Forecasting the path towards a Net Positive Impact on biodiversity for Rio Tinto QMM

H. J. Temple, S. Anstee, J. Ekstrom, J. D. Pilgrim,
J. Rabenantoandro, J-B. Ramanamanjato,
F. Randriatafika and M. Vincelette.

IUCN and Rio Tinto Technical Series No.2

Forecasting the path towards a Net Positive Impact on biodiversity for Rio Tinto QMM

H. J. Temple, S. Anstee, J. Ekstrom, J. D. Pilgrim, J. Rabenantoandro, J-B. Ramanamanjato, F. Randriatafika and M. Vincelette

IUCN and Rio Tinto Technical Series No.2

ISBN: 978-2-8317-1441-7

Cover photo:
© David Rabehevitra

Layout by:
millerdesign.co.uk

Printed by:
SRO-Kundig SA, Switzerland

Available from:
IUCN
(International Union for Conservation of Nature)
Publications Services
Rue Mauverney 28
1196 Gland Switzerland

Tel +41 22 999 0000
Fax +41 22 999 0020

books@iucn.org
www.iucn.org/publications

The text of this book is printed on FSC paper.

The designation of geographical entities in this book, and the presentation of the material, do not imply the expression of any opinion whatsoever on the part of IUCN or Rio Tinto concerning the legal status of any country, territory, or area, or of its authorities, or concerning the delimitation of its frontiers or boundaries.

This publication captures the experience of an innovative and scientifically robust attempt to assess, forecast, and subsequently account for procedures put in place by Rio Tinto to mitigate and remediate the input of their operations at the QMM site.

As the scientific basis and operational procedures to attain a net positive impact are still in the process of being established, this report is intended to be strictly technical in nature. It does not represent endorsement of a particular approach or standard towards attaining "net positive impact".

IUCN does not take responsibility for the operational delivery of the outcomes anticipated in the forecast.

Published by: IUCN, Gland, Switzerland and Rio Tinto, London, UK

Copyright: © 2012 International Union for Conservation of Nature and Natural Resources

Reproduction of this publication for educational or other non-commercial purposes is authorized without prior written permission from the copyright holder provided the source is fully acknowledged.

Reproduction of this publication for resale or other commercial purposes is prohibited without prior written permission of the copyright holder.

Citation: Temple, H.J., Anstee, S., Ekstrom, J., Pilgrim, J.D., Rabenantoandro, J., Ramanamanjato, J.-B., Randriatafika, F. & Vincelette, M. (2012). *Forecasting the path towards a Net Positive Impact on biodiversity for Rio Tinto QMM.* Gland, Switzerland: IUCN. x + 78pp.

Contents

List of tables

List of figures

FOREWORD

This publication aims to provide the data, theory, and predictions for the potential long-term outcome of a biodiversity conservation programme at a mining site. Forecasting the path towards a Net Positive Impact on biodiversity for Rio Tinto QMM is a joint initiative between IUCN and Rio Tinto, a global mining Group.

Rio Tinto and IUCN signed a three year collaborative agreement in 2010, with the overall objective to build a business focused collaboration that enables Rio Tinto to improve its conservation outcomes, strengthen IUCN and Rio Tinto capacities for market-based approaches to conservation, and contribute to industry-wide improvements in the mining and associated sectors. By working together, both organizations aim to better understand each other's issues and priorities, draw on each other's experience and expertise, and develop programmes and actions that provide on-the-ground conservation value and contribute to improved performance – for IUCN, Rio Tinto, and the mining sector more broadly.

This report contributes to the ongoing discussion around applying a mitigation hierarchy to managing biodiversity risks and challenges and discussion around biodiversity offsets and biodiversity metrics. IUCN and Rio Tinto believe an important input to the discussion is rigorous on-the-ground testing of theories and methodologies, which is robustly and transparently documented.

IUCN is the world's oldest and largest global environmental organisation, with more than 1200 government and NGO members and almost 11 000 volunteer experts in some 160 countries. IUCN's work is supported by more than 1000 staff in 45 offices and hundreds of partners in public, NGO and private sectors around the world. IUCN works on biodiversity, climate change, energy, human livelihoods and greening the world economy by supporting scientific research, managing field projects all over the world, and bringing governments, NGOs, the UN and companies together to develop policy, laws and best practice.

Rio Tinto is a leading global mining group, involved in every stage of the mining business. Its interests are diverse both in geography and product and it works in some of the world's most difficult terrains and climates. Most of Rio Tinto's assets are in Australia and North America, but it also operates in Europe, South America, Asia and Africa. Businesses include open pit and underground mines, mills, refineries and smelters as well as a number of research and service facilities. Rio Tinto comprises five principal product groups - Aluminium, Copper, Diamonds & Minerals, Energy, and Iron Ore – plus two support groups: Technology & Innovation, and Exploration.

Clare Verberne, Dennis Hosack, and Stuart Anstee

ACKNOWLEDGEMENTS

This report has been written by The Biodiversity Consultancy Ltd., Cambridge, UK, with contributions from the QMM Biodiversity Team and Rio Tinto HSE.

The first draft of this report was prepared by Helen Temple (The Biodiversity Consultancy), with input from the Rio Tinto QMM biodiversity team (Manon Vincelette, Johny Rabenantoandro, Faly Randriatafika, Jean-Baptiste Ramanamanjato, Dominique Andriambahiny) and Jonathan Ekstrom (The Biodiversity Consultancy) gathered in workshops held in Fort Dauphin, Madagascar in January and February 2010. At this stage, the document was intended as a discussion paper to inform debate with the Rio Tinto QMM Biodiversity Committee regarding what 'Net Positive Impact' meant in practice for Rio Tinto QMM. The methodology and draft text was reviewed by the Rio Tinto QMM Biodiversity Committee at a workshop held on 3-6 May 2010 in Fort Dauphin (a full day was dedicated to this task). The following committee members were present and contributed to the discussion: Porter P. Lowry (Missouri Botanical Gardens); Jörg Ganzhorn (Hamburg University); Alison Jolly (Sussex University); Rob Brett (Fauna and Flora International); Paul Smith (Royal Botanic Gardens, Kew); and Lisa Gaylord (Wildlife Conservation Society). A number of significant changes and improvements were made to the methodology and draft report based on the Committee's requirements. The document was then internally reviewed by Rio Tinto Health, Safety, Environment and Communities (Stuart Anstee), Rio Tinto QMM (Manon Vincelette, Johny Rabenantoandro) and The Biodiversity Consultancy (John Pilgrim, Jonathan Ekstrom). At this stage it was decided that the document would be of value to a number of external audiences and should be formally published. Consequently a further round of review and improvement was initiated in December 2010, involving the Rio Tinto QMM Biodiversity Committee and a number of additional experts. These experts were selected by IUCN rather than Rio Tinto QMM, and were: Thomas Brooks (NatureServe), Sue Mainka (IUCN), Dennis Hosack (IUCN), Monica Barcellos-Harris (UNEP-WCMC), Leon Bennun (BirdLife International), Conrad Savy (Conservation International) and James Watson (Wildlife Conservation Society). In addition, the document was reviewed at the first meeting of the IUCN-Rio Tinto Working Group on NPI Verification, held on 17-18 March 2011 in London, attended by Stuart Anstee (Rio Tinto), Rachel Asante-Owusu (IUCN), Dennis Hosack (IUCN), Sally Madden (Rio Tinto), Thomas Brooks (NatureServe), Manon Vincelette (Rio Tinto), Conrad Savy (Conservation International), Simon Wake (Rio Tinto), Monica Harris (UNEP-WCMC), James Watson (Wildlife Conservation Society) and Rainer Schneeweiss (Rio Tinto). Finally, the document was also graciously reviewed by Richard Jenkins (IUCN) and Paul Racey (University of Exeter).

The authors should like to thank all of them for their contributions to this report.

EXECUTIVE SUMMARY

The Rio Tinto ilmenite mine in southeastern Madagascar, run by QIT Madagascar Minerals, has been chosen as a pilot site to test the tools designed to achieve and quantify a NPI on biodiversity.

Rio Tinto is committed to achieving a Net Positive Impact (NPI) on biodiversity, a strategy launched at the 2004 IUCN World Conservation Congress. The Rio Tinto ilmenite mine in southeastern Madagascar, run by QIT Madagascar Minerals (Rio Tinto QMM), has been chosen as a pilot site to test the tools designed to achieve and quantify NPI on biodiversity. The most important direct negative biodiversity impact resulting from the Rio Tinto QMM operation is the loss of littoral forest habitat at the Mandena, Petriky and Sainte Luce (hereafter Ste Luce) mining sites. Approximately 1,665 ha (3.5% of Madagascar's remaining 47,900 ha of littoral forest) are expected to be lost over the next 40 years as a result of mining and associated activities. Rio Tinto QMM operates a dredge mine rather than a conventional open cast mine so habitat loss will be incremental over decades as the mine moves slowly through the landscape; the total direct footprint is anticipated to be c.8,000 ha over the mine's lifetime; however the mine itself occupies c.50 ha at any one time (covering c.100 ha per year: Rio Tinto QMM, 2001). Rio Tinto QMM began its mining activities in 2009. Littoral forest has been identified as a national conservation priority (Ganzhorn *et al.*, 2001) owing to its limited extent and its high concentrations of nationally and locally endemic plant species (Du Puy and Moat, 1998; Dumetz, 1999), diverse tree flora (Dumetz, 1999), and high diversity of fauna (Ganzhorn, 1998; Ramanamanjato *et al.*, 2002; Watson *et al.*, 2005). Littoral forests on the mining concession harbour many restricted-range species and species classified as Threatened on the IUCN Red List, including 42 plants and at least 14 invertebrate species that are found nowhere else in the world.

In the present analysis, biodiversity losses and gains were measured and forecast for the period 2004–2065 (i.e. from the date of the NPI commitment to the anticipated date of mine closure), in order to determine whether the current and proposed mitigation activities of Rio Tinto QMM are sufficient to achieve NPI by closure. NPI was defined (in consultation with Rio Tinto QMM's Biodiversity Committee) as Net Positive Impact on littoral forest (measured in Quality Hectares, QH) and Net Positive Impact on High Priority species (measured in Units of Global Distribution, UD).

Four main types of conservation actions are being implemented by Rio Tinto QMM to mitigate project impacts on key habitats and species. These are:

- Avoidance—at Mandena, Petriky and Ste Luce. Avoidance Zones (AZ) have been established. They represent a cost to Rio Tinto QMM of c.8% of foregone ilmenite, as well as the management cost of maintaining these areas, and protect 27% of the best quality remaining forest cover on the deposit. Collectively, these cover an area of 624 ha.

