2008) found, depending on the year, around 20-30 *T. paynterae* subsp. *paynterae* seeds produced per plant per year on average, and a mean adult to new seedling ratio of between 5 to 30 per year, suggesting (early) establishment rate of one seedling in every 100-900 seed produced. These establishment rates are broadly consistent with the results of the first trial.

The second trial in 2014-5 was done with more considerably more seed (3200), but has not resulted in any germination or establishment to date, despite the reasonably good rain years (Cliffs Asia Pacific Iron Ore, 2015b).

Both these studies demonstrate the difficulty in establishing the species from direct seeding. More research and trials are needed before we can be confident the species can be re-established or translocated to new locales. Further, the ultimate aim of revegetation should be the creation of new self-sustaining populations and not just successful germination and early survival, and the proponent is a fair way from achieving this for *T. paynterae* subsp. *paynterae*.

Several germination studies involving various treatments have showed strongly developed dormancy and generally low rates of germination for *T. paynterae* subsp. *paynterae* and other nearby *Tetratheca* species (Yates et al. 2008; Cliffs Asia Pacific Iron Ore, 2015b). The best treatment seems to be heat application on older seed suggesting a hard testa (seed coat) and long-lived seed with pronounced dormancy. In situ, these *Tetratheca* may require physical scarification such as abrasion by soil or rocks for seed germination (given they do not tend to grow in fire prone environments). But it also suggests that seed applied via direct seeding may remain dormant for considerable periods until conditions are right, building up an ample soil seed bank in the interim (although this has not been formally tested in research to date). *T. paynterae* subsp. *paynterae* can also be successfully propagated by cuttings (Cliffs Asia Pacific Iron Ore, 2015b), which opens up a promising avenue of transplanting whole plants.

Conclusions & Recommendations. Although there is much potential for restoring numbers of *Tetratheca erubescens* via seeding, and perhaps transplanting, the general lack of success with similar species nearby suggest it is a difficult and risky conservation strategy with no guarantees that it will ensure the long-term viability of the species. However I do acknowledge the inherent low and highly variable rates of establishment in the field, which suggests a commitment by the proponent to a sustained restoration effort will be important (ie they can't just rely on one or two years of seeding).

References

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