- Minimization—reduction of the likelihood or magnitude of biodiversity impacts from mining activities that cannot be avoided. At Rio Tinto QMM this includes a diverse range of activities such as minimizing disturbance and roadkill from mining-related traffic by educating drivers and enforcing strict speed limits.
- Rehabilitation and restoration—re-establishment of littoral forest on areas that have been completely cleared, by replacing topsoil (stored during the mining process) and planting with appropriate native species propagated in Rio Tinto QMM's nursery. There are plans for the restoration of c.225 ha at each of the three sites (Mandena, Petriky and Ste Luce), amounting to c.675 ha in total. Restoration zones will be located adjacent to the Avoidance Zones, to provide a buffer, improve connectivity and facilitate natural regeneration and re-colonization.
- Biodiversity offsets—Rio Tinto QMM is investing in biodiversity offsets at several forest sites in the region, with the aim of reducing the high background rate of deforestation. These offset sites cover c.6,000 ha of forest.

In addition, Rio Tinto QMM is carrying out a number of additional conservation actions (e.g. environmental education, capacity-building, livelihoods alternatives, etc.) with the aim of making a positive contribution to sustainable development in the region and reducing human pressure on biodiversity.

Net impact on littoral forest is forecast to be +350 QH in 2065,[1] representing an increase in forest extent and quality of 13% in comparison to 2004 (measured in QH). Net impact on littoral forest is forecast to be +48 QH in 2015, representing an increase of 2% in comparison to 2004 levels. Net impact on the forest as a whole (including the humid forests of the Bemangidy[2] offset) is forecast to be +1,251 QH.

Loss of littoral forest caused by direct impacts of mining is predicted to be -428 QH. Total littoral forest gain is predicted to be +778 QH. Consequently the ratio of gain to loss is approximately 2:1. Considering all forest types, loss remains constant at -428 QH; gain in all forest types (including Bemangidy humid forest) is +1,679 QH. In this case the ratio of gain to loss is approximately 4:1.

Of the 90 High Priority terrestrial species (54 plants, 26 invertebrates, 10 vertebrates) individually, 83 (92%) are forecast to show a Net Positive Impact at 2065. For 59 of these, area-based calculations predict that NPI will be reached; for a further 24 plant species, area-based calculations predict a moderate negative impact (-1.3% to -17.9%) requiring Rio Tinto QMM to reach NPI by 2065 through enrichment of the avoidance and restoration zones (e.g. returning species from their current depleted levels towards estimated natural densities in

---

[1] Based on a background deforestation rate of the Madagascar national average for c.1990 to c. 2000 of 0.9% per year.

[2] Bemangidy is part of the Tsitongambarika forest – it lies within the area of the forest that is sometimes called 'TGK III'.

optimal conditions[3]). Seven animal species show residual negative impacts—four vertebrates (including the Critically Endangered gecko *Phelsuma antanosy*) show residual negative impacts of up to 5.1%, and three invertebrates show residual negative impacts of up to 17.9%. It is not known whether enrichment would be feasible or desirable for these species,[4] research is underway to investigate options.

Only 32 of the 90 High Priority species are likely to be at NPI by 2015, and some species show losses of up to 39% of their global distribution at this point (two millipedes and one plant, all endemic to Mandena, show population reductions of this magnitude). This is because there will already have been major impacts by this date (particularly at Mandena), but rehabilitation/restoration zones will not as yet have reached sufficient maturity to generate gains that can count towards NPI.

Importantly, this analysis is primarily a forecast based on the best available data. Accounting of biodiversity losses and gains will be required periodically, using the same principles and methods, and incorporating better information as it becomes available.

Overall, this analysis shows that Rio Tinto QMM could be on track to achieve a Net Positive Impact on biodiversity by the date of closure of the mine, provided that:

1. The assumptions upon which the analysis is based (*inter alia* background deforestation rate, levels of habitat degradation, rate at which habitat quality can be restored) are either accurate or precautionary.
2. The conservation measures detailed here are successfully implemented.
3. Further research is conducted into conservation options for the four vertebrate and three invertebrate species predicted to have a net negative impact in 2065, and the best of these options is implemented as a high priority.
4. Sustained investment in conservation action is assured.
5. Rigorous monitoring and independent verification are implemented to ensure that real biodiversity gains are achieved.

---

[3] At present, littoral forest at Mandena, Petriky and Ste Luce is somewhat degraded as a result of various human activities (not only mining)—consequently, for some species (e.g. plant species highly sensitive to disturbance or degradation) it is desirable to ultimately aim to restore them to greater densities than are currently observed.

[4] Note that *Phelsuma antanosy* is found at Ambatotsirongorongo, which has been protected through a joint QMM-Wildlife Conservation Society initiative. The 'gains' from this site are not included in the summary figures presented here.

1 INTRODUCTION

Rio Tinto is committed to achieving NPI on biodiversity at sites where it operates, a strategy launched at the 2004 IUCN World Conservation Congress and reinforced at the 2008 Congress.

Rio Tinto is committed to achieving a Net Positive Impact (NPI) on biodiversity at sites where it operates, a strategy launched at the 2004 IUCN World Conservation Congress and reinforced at the 2008 Congress (Rio Tinto, 2008a). The Rio Tinto ilmenite mine in the Fort Dauphin region of southeastern Madagascar run by QIT Madagascar Minerals (Rio Tinto QMM) has been chosen as one of Rio Tinto's pilot sites to test the tools designed to achieve and quantify NPI on biodiversity. It consists of three sites to be mined sequentially (Mandena, Ste Luce and Petriky), a new deepwater port, and ancillary infrastructures such as roads, quarry, housing and industrial areas (**Figure 1**). Mining at the first of these three sites, Mandena, began in 2009. Rio Tinto QMM has made a formal commitment in its Biodiversity Action Plan to achieve NPI on biodiversity.

The most important direct negative biodiversity impact resulting from Rio Tinto QMM's activities is the loss of littoral forest habitat at Mandena, Petriky and Ste Luce. Littoral forest is a rare and threatened habitat within Madagascar—c.90% of this habitat type has already been lost as a result of human activities (Consiglio *et al.*, 2006). Approximately 1,665 ha (3.5% of Madagascar's remaining 47,900 ha of littoral forest) is expected to be lost to dredging, which entails not only clearance of vegetation but also removal of soil and its constituent seed bank.

Littoral forests on the mining concession harbour many restricted-range species and species classified as Threatened by the IUCN Red List, including 42 plants and at least 14 invertebrate species that are found nowhere else in the world. The project will have substantial residual impacts on a number of these species.

Four main types of conservation actions are being used by Rio Tinto QMM to mitigate project impacts on key habitats and species. These are:

- **Avoidance Zones (AZ)**—at Mandena, Petriky and Ste Luce, Avoidance Zones have been established on the ilmenite deposits to protect those blocks of littoral forest that are in the best condition. These AZ have been officially incorporated into Madagascar's national Protected Areas network. They represent a cost to Rio Tinto QMM of c.8% of foregone ilmenite and protect 27% of forest cover on the deposit. Collectively, they cover a total area of 624 ha.
- **Minimization**—reduction of the likelihood or magnitude of biodiversity impacts from mining activities that cannot be avoided. At Rio Tinto QMM this includes a diverse range of activities such as minimizing disturbance and roadkill from mining-related traffic through road-safety awareness campaigns and by enforcing strict speed limits.

- **Rehabilitation and restoration**—attempts to re-create littoral forest on areas that have been completely cleared, by replacing topsoil (stored during the mining process) and planting with appropriate native species propagated in Rio Tinto QMM's nursery. Rehabilitation/restoration zones will be located adjacent to the AZ to provide a buffer, improve connectivity and facilitate natural regeneration and re-colonization.
- **Biodiversity offsets**—Rio Tinto QMM is investing in biodiversity offsets at several forest sites in the region, with the aim of reducing the high background rate of deforestation. These offset sites cover c.6,000 ha of forest.

Rio Tinto QMM is implementing a number of additional conservation actions intended to make a positive contribution to biodiversity conservation and sustainable development in the region.

In addition, Rio Tinto QMM is implementing a number of additional conservation actions (environmental education, capacity-building, livelihoods alternatives, etc.) intended to make a positive contribution to biodiversity conservation and sustainable development in the region. These actions will be essential to reduce human pressure on remaining forest and to allow restoration, biodiversity offsets and avoidance to deliver conservation gains.

This report quantifies the current and projected direct impacts on key habitats and species caused by mining and associated activities, and the potential conservation gains that may be achieved through habitat restoration and averted deforestation at Avoidance and Offset Zones. It is intended to shed light on the following questions:

1. Is Rio Tinto QMM on track to achieve a Net Positive Impact on biodiversity for the period 2004-2065?
2. Is Rio Tinto QMM on track to achieve a Net Positive Impact on biodiversity by 2015?

The 2004 to 2065 time frame has been chosen as it corresponds to the period starting from the launch of the biodiversity NPI policy in 2004 to the current projected date of mine closure and relinquishment of the tenement in 2065. The 2015 date represents an interim milestone that has been set as part of Rio Tinto's performance target-setting process.

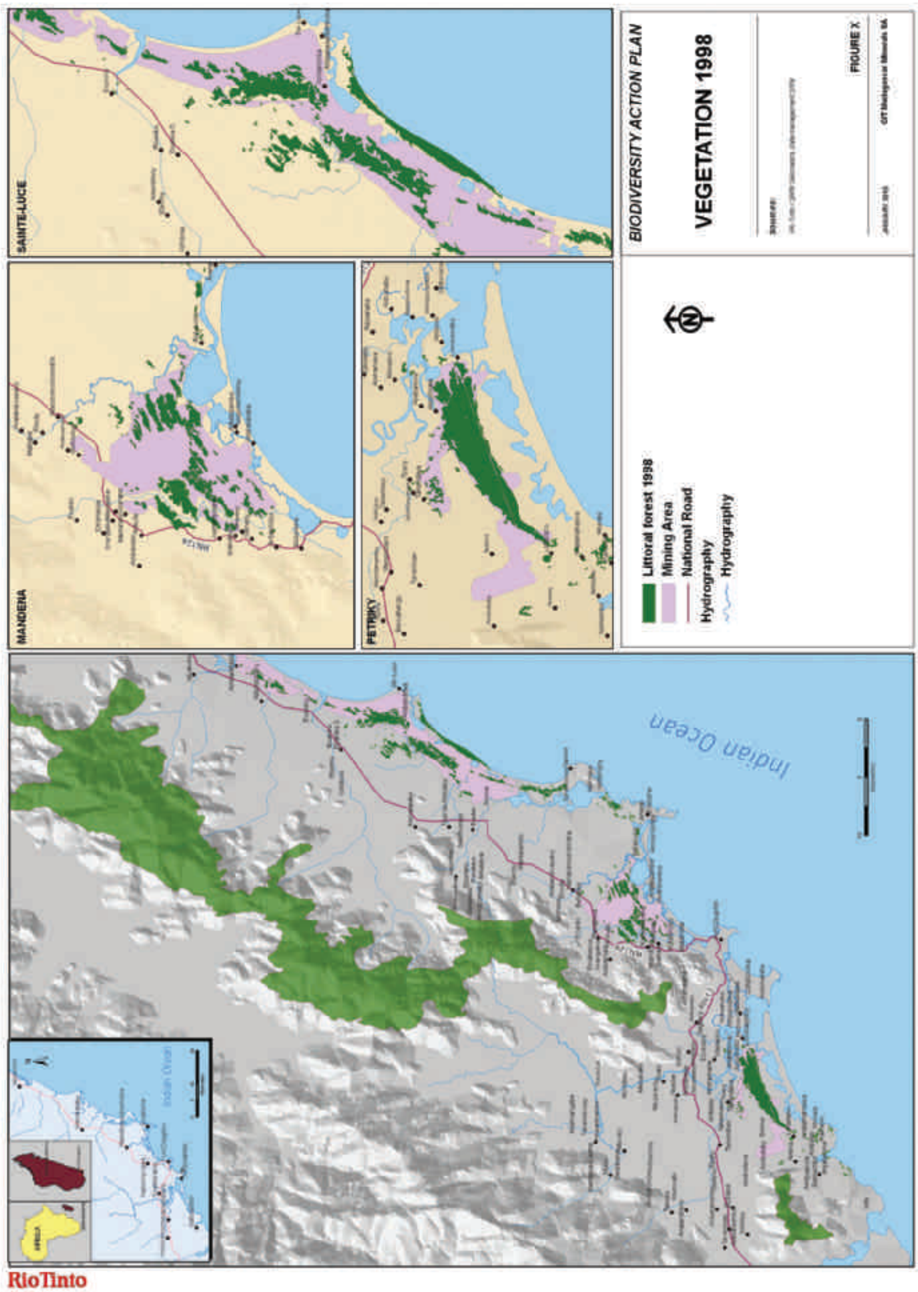
It should be noted that the complexity associated with setting and monitoring biodiversity metrics means that value judgements are often required in the initial establishment of relevant targets for achieving NPI. In the case of the Rio Tinto QMM project the validity of these value judgements was tested by an external committee of biodiversity and conservation specialists.[5] Quantitative analyses such as those presented here can provide useful background information and

[5] A Biodiversity Advisory Committee was formed in 2001 to review the Rio Tinto QMM biodiversity strategy and conservation measures on the ground. It consists of biodiversity experts with extensive experience and global renown for their research in Madagascar. This committee currently comprises: Dr. Porter P. Lowry (Missouri Botanical Gardens); Prof. Joerg Ganzhorn, (Hamburg University); Prof. Alison Jolly (Sussex University); Dr. Rob Brett (Fauna & Flora International); Dr. Paul Smith (Royal Botanic Gardens, Kew); and Lisa Gaylord (Wildlife Conservation Society).

insights, but they should not replace consultation with appropriate biodiversity stakeholders and experts.

Finally, it should be noted that this report focuses on technical biodiversity issues because its remit is to answer specific technical questions. It only very briefly touches on local communities and broader sustainable development issues. This should not be taken as implying that "biodiversity issues are more important than social issues for Rio Tinto QMM", rather it reflects the specific aims of the report. It is essential that mining and implementation of mitigation and offset measures are done in a way that takes into account the needs and rights of local communities and does not leave them worse off than before. Faced with development of a mine and development of biodiversity offsets, there is a real risk that local communities may face a 'double whammy' of negative impacts from both initiatives (e.g. if a community is dependent upon forest resources, and its access to forest is reduced through mining-caused deforestation and the implementation of a 'fortress-style' protected area)(BBOP, 2009). Rio Tinto QMM's expressed aim is to implement mitigation and offsets in a way that benefits both biodiversity and local communities (Rio Tinto QMM, 2010).

Figure 1. **Map of Rio Tinto QMM project area, showing the three deposits (Mandena, Petriky, Ste Luce) and remaining littoral forest cover on the deposits in 1998.**



2 BACKGROUND

This section provides an overview of the environmental context for Rio Tinto QMM's operation in the Fort Dauphin region of southeastern Madagascar. It also summarises Rio Tinto's Net Positive Impact commitment and outlines the mitigation hierarchy, a conceptual tool used by Rio Tinto and others to think about impacts and mitigation measures. A large number of technical reports, scientific papers, a Social and Environmental Impact Assessment[6] (Rio Tinto QMM, 2001), a Biodiversity Action Plan (Rio Tinto QMM, 2010) and a 400-page monograph (Ganzhorn *et al.*, 2007. *Biodiversity, ecology and conservation of littoral ecosystems in southeastern Madagascar*) have been compiled by Rio Tinto QMM and the many scientists who have worked at the mine site and its environs. This section does not replicate this detailed information but rather gives a concise summary and directs the reader to sources where more detailed information can be found.

2.1 National and regional context

2.1.1 Madagascar

Madagascar is a global biodiversity hotspot with a rich and unique biodiversity that is subject to high levels of threat. It is home to 12–14,000 vascular plant species, 90% of which are endemic and found only at a few sites.

Madagascar is the fourth largest island in the world, covering 587,000 km^2, about the size of Texas or France. The country is a global biodiversity hotspot with a rich and unique biodiversity that is subject to high levels of threat (Mittermeier *et al.*, 2004). Madagascar is home to 12–14,000 vascular plant species, 90% of which are endemic and found only at a few sites (Mittermeier *et al.*, 2004). The island has 340 native species of reptile, including more than half the world's chameleon species (Raxworthy, 2003). There is almost 100% endemism among Madagascar's 222 amphibian species. The country is characterized by high rates of poverty, large rural populations, subsistence agriculture, and low levels of industry (Vincelette *et al.*, 2007a). It ranks amongst the poorest of the world's countries with per capita GDP estimated at US$221 in 2003 (Vincelette *et al.*, 2007a) and US$392 in 2010 (IMF, 2011).

2.1.2 Fort Dauphin region

The mine is situated near the town of Fort Dauphin in the Anosy region of southeastern Madagascar. This is one of the most ecologically diverse regions of Madagascar (Goodman and Ramanamanjato, 2007), but also one of the poorest and most isolated. Eighty-two per cent of Anosy inhabitants live below the poverty line (US1$/day) and the regional population is expected to double by 2020 (Vincelette *et al.*, 2007a). The low-level commercial economy is supported by just three main products—rice, sisal and lobster—and there is growing pressure on the environment from unsustainable subsistence use of natural resources (Vincelette *et al.*, 2007b)[7].

[6] This SEIA covers the Mandena site. SEIAs for the other sites (Petriky and Ste Luce) will be carried out in the future (and in advance of any mining activity at those sites).

[7] Further information on the national and regional context can be found in the Social and Environmental Impact Assessment (SEIA) (Rio Tinto QMM, 2001) and in Vincelette *et al.* (2007a).

2.2 Physical environment

The Fort Dauphin region is dominated by the Vohimena Mountains and a rolling coastal plain that extends down to the Indian Ocean. This plain is composed mainly of littoral sands (often mineralized) that form a series of low dunes terminating at the shoreline in a series of coastal lagoons. The regional climate is warm and humid, with occasional cyclones. Average monthly temperatures range from 26.9°C in January to 20.3°C in July. January is typically the wettest month and September the driest. Annual precipitation shows a steep gradient from Petriky in the south (the driest of the three sites) to Ste Luce in the north. Mandena, located between Petriky and Ste Luce, has a mean annual rainfall of about 1,600 mm.[8]

2.3 Biological environment

2.3.1 Habitats

Southeastern Madagascar contains a significant diversity of natural forest habitats within a complex topographic relief, with few parallels in any other region of the island. Forest types include coastal littoral forests on sandy substrates, humid forest habitats ranging from lowland to montane formations, dry forest and spiny bush. A diverse biota is associated with these habitats, many species and sub-species of which are locally endemic (Rio Tinto QMM, 2001; Goodman and Ramanamanjato, 2007). The north-south aligned Anosyenne Mountains act as a major barrier for weather systems reaching the island from the east. There are very abrupt ecotones[9] on the western flank of this chain on account of this rain shadow effect, including one of the most extreme known in the world on the western flank of the Anosyenne Mountain chain between parcels I and II of Andohahela National Park (Nussbaum *et al.*, 1999). Here, evergreen humid forest characteristic of the east coast mountain ranges merges into the spiny sub-desert scrub characteristic of southwestern Madagascar over a remarkably short distance of about 5 km. For those unfamiliar with Madagascan vegetation types, this is equivalent to a change from 'rainforest' to 'scrub or maquis-type' habitat, a change of structural and compositional magnitude with few parallels globally (Goodman and Ramanamanjato, 2007).

Southeastern Madagascar contains a significant diversity of natural forest habitats within a complex topographic relief, with few parallels in any other region of the island.

2.3.1.1 Littoral forest

A particularly important terrestrial habitat type found in the mining zone is littoral forest. Madagascan littoral forests are a sub-type of humid and sub-humid evergreen forest occurring on sandy substrates (Rabevohitra *et al.*, 1998; de Gouvenain and Silander, 2000). Littoral forest is notable for its high floristic diversity—although it originally occupied less than 1% of Madagascar's land surface, 13% of the island's total native flora has been recorded from this habitat type (Consiglio *et al.*, 2006). Littoral forest is thought once to have formed a

[8] For further information on geology, hydrology and climate in the Fort Dauphin region, see Vincelette *et al.* (2007c).

[9] An ecotone is a transitional area between two distinct habitats, where the ranges of the organisms in each bordering habitat overlap.

continuous 1,600 km strip along most of Madagascar's eastern seaboard, however only c.10% of this remains in the form of small fragments, with only 1.5% included within the existing Protected Areas network (Consiglio *et al.*, 2006).

Between 1950 and 2005 forest cover in the Fort Dauphin region further declined by over 50%.

Prior to human disturbance, the coastal region including the mining zone is believed to have been covered in coastal littoral forest (Lowry and Faber-Langendoen, 1991; Consiglio *et al.*, 2006; but see Virah-Sawmy, 2009). By 1950, when the first known aerial images of the area were taken, forest cover was already fragmented and patchy;[10] between 1950 and 2005 forest cover in the Fort Dauphin region further declined by over 50% (Vincelette *et al.*, 2007b).[11] At the present time, the mining zone is made up of littoral forest fragments of varying size and quality, interspersed with highly degraded vegetation, bare sand, agricultural and inhabited land, and stands of exotics (e.g. Eucalyptus sp.) and alien invasive tree species (e.g. *Melaleuca quinquenervia*) (Rio Tinto QMM, 2001; Vincelette *et al.*, 2007a; Rabenantoandro *et al.*, 2007).

In 2005, 3,128 ha of coastal littoral forest remained in the mining zone (Mandena, Petriky, and Ste Luce; Vincelette *et al.*, 2007b). Since only 47,900 ha of this habitat remain in the whole of Madagascar (Consiglio *et al.*, 2006), the mining zone's forests represent 6.5% of the residual area of this distinctive and highly floristically diverse habitat type.

2.3.1.2 Comparison of the three sites—Mandena, Petriky and Ste Luce

Dumetz (1999) classified the three southeastern forests (Mandena, Petriky and Ste Luce) as a unique sub-type of littoral forest on sand. Each of these three sites has distinct social, physical and ecological characteristics despite their close geographic proximity to one another (Ingram and Dawson, 2006).

One of the distinctive features of Ste Luce, by comparison with the two other sites, is that it contains relatively large tracts of littoral forest that remain in fairly good condition. For example, parcel S9[12] shows all the characteristics of nearly intact low elevation dense humid forest, with about 60% cover among trees that are 12 m or more in height, and a clearly stratified structure (Lowry and Faber-Langendoen, 1991; Rabenantoandro, 2001; Rabenantoandro *et al.*, 2007).

---

[10] The extent to which this is due to natural factors versus anthropogenic factors is debated in the literature (see e.g. Virah-Sawmy, 2009). The landscape in the Fort Dauphin region may well be naturally a mosaic habitat (Virah-Sawmy, 2009), but there is also evidence of anthropogenic loss and degradation dating from before the arrival of QMM (Vincelette *et al.*, 2007b; Virah-Sawmy, 2009), although this was potentially mainly caused by immigrants from other parts of Madagascar rather than by local people and may have been exacerbated by QMM's exploration-related activities since the 1990s (Ingram and Dawson, 2006; Virah-Sawmy, 2009).

[11] It is possible that, in more recent years, (e.g. 1990s and 2000s) the rate of loss has been exacerbated by the presence of the mining project. However, comparison of imagery from c.1950, 1972 and 1989 indicates that there was considerable loss of forest cover over this earlier time period (Figures 2 & 4 in Vincelette *et al.*, 2007; e.g. from c.7,000 ha in 1950 to c.4,500 ha in 1989).

[12] All parcels of littoral forest at Mandena, Petriky and Ste Luce have been mapped and given individual numbers.

At Mandena, the bioclimatic factors are nearly identical to those at Ste Luce, although precipitation is slightly less. However, remnant parcels of forest are smaller and in poorer condition, with lower canopy height, smaller trunk diameters and less stratification. The observed differences in structure found at Mandena indicate that the forest present there today is a degraded form of a vegetation type that is shared with Ste Luce. Located just 9 km north of the town of Fort Dauphin, Mandena has clearly been heavily impacted by humans. By comparison with Ste Luce, Mandena shows a striking lack of individual trees belonging to families that are widely used for their wood, such as Ebenaceae, Sapotaceae and Lauraceae. This is likely a reflection of the previous exploitation of economically valuable species (Rabenantoandro *et al.*, 2007).

Floristically and faunistically, Petriky can be interpreted as a transition between dry forest and humid littoral forest (Rabenantoandro *et al.*, 2007). Located at the extreme southern end of Madagascar's east coast, Petriky has species characteristic of humid formations, such as *Intsia bijuga* (Fabaceae), *Homalium axillare* (Flacourtiaceae), *Asteropeia multiflora* (Asteropeiaceae), and *Beilschmiedia madagascariensis* (Lauraceae) but differs from the other two sites through the presence of taxa typical of dry areas, including *Oplonia vincoides* (Acanthaceae), *Folotsia madagascariense* (Asclepiadaceae), *Deinbolia boinesis* (Sapindaceae) and *Cordia caffra* (Boraginaceae). Similarly, the fauna of Petriky shows clear affinities with those of dry forest areas in southwestern Madagascar (Ramanamanjato *et al.*, 2002). One other notable characteristic of the Petriky forest is the lack of members of the Arecaceae and Pandanaceae families, which are prominent in the Mandena and Ste Luce forests (Rabenantoandro *et al.*, 2007).

2.3.2 Species

2.3.2.1 Terrestrial species—vascular plants

Of the 614 vascular plant species and varieties recorded from remnant littoral forest in the mining zone, 83% are endemic to Madagascar, of which 54% are shared with low- and mid-elevation humid forests, 7% are restricted to southeastern Madagascar littoral forests,[13] 6% are restricted to scattered small remnants of regional littoral forests in the zone between Petriky and Manantenina, and 7% are found only in the mining zone (Rabenantoandro *et al.*, 2007).[14] The number of plant species strictly endemic to the mining zone currently stands at 42.[15]

2.3.2.2 Terrestrial species—vertebrates

About 168 species of reptiles and amphibians are found in the Anosy region, representing around a third of the total herpetofauna of Madagascar (Goodman and Ramanamanjato, 2007). Ninety-six of these are found in the mining zone.

---

[13] E.g. forests between Mananjary and Fort Dauphin.

[14] See Rabenantoandro *et al.* (2007) for further details and a complete vascular plant species list.

[15] The exact number changes over time as a result of research and taxonomic revisions.

Species richness is highest at Ste Luce (69 species), followed by Mandena (63) and Petriky (45) (Ramanamanjato, 2007).

The Fort Dauphin region exhibits a particularly high bird species richness, reflecting the exceptional habitat diversity in the Anosy region.

The Fort Dauphin region exhibits a particularly high bird species richness, reflecting the exceptional habitat diversity in the Anosy region. Goodman *et al.* (1997) listed 189 species occurring in the area south of Manantenina and east of the Mandrare River, representing 68% of the island's known avifauna at that time. Within the mining zone, Watson (2007) recorded 77 bird species in littoral forest fragments, and Watson *et al.* (2005) describe these fragments as holding a unique assemblage of avian species, including both humid and spiny forest-dependent species, a combination found nowhere else on the island. However, endemism[16] in the region is low—there is only one regional endemic, Bluntschli's Vanga *Hypositta perdita*, which has not been recorded in the mining zone (Goodman and Ramanamanjato, 2007; Watson, 2007).

The southeastern portion of the island has a rich small mammal fauna, owing to the varied habitats in the region and the high mountains of the Anosyenne and Vohimena Mountains. No endemic species of extant small mammal are known from the Anosy region. As with other groups of organisms, there are two principal gradients that show high levels of species turnover within this region: an east-west gradient from humid forests to dry forests and an elevational gradient, particularly in parcel I of the Parc National d'Andohahela, from lowland habitats to sclerophyllous forest in the higher areas. However, compared with other Malagasy forest types, the littoral forests are depauperate in large mammals. The Malagasy Ring-tailed Mongoose *Galidia elegans* and Malagasy Civet *Fossa fossana*, familiar inhabitants of many Madagascar ecosystems, are present. In addition, the Fossa *Cryptoprocta ferox*, the island's top predator, was recorded in Mandena for the first time in 2004. Both micro- and mega-chiropterans have been recorded in the project area. Several of the mega-chiropteran species roost at locations near the mining zone, and are believed to be important dispersers of seeds of the littoral forest. Additionally, the zone has an interesting collection of primate species. There is at least one restricted-range form of lemur, *Eulemur (fulvus) collaris* present in southeast Madagascar and within the mining zone.[17]

2.3.2.3 Terrestrial species—invertebrates

Invertebrate groups surveyed at the Rio Tinto QMM site to date include dragonflies (Odonata: Schütte and Razafindraibe, 2007), mantids (Mantodea: Schütte, 2007), stick insects (Phasmatodea: Schütte, 2007), giant pill-millipedes (Sphaerotheriida: Wesener and Wägele, 2007; Wesener, 2009), and spirobolid millipedes (Spirobolida: Wesener *et al.*, 2009).

---

[16] 'Endemism' here refers to Anosy regional endemics; see Goodman and Ramanamanjato (2007) for further details.

[17] For more details on the vertebrate species found at QMM's sites, see Ganzhorn (2007) and references therein.

Based on these surveys, the littoral forests within the mining zone at Mandena, Petriky and Ste Luce hold a diverse array of invertebrate species, including a number of species that are endemic or near-endemic to the mining zone.[18] The surveys resulted in the discovery and description of a number of new species, including the genus *Riotintobolus*.

2.4 Rio Tinto QMM project

The Rio Tinto QMM project will mine ilmenite ore as a mineral sand, to provide titanium dioxide to the world market. Titanium is a major ingredient in steels and other alloys; titanium dioxide is the white pigment found in most paints and plastics.

The Rio Tinto QMM project will mine ilmenite ore as a mineral sand, to provide titanium dioxide to the world market. Titanium is a major ingredient in steels and other alloys; titanium dioxide is the white pigment found in most paints and plastics. The Rio Tinto QMM project consists of three sites to be mined sequentially (Mandena, Ste Luce and Petriky) over a period of c.40–50 years. A new deepwater port has been constructed at Fort Dauphin. Ancillary infrastructure includes a dedicated port industrial zone, road networks, housing areas and a stone quarry. Ilmenite is mined using a dredge situated on artificial ponds that moves across the ore body as mining progresses; the mining process entails the removal of all vegetation cover along with the soil. Approximately 100 ha of the deposit will be mined each year; the mine itself occupies about 50 ha of land as it progresses slowly through the deposit area. Rehabilitation of the mined area will be carried out once the dredge has moved on to the next part of the deposit. The total mine footprint at all three sites collectively is about 8,000 ha. Ore processing is minimal and takes place on site through physical separation. Processed ore is transported by truck to the port for export.[19]

2.5 The Biodiversity Committee

A Biodiversity Advisory Committee was formed in 2001 to review the biodiversity strategy and conservation measures on the ground. It consists of biodiversity experts with extensive experience and global renown for their research in Madagascar. This committee currently comprises: Dr. Porter P. Lowry (Missouri Botanical Gardens); Prof. Jörg Ganzhorn, (Hamburg University); Prof. Alison Jolly (Sussex University); Dr. Rob Brett (Fauna & Flora International); Dr. Paul Smith (Royal Botanic Gardens, Kew); and Lisa Gaylord (Wildlife Conservation Society). Further details are given in **Appendix 1**.

2.6 Rio Tinto's NPI commitment

The goal of Rio Tinto's biodiversity strategy is a 'Net Positive Impact' (NPI) on biodiversity (Rio Tinto, 2004, 2008a). This means "minimising [sic.] the impacts of our business and contributing to biodiversity conservation to ensure a region ultimately benefits as a result of our presence" (Rio Tinto, 2008a). Rio Tinto's position on biodiversity is embedded in the company's land use stewardship standard (Rio Tinto, 2008b). The company's environmental approach is described in the policy document The Way We Work (Rio Tinto, 2009). The biodiversity

[18] For some of these species, there has been insufficient study conducted outside the mining zone to determine conclusively whether they are strictly endemic to the mining zone or more widespread.

[19] More information on the project can be found in the Social and Environmental Impact Assessment (Rio Tinto QMM, 2001) and at www.riotintomadagascar.com.

strategy was launched in 2004 at the IUCN World Conservation Congress in Bangkok. Since then, Rio Tinto's Chief Executive Officer, Tom Albanese, has reaffirmed the NPI policy in a number of subsequent forums including the 2008 IUCN World Conservation Congress in Barcelona. Rio Tinto's position statement and guiding principles on biodiversity are presented in **Boxes 2** and **3**.

The NPI goal means ensuring that Rio Tinto's actions have positive effects on biodiversity that not only balance but are broadly accepted to outweigh the inevitable negative effects of the physical disturbances and impacts associated with mining and mineral processing.

In simple terms, the NPI goal means ensuring that Rio Tinto's actions have positive effects on biodiversity that not only balance but are broadly accepted to outweigh the inevitable negative effects of the physical disturbances and impacts associated with mining and mineral processing. The company proposes to achieve this by:

- Avoiding unacceptable impacts on ecosystems.
- Reducing the impacts that may occur.
- Restoring impacted ecosystems.
- Compensating for residual impacts with offsets.
- Seeking additional opportunities to contribute to local conservation.

A key facilitator of the commitment to NPI is the development of comprehensive, simple, scientifically sound metrics to quantify losses and gains. The lack of such metrics has been a major reason for the lack of investment and enthusiasm by developers (public and private alike) to attempt measurement and full mitigation of biodiversity impacts (ten Kate *et al.*, 2004).

Box 1: Rio Tinto's position statement on biodiversity (from Rio Tinto, 2008a)

Rio Tinto recognizes that conservation and responsible management of biodiversity are important business and societal issues. Our goal is to have a net positive impact on biodiversity.

We are committed to the integration of biodiversity conservation considerations into environmental and social decision making in the search for sustainable development outcomes. We recognize that this might mean that we do not proceed in some cases.

We want to be biodiversity leaders within the mining industry, for the competitive advantage and reputational benefit this provides. Our performance on biodiversity conservation and management issues will create benefits for our business.

We are committed to:

- The identification of biodiversity values impacted by our activities.
- The prevention, minimization, and mitigation of biodiversity risks throughout the business cycle.
- Responsible stewardship of the land we manage.
- The identification and pursuit of biodiversity conservation opportunities.
- The involvement of communities and other constituencies in our management of biodiversity issues.

Box 2: Rio Tinto's guiding principles on biodiversity (from Rio Tinto, 2008a)

- Our goal is to have a net positive impact on biodiversity by minimizing the negative impacts of our activities and by making appropriate contributions to conservation in the regions in which we operate.
- We are committed to the conservation of threatened and endemic species and high priority conservation areas, and support local, national and global conservation initiatives.
- We will seek equity and the reconciliation of differing perspectives and ideals in biodiversity decisions and actions.
- We will enhance biodiversity outcomes through consultation, constructive relationships, and partnerships with key stakeholders.
- We will integrate the identification, evaluation, and management of biodiversity issues into the planning, decision making, and reporting processes throughout the business cycle.
- We will apply appropriate expertise and resources to biodiversity issues, building internal and external capacity where necessary.
- Subject to appropriate consent, we promote the collection, analysis, and dissemination of biodiversity information and knowledge.

2.7 The mitigation hierarchy (avoidance, minimization, restoration and rehabilitation, and biodiversity offsets)

The mitigation hierarchy is a conceptual framework for thinking about biodiversity risks and opportunities and developing appropriate responses.

The mitigation hierarchy (**Figure 2**) is a conceptual framework for thinking about biodiversity risks and opportunities and developing appropriate responses. Variations on the mitigation hierarchy were first developed around 2004 by Rio Tinto and others. It is now a well established model for private sector biodiversity management and conservation and has been adopted by a number of government initiatives and private sector organizations (McKenney and Kiesecker, 2010; TEEB, 2010). Proper use of the mitigation hierarchy means one must first seek to avoid impacts, then minimize, then restore, and finally only use offsets as an option to compensate for the residual impacts after all other options have been exercised (ten Kate *et al.*, 2004; Rio Tinto, 2008a). The meaning, scope and use of stages in the mitigation hierarchy are summarized in this section.

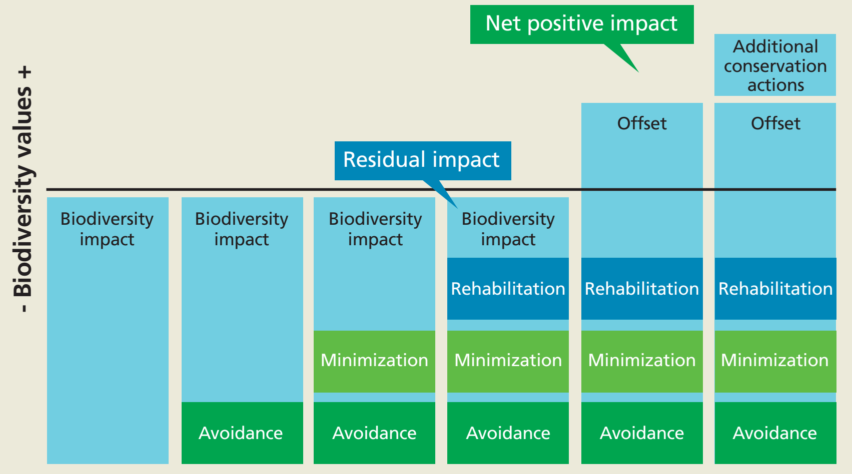


Figure 2. The mitigation hierarchy. From Rio Tinto and Biodiversity: achieving results on the ground (Rio Tinto, 2008a).

The biggest opportunity for avoidance is during project development—it is often possible to implement relatively cheap avoidance measures that significantly reduce impacts on biodiversity, thereby reducing future costs of restoration, offsets and closure.

Avoidance

Rio Tinto (2008a) defines 'avoidance' as activities that change the scope of impacts (reducing them, moving them, or avoiding them completely). Avoidance changes or stops actions before they take place, preventing their expected impacts on biodiversity. It involves a decision to change the expected or normal course of action. A real-world example can be found at Rio Tinto Simandou's iron ore project in southeastern Guinea where stockpiles and waste dumps have been relocated to avoid impacts on tropical forest; they are instead mainly being located in areas of relatively degraded savannah (a common habitat type in the region). The biggest opportunity for avoidance is during project development—it is often possible to implement relatively cheap avoidance measures that significantly reduce impacts on biodiversity, thereby reducing future costs of restoration, offsets and closure.

Minimization

'Minimization' reduces the severity of impacts on biodiversity that result from mining and associated activities[20] already underway. These actions reduce the likelihood or magnitude of biodiversity impacts, but cannot completely prevent them. It can sometimes be difficult to distinguish between avoidance and minimization because some actions have aspects of both. Improvements to the water quality treatment of outflows from mining areas, thereby reducing impacts on aquatic systems is a good example of minimization, while routing water outflows away from biodiversity-sensitive areas would qualify as avoidance.

[20] 'Mining and associated activities' include all activities required to find, mine and process minerals, at any stage of the mine life cycle from exploration to closure.

Rehabilitation and restoration

'Rehabilitation' involves the preparation of safe and stable landforms on sites that have been disturbed by mining and associated activities, followed by re-vegetation with the aim of establishing a specific habitat type. Rehabilitation is important for improving basic ecosystem functions such as erosion control and water quality regulation. 'Restoration' is a term generally used where the aim is to recreate a habitat type similar to the original vegetation type, including the targeting of some specific biodiversity features such as rare species.[21] The re-establishment of dune forest at Richard's Bay Minerals on recreated sand dune systems (following ilmenite sand mining) is an example of attempted restoration within Rio Tinto's portfolio (van Aarde *et al.*, 1996). For the purposes of NPI calculations, typically restoration can count towards achieving NPI[22] but rehabilitation cannot.

Offsets

Offsets are not employed in place of appropriate on-site avoidance and minimization measures, but rather seek exclusively to address the residual loss after mitigation.

Rio Tinto is committed to achieving a Net Positive Impact on biodiversity. Even with the best possible mitigation measures in place at business units, mining and associated activities will result in some level of residual impacts on biodiversity. Consequently biodiversity offsets are needed—conservation activities in the wider region that result in measurable biodiversity gains to compensate for these residual losses, resulting in a Net Positive Impact at the regional level.

Offsets are not employed in place of appropriate on-site avoidance and minimization measures, but rather seek exclusively to address the residual loss after mitigation. Offsets can achieve biodiversity 'gains' in two ways. They may reduce existing pressures and therefore losses to biodiversity (e.g. reducing background deforestation rates)—this is known as an 'averted loss offset'. Alternatively, they may directly enhance the state of biodiversity (such as through species re-introductions or habitat restoration).

Additional conservation actions

'Additional conservation actions' include a broad range of activities that are intended to benefit biodiversity, but where effects or outcomes are difficult to quantify in terms of biodiversity gains. Examples include scientific research, environmental education, and building capacity and expertise in conservation organizations. Although the biodiversity outcomes of these actions are difficult to measure, these kinds of intangible assets form an essential part of Rio Tinto's contribution to biodiversity conservation, often underpinning the success of other mitigation actions, and are often some of the most highly valued by interested stakeholders.

[21] E.g. see Society for Ecological Restoration International Science & Policy Working Group (2004).

[22] Partially successful restoration, or restoration that is in progress but has not yet reached its end goal, will be accounted for *pro rata* based on the extent to which biodiversity value has been restored. This can be taken into account using the Quality Hectares and Units of Global Distribution metrics. Restoration is very seldom (or never) '100% successful' in returning an area to a facsimile of its previous 'natural' state (or to the appropriate defined benchmark). Nevertheless, biodiversity gains from restoration attempts can be quantified.

3 METHODS

To obtain the information needed to determine if Rio Tinto QMM is on track to achieve NPI, the following steps were followed:

1. Identify and prioritize biodiversity features for inclusion in NPI accounting.
2. Decide which metrics to use.
3. Select the counterfactual scenario(s) against which to measure losses and gains.
4. Quantify biodiversity losses likely to be caused by Rio Tinto QMM in the periods 2004–2015 and 2004–2065.
5. Quantify biodiversity gains likely to be caused by Rio Tinto QMM in the periods 2004–2015 and 2004–2065.

Each of these five steps is summarized below.

3.1 Identify and prioritize biodiversity features for inclusion in NPI accounting

Biodiversity is complex and can be measured at many levels, but lacks a single uniform and globally fungible metric (in contrast with carbon, for example).

Biodiversity is complex and can be measured at many levels, but lacks a single uniform and globally fungible metric (in contrast with carbon, for example). In addressing this issue an attempt was made to identify metrics that were both practical to measure and reflective of the impacts associated with the development of the Rio Tinto QMM mining operation. This report therefore only considers losses and gains in terrestrial systems and in intrinsic/existence values of biodiversity. For the purposes of this study, this effectively means consideration of natural habitats and species.

Losses and gains in aquatic systems and in service values of biodiversity (biodiversity-based ecosystem services, livelihoods and cultural values) have been covered in previous reports and discussion papers, including Rio Tinto (2008c) and Rio Tinto QMM (2001, 2008); and several aquatic studies including Jacques Whitford Inc. (2007). Aquatic systems and service values are not considered further in the quantitative analysis presented here. Mitigation measures for these biodiversity features are detailed in the Biodiversity Action Plan (Rio Tinto QMM, 2010).

Potential losses and gains were measured for the following biodiversity features:

- *Habitats*—all forest; littoral forest and its sub-types (including Fort Dauphin-type littoral forest; losses and gains were measured individually for Mandena, Petriky and Ste Luce).
- *Species*—all High Priority terrestrial species listed in the BAP (restricted-*range*[23] and/or highly threatened[24] vertebrates, invertebrates and plants).

[23] 'Restricted-range' here includes site endemics and near-endemics, and possible site endemics.

[24] 'Highly Threatened' here includes species assessed as Critically Endangered or Endangered on the IUCN Red List.

For further information on how biodiversity features were identified and prioritized, refer to the QMM Biodiversity Action Plan (Rio Tinto QMM, 2010).

3.2 Decide which metrics to use

Quality Hectares are Rio Tinto's current metric for tracking progress towards the NPI target at the global and site levels.

Two metrics (or currencies) were used—*Quality Hectares (QH)* and *Units of Global Distribution (UD)*. Quality Hectares are Rio Tinto's current metric for tracking progress towards the NPI target at the global and site levels. A wide range of biodiversity values, including threatened species, rare habitats or non-timber forest products, may be expressed in terms of their quantity and quality. For example, 100 ha of forest in pristine condition would count as 100 Quality Hectares (100 ha × 100% quality = 100 QH), whereas 100 ha of fairly degraded forest at 40% 'optimum quality' would be expressed as 40 Quality Hectares (100 ha × 40% quality = 40 QH).

Units of Global Distribution are a novel metric, developed for this analysis, but conceptually related to Quality Hectares. A Unit of Global Distribution is equivalent to 1% of a species' global population[25] (or 1% of its global distribution,[26] in the event that population data are unavailable).[27] Units of Global Distribution are calculated as follows: if a species has a global population of 1,000 individuals, and 10 of those are killed, that would be a loss of 1% of the global population or 1 'Unit of Global Distribution' (UD). Similarly, if a species has a global distribution of 100 ha, and 1 ha of its distribution is lost as a result of habitat loss caused by mining, that would be a loss of 1% of its global distribution or 1 'Unit of Global Distribution' (UD).

A detailed discussion of both metrics is provided in **Appendix 2**.

Losses and gains were measured in Quality Hectares for all habitats considered. For species, losses and gains were measured in Units of Global Distribution. For a very small number of High Priority species it was not possible to measure losses and gains in UD as global range and/or population size could not be quantified. For these species, losses and gains were simply measured in hectares.

The UD metric provides additional information which is useful for making 'like-for-not-like' biodiversity offset comparisons. Most frequently, biodiversity offsetting involves 'like-for-like' or 'like-for-better' (also known as 'trading up') exchanges. For example, a like-for-like offset would occur when a loss of an area of a particular habitat type is offset by proportionately equal or greater gains in area in an essentially identical habitat type. A like-for-better offset might

[25] Calculated in number of mature individuals.

[26] Calculated in hectares.

[27] It should be noted that assuming such a link between distribution and population size may be particularly problematic for wide-ranging and nomadic species (it goes against ecological theory on population and range size). However, no such species are included in the present analysis. A precedent for making such a link is given in the Key Biodiversity Area guidelines (Langhammer *et al.*, 2007, p.65).

entail offsetting an area of low-value habitat (e.g. a very common habitat type harbouring no threatened species) with a greater area of higher-value habitat (e.g. a rare habitat type harbouring several threatened species). The Rio Tinto QMM project is particularly complex because it potentially involves like-for-not-like offsets, where the offset has different values to the area lost, but it is not always objectively possible to claim that the values of the offset site are greater.[28]

The relative values of different habitat types or biodiversity features (e.g. what constitutes 'trading up') are fundamentally societal and thus require subjective judgements and stakeholder consultation. In the case of Rio Tinto QMM, guidance would be given by a range of stakeholders including (but not restricted to) the Biodiversity Committee.[29]

3.3 Select counterfactual scenario(s) against which to measure losses and gains

When measuring losses and gains, a key factor to consider is the counterfactual scenario (or baseline) against which any loss or gain is measured. For Rio Tinto QMM, this is particularly significant because the project is located in an area which has experienced significant deforestation since at least the 1950s when the first aerial photographs of the region were taken (Du Puy and Moat, 1998; Vincelette *et al.*, 2007b).

Three counterfactual scenarios were considered in the present analysis:

- No mining and 'no deforestation'.
- No mining and a 'national average' deforestation rate for all forest types extrapolated from c.1990—c.2000 of 0.9% per year (Table 4 in Harper *et al.*, 2007).[30]

---

[28] For example, the Bemangidy offset is humid forest rather than littoral forest. QMM's target is 'Net Positive Impact on littoral forest', so in this specific case Bemangidy is a kind of 'insurance policy' against incomplete mitigation/offset success elsewhere because it contains many of the same species, but it is also a like-for-not-like offset.

[29] Such guidance has not been needed at QMM to date, because the Biodiversity Committee set a relatively strict 'like-for-like' target requiring that NPI is achieved for (i) littoral forest, and (ii) all priority species, individually. This target is described here as 'relatively strict' rather than 'very strict' because it could be argued that, for example, because 'Petriky-type littoral forest' is distinct from 'Mandena-type littoral forest' (Dumetz, 1999), NPI should be achieved at the level of these forest sub-types rather than for littoral forest as a whole. However the recommendation of the committee at the end of the May 2010 meeting was to measure NPI at the level of littoral forest sensu lato.

[30] Note that there is much evidence to show that historic deforestation rates do not necessarily reflect future deforestation rates. A number of REDD (Reducing Emissions from Deforestation and Degradation—another methodology where background deforestation rate is very important) projects around the world are moving away from using past baselines to predict future rates, to methods that that look at population density, roads, etc. to predict future deforestation. The issue of calculating background deforestation rates is one that would merit further consideration in future, as discussed in the 'Lessons learned' section.

- No mining and a calculated Fort Dauphin regional average deforestation rate extrapolated from c.1995—c.2005 of 3.89% per year. Regional average deforestation rate was calculated for the period 1995–2005 based on digitized aerial photographs using GIS[31].

Figure 3 shows how forest cover would be predicted to change from 2004 to 2065 for Scenarios 1–3 in remaining forest at Mandena, Petriky and Ste Luce. In 2004, there were 2,289 ha of littoral forest on the mining leases (Mandena, Petriky and Ste Luce), of which 1,665 ha fell under the mine path. Within the Avoidance Zones (AZs), 624 ha of littoral forest are protected.

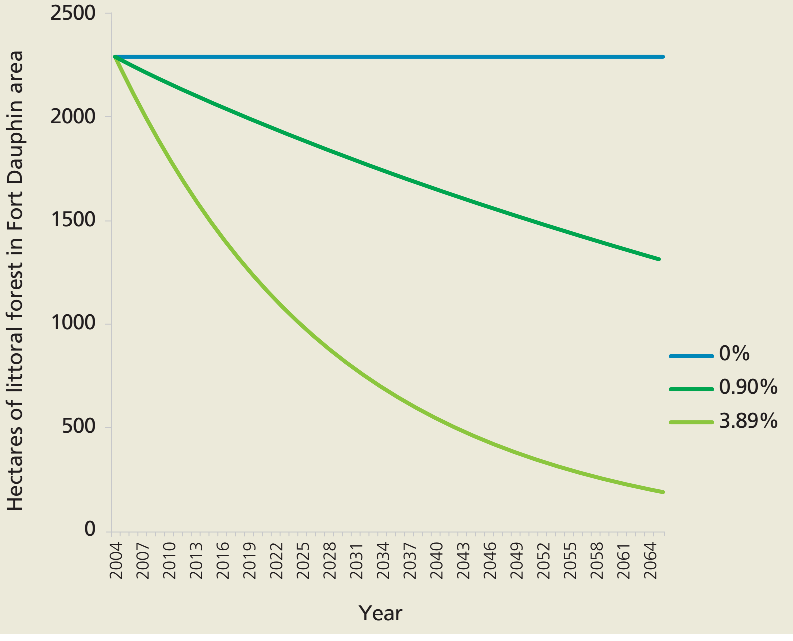


Figure 3. Predicted changes in littoral forest cover on the Rio Tinto QMM mining leases from 2004 to 2065, under three different annual deforestation rate scenarios—0% (no deforestation from 2004 onwards), 0.9% (Madagascar national average) and 3.89% (Fort Dauphin regional average).

The counterfactual scenario is a critical element of the NPI loss and gain calculations as it determines the magnitude of loss for which Rio Tinto QMM is considered to be responsible.

The counterfactual scenario is a critical element of the NPI loss and gain calculations as it determines the magnitude of loss for which Rio Tinto QMM is considered to be responsible (**Figure 4**). Point 'a' in **Figure 4** shows that if there had been no mine and if deforestation had continued at the Fort Dauphin regional rate of 3.89%, by c.2035 there would have been less forest remaining than the 624 ha that are currently protected in the Avoidance Zones.

[31] Note that although mining did not start until 2009, Rio Tinto QMM was active in the region during this period and its activities (e.g. road construction) may have facilitated access and indirectly resulted in elevated rates of forest loss.

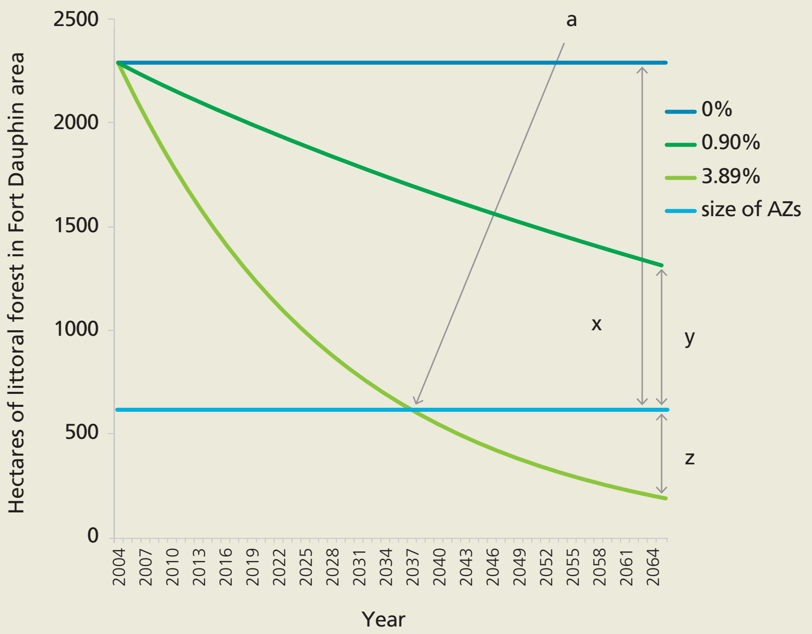


Figure 4. The three counterfactual scenarios considered. Distance x shows that, assuming no mitigation beyond Avoidance Zones (AZs), based on Scenario 1 (0% annual deforestation), Rio Tinto QMM would be responsible for the loss of 1,665 ha of forest by 2065, i.e. the whole area of forest on the ilmenite deposit (2,289 ha) minus the 624 ha protected within the AZs. Distance y shows that, based on Scenario 2 (0.9% annual deforestation: national average), Rio Tinto QMM would be responsible for the loss of 695 ha by 2065. Distance z shows that, based on Scenario 3 (3.89% annual deforestation: Fort Dauphin regional average), Rio Tinto QMM would be responsible for a net gain of 421 ha of forest by 2065 simply by putting in place the Avoidance Zones: the AZs protect an area of 624 ha of forest, whereas only 203 ha would be left by 2065 if forest loss continued at a rate of 3.89% per year. Point 'a' shows the point at which, under Scenario 3, net impact becomes positive based on AZs alone.

We suggest that out of these three possible counterfactual scenarios, Scenario 2—the conservative national deforestation rate of 0.9%—is the most appropriate baseline against which to measure NPI. To use a 0% deforestation rate baseline would be highly unrealistic, given the very high rate of deforestation that has occurred since 1950 and continues to occur in the local region. The 3.89% regional deforestation rate was not selected, partly to be precautionary, and partly because it is problematic to use a rate that may have been caused (at least in part) by the mine. For example, it is possible that prospecting activities undertaken by Rio Tinto QMM since the 1990s, including road construction, have indirectly facilitated the loss and degradation of the remaining forest (e.g. Ingram and Dawson, 2006; Virah-Sawmy and Ebeling, 2010). Based on aerial photographs from 1950, 1974 and 1989 (before the arrival of Rio Tinto QMM), the annual deforestation rate in the Fort Dauphin region was 1.1% per year (Vincelette *et al.*, 2007b). Thus, adopting the 1990–2000 national average (0.9%) as a baseline is conservative in comparison to this historical rate.

Furthermore, there is a view amongst some stakeholders that, given the occurrence of many site endemic and Critically Endangered plants and animals, it is possible that the remaining forests would have been designated a Protected Area at some point in the next decade or so.[32] If a protected area covering the whole of Mandena, Petriky and Ste Luce were to have been put in place in 2020 (and if that protected area was 100% successful in stopping forest loss), the forest cover would have stabilized at 1,213 ha (**Figure 4**), assuming a background rate of 3.89% annual loss. By comparison with this alternative scenario, Rio Tinto QMM would be considered responsible for the loss of 589 ha. Consequently this scenario is somewhat less conservative than Scenario 2 (under which Rio Tinto QMM is considered responsible for the loss of 695 ha). Following the same logic but assuming a 0.9% rate of loss, Rio Tinto QMM would be considered responsible for the loss of 1,356 ha. This is more conservative than Scenario 2, although Rio Tinto QMM would still be predicted to achieve NPI on the littoral forest under this counterfactual scenario.[33]

3.4 Quantify habitat losses for the periods 2004–2015 and 2004–2065

Losses caused by Rio Tinto QMM's mining activities were measured and predicted for littoral forest habitat, using the Quality Hectares metric.

Losses caused by Rio Tinto QMM's mining activities were measured (past losses) and predicted (future losses) for littoral forest habitat, using the Quality Hectares metric. Only primary impacts of Rio Tinto QMM's mining operations were quantified (e.g. loss of habitat directly caused by mining and associated activities such as building roads and other infrastructure). Secondary impacts (e.g. potential negative impacts caused by invasive alien species brought into the region by mine transport, increased human pressure on ecosystems caused by prospective in-migration) are difficult to measure and no attempt has been made to formally quantify them here. In Rio Tinto QMM's particular case, because there is so little littoral forest left in the Fort Dauphin region, it is almost all within Rio Tinto QMM's direct influence (e.g. part of the Avoidance Zones, the Ste Luce offset or the wider mining lease). Consequently Rio Tinto QMM has more influence over what happens in the whole region's littoral forest than would be typical of a mining operation in another area. Rio Tinto QMM has

[32] This view was expressed verbally by Porter P. Lowry at the QMM Biodiversity Committee meeting in May 2010.

[33] Under Scenario 2 (0.9% deforestation), net impact by 2065 is +350 QH of littoral forest. Under an alternative scenario of 0.9% deforestation per year to 2020, followed by Protected Area designation for Mandena, Petriky and Ste Luce forests and no further forest loss, the project would be projected to have a Net Positive Impact of c.+190 QH by 2065.

programmes to monitor and mitigate secondary impacts such as those described above; mitigation measures include those described elsewhere in this report such as planting fast-growing tree plantations to meet community needs for wood and fuel and to relieve pressure on littoral forest. Indeed, the success of Rio Tinto QMM's Avoidance Zones and offsets rests on the ability of Rio Tinto QMM (in partnership with local communities, government and other relevant organizations) to address these secondary impacts; without doing so it would be very difficult to slow or halt deforestation.

Losses were estimated by mapping forest extent and assessing forest condition at all three mining leases, and overlaying these maps with the predicted dredge path and any other mining infrastructure using GIS. Because no littoral forest condition index existed in Madagascar, Rio Tinto QMM developed a five-category scale of forest condition, based on a range of habitat structure variables that were measured in the field, particularly canopy cover (Vincelette *et al.*, 2007b). The five categories range from 'very good' to 'extreme deterioration' (**Figure 5**). The methodology for assessing forest condition is summarized in the following section (a full description can be found in Vincelette *et al.*, 2007b and Rabenantoandro *et al.*, 2007).

For Scenario 2 (no mining and national average deforestation rate of 0.9% per year) and Scenario 3 (no mining and a Fort Dauphin average deforestation rate of 3.89% per year), losses were adjusted to take into account the amount of forest that would have been remaining by 2065 under these counterfactuals. For Scenario 1 (0% annual deforestation), losses were not adjusted.

3.4.1 Assessing forest condition

The forest condition assessment method involves mapping all remaining littoral forest blocks (based on the interpretation of the most recent aerial photographs or satellite images) and establishing transects to cover each forest block with a 50 × 50 m grid. Sample points are established at the grid intersections. The following data are obtained at each sampling position within the grid: general condition of the forest; signs of cutting (stumps); openings; agricultural areas; fires; and observations of the vertical structure of the forest canopy level (upper, intermediary, or lower). Finally, the field observer evaluates percentage canopy cover at the sampling position.

There is a progressive decrease in canopy height and tree diameter at breast height (dbh) from Ste Luce to Mandena to Petriky; this is a natural feature of these areas that relates to climatic differences (e.g. Petriky sees markedly less rainfall than Ste Luce; Rabenantoandro, *et al.* 2007). For example, in the study plots sampled by Rabenantoandro *et al.* (2007), canopy height decreased from a mean of 14.7 m in Ste Luce to 4.4 m in Petriky. Consequently it was necessary to calibrate the method to reflect these intrinsic differences in stature, and so the reference ('100% optimal quality') was different for each of the three sites.

The forest condition assessment was first carried out in 1998; the method used in this assessment was verified by Missouri Botanical Garden, Royal Botanic Gardens, Kew and FOFIFA.

The forest condition assessment was first carried out in 1998; the method used in this assessment was verified by Missouri Botanical Garden (MBG), Royal Botanic Gardens (RBG Kew), and FOFIFA[34] (Lowry *et al.*, 2001). The forest condition assessment was updated and improved based on new field data and Quickbird images obtained in 2005 and by adding information from other studies on the level of deterioration of a given block, dendrometric criteria, and floristic composition (Henderson, 1999; Ingram and Dawson, 2005, 2006; Ingram *et al.*, 2005a, 2005b).

The analysis presented in the present report is based on the updated 2005 habitat condition assessment. **Figure 5** shows the results of the 2005 forest condition assessment.[35]

3.5 Quantify habitat gains for the periods 2004–2015 and 2004–2065

Measurable biodiversity gains can be generated either by increasing quality or quantity (or both) of a given biodiversity value, for example a habitat type. The key factor in each case is *additionality*—there must be a measurable increase in quality or quantity *that can reasonably be attributed to actions taken by Rio Tinto QMM.*

Three types of biodiversity gains are considered in the present analysis—**quality gains and averted deforestation** in the Avoidance Zones, **restoration** on post-mining land, and **averted deforestation** at the biodiversity offset sites.

3.5.1 Restoration

At Rio Tinto QMM, restoration entails the replacement of natural habitat surrogates following the completion of the mining process. Strictly speaking, restoration on post-mining land does not represent a true gain in biodiversity value, but instead reduces loss of biodiversity compared to a scenario where no post-mining restoration was to take place, or a monoculture habitat was returned post-mining. However for the sake of simplifying the loss-gain calculation we treat post-mining restoration as a biodiversity gain.

Restoration gains were calculated in terms of Quality Hectares (area × quality), assuming that by 2065 habitat will have been restored to 35% of optimal quality at Mandena, 25% of optimal quality at Ste Luce and 20% of optimal

---

[34] The National Centre for Applied Research into Rural Development, www.fofifa.mg.

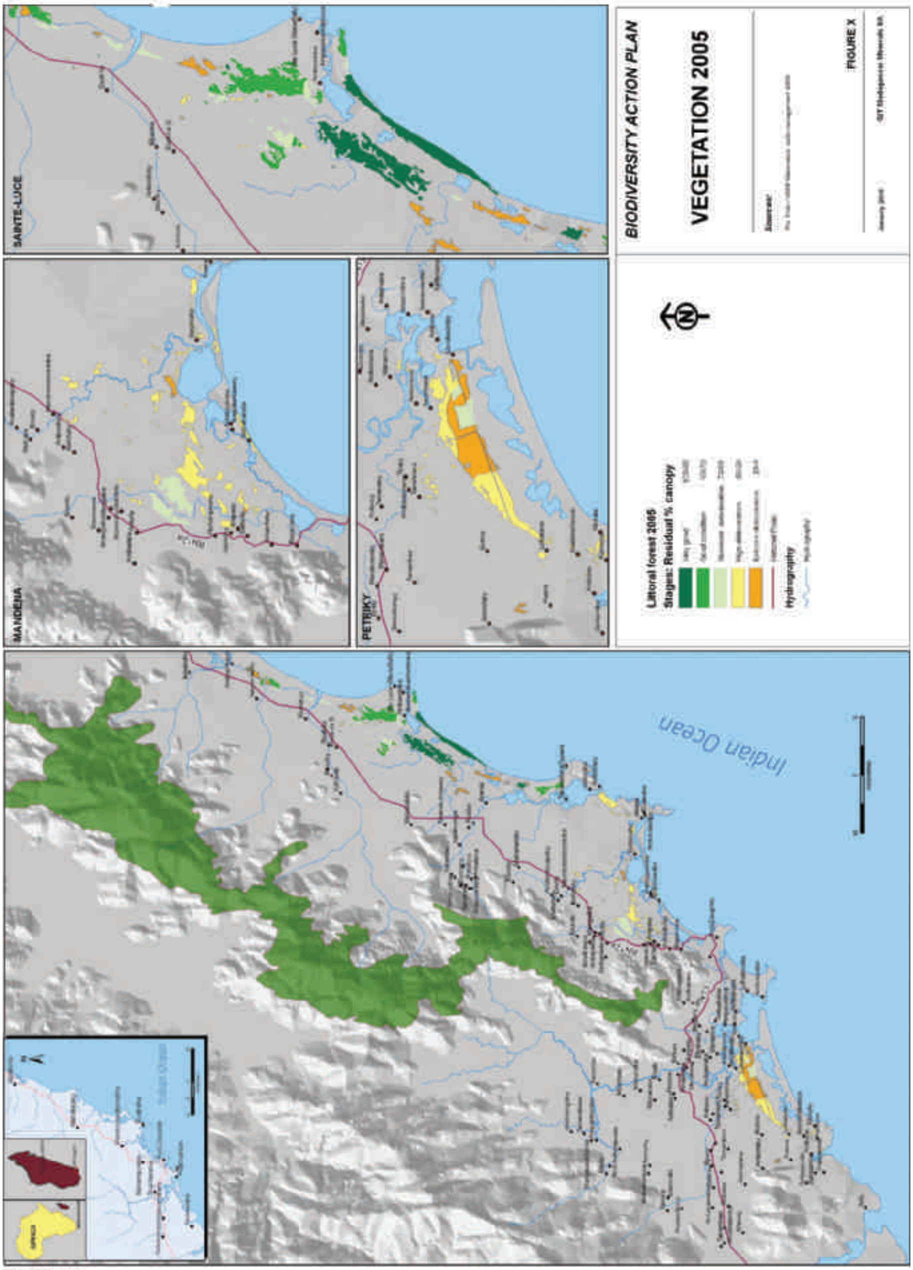
[35] Note that, in an earlier draft version of this analysis, a map showing forest cover and condition in 1998 was erroneously included. However, the analyses presented in this report (and in previous draft versions of the report) are based on forest condition assessment data from 2005.

quality at Petriky.[36] This was estimated with reference to the littoral forest quality measures developed by Vincelette *et al.* (2007b). Predictions of future forest quality were made in consultation with botanical experts from RBG Kew and Missouri Botanical Garden, along with Rio Tinto QMM's in-house botanists. The predictions took into account experience from restoration field trials carried out since 1999 (Vincelette *et al.*, 2007d).

These quality estimates are conservative, taking into account some uncertainties that exist around restoration of Madagascan littoral forest. They are based on the assumption that restoration at Mandena will start in c.2020, at Petriky in c.2030 and Ste Luce in c.2035 (this is possible because Rio Tinto QMM is a dredge mine; restoration can start on post-mining areas while mining is still ongoing elsewhere on the site). They are also based on the assumption that restoration at Petriky will be more difficult and quality gains will accrue more slowly (this is the advice of botanical experts; Petriky is significantly more arid and trees establish with greater difficulty and grow more slowly).

[36] These assumptions about forest quality in 2065 were based on discussion with M. Vincelette, J. Rabenantoandro and F. Randriatafika (who have been running littoral forest restoration trials for 10+ years), experience of success to date with the field trials, and consultation with botanical experts on the biodiversity committee (Porter P. Lowry and Paul Smith). The intention is to err on the side of caution as littoral forest restoration has never been attempted before.

Figure 5. Littoral forest extent and condition at Rio Tinto QMM in 2005.[37]



RioTinto

[37] Note that, in an earlier draft version of this analysis, a map labelled as showing forest cover and condition in 1998 was erroneously included. However, the analyses presented in this report (and in previous draft versions of the report) are based on the forest condition assessment data for 2005, which according to Vincelette *et al.* (2007) take into account the work of Henderson (1999), Ingram and Dawson (2005, 2006), and Ingram *et al.* (2005a, 2005b).

3.5.2 Quality gains in the Avoidance Zones

The Avoidance Zones reduce the amount of habitat lost, by protecting areas of forest on top of the deposit that would otherwise have been cleared for mining. However, if Rio Tinto QMM carries out conservation activities that improve the quality of the littoral forest in the AZs, it is valid to count this as a biodiversity gain.

The Avoidance Zones reduce the amount of habitat lost, by protecting areas of forest on top of the deposit that would otherwise have been cleared for mining.

Although the Avoidance Zones were situated to protect the best-quality habitat remaining at Mandena, Petriky and Ste Luce, the habitat quality at each AZ site varies considerably and is often far from pristine. In 2004, average quality scores were 0.57 for forest fragments in Mandena AZ, 0.39 for Petriky AZ and 0.80 for Ste Luce AZ (**Figure 5**). Consequently there is significant scope for the quality to be improved, generating gains in QH. This will be achieved through appropriate habitat management and by relieving pressure from local human populations by *inter alia* providing plantations[38] of fast-growing non-native[39] trees outside the Avoidance Zones for charcoal production and providing alternative livelihoods. Quality scores were predicted to increase by 0.1 every 15 years in the Mandena and Ste Luce AZs and by 0.05 every 15 years at Petriky.[40, 41]

3.5.3 Averted deforestation gains (long-term protection of Avoidance Zones and biodiversity offsets)

Averted deforestation (also known as 'averted loss') generates biodiversity gains both at Rio Tinto QMM's biodiversity offset sites (Mahabo, Bemangidy, Ste Luce Forests) and in the Avoidance Zones (Mandena, Ste Luce and Petriky AZs). Mahabo, Ste Luce, Mandena and Petriky all contain littoral forest.

It is important that 'averted deforestation' is not confused with 'avoidance'. The Avoidance Zones (AZs) are, as their name implies, primarily an avoidance measure—they represent a significant area of the deposit (c.8% of total ilmenite, and 27% of remaining forest on the deposit) foregone in order to protect habitat and in particular to save certain locally endemic species from extinction.

[38] These plantations will principally be located in areas that have been cleared for mining, after the dredge has passed (dredge mining moves steadily through the landscape, so such areas will be available from an early stage in the project). We say 'principally' rather than 'entirely' because some plantation has been established already as there is a pressing need among local communities for wood; these plantations were sited taking into account the conservation value of the existing landscape as well as human needs. There has been and will be no additional clearance of littoral forest to site these plantations.

[39] Both native and non-native tree species (including littoral forest species, species from elsewhere in Madagascar, and exotic species that were already found in the Fort Dauphin area) were included in rehabilitation trials (Rarivoson and Mara, 2007; Vincelette *et al.*, 2007), but ultimately the decision was made to use non-natives.

[40] The rates of improvement in quality score were estimated based on discussion with M. Vincelette, J. Rabenantoandro and F. Randriatafika, and informed by progress with restoration trials to date. Restoration trials started in earnest in 1999 (field observations and less formal experiments related to littoral forest restoration had been ongoing since 1992), details can be found in Vincelette *et al.* (2007d). These estimates were discussed and agreed with the Biodiversity Committee (in particular Paul Smith [RBG Kew] and Porter P. Lowry [MBG]) at a workshop in Fort Dauphin, Madagascar, in May 2010.

[41] In comments on an earlier draft of this analysis, Paul Smith (RBG Kew) noted that "This is quite conservative. But better to err on the side of caution."

However, had Rio Tinto QMM not taken active steps to protect the AZs, the forest within them would have continued to decline at the same rapid rate as before due to pressure from local human populations, particularly for charcoal production. Consequently, over time, this averted deforestation is effectively an additional measurable gain (in the two scenarios where a shifting baseline of 0.9% or 3.89% background annual deforestation rate is used; in the scenario of 0% background deforestation on the mining leases there are no gains from averted loss in the AZs).

By implementing active conservation measures at offset sites and providing alternative livelihoods to local communities, this high rate of deforestation can be decreased.

The background rate of deforestation in the project area and surrounding region is high. By implementing active conservation measures at offset sites and providing alternative livelihoods to local communities, this high rate of deforestation can be decreased, and consequently the area of forest remaining after one year (or 50 years) is greater than would have been the case if the offset sites had not been brought under conservation management.

Gains accruing through averted deforestation were estimated based on the assumption that the background deforestation rate will be reduced by 50% through Rio Tinto QMM's conservation activities in the period 2004–2065. For example, in the case of a 1,000 ha forest that had been declining at a rate of 2% per year prior to 2004, one could assume an averted loss of 10 ha in the first year (1000 ha × (0.02/2)).

Gains were calculated in an analogous way to compound interest on a bank account, as follows.

Gains from averted loss were calculated as:

$$G = [x \times (1-0.5y)^{z}] - [x \times (1-y)^{z}]$$

Where G = gains; x = QH at a site; y = background deforestation rate and z = years of intervention.

For example, from 2004–2015 (11 years of intervention), gains would be:

$$G = [x \times (1-0.5y)^{11}] - [x \times (1-y)^{11}]$$

However, if at one site interventions were only started in 2011, then from 2004–2015 there would be eight years of 'business as usual' and three years of conservation intervention, and so gains would be:

$$G = [x \times (1-y)^{8} \times (1-0.5y)^{3}] - [x \times (1-y)^{11}]$$

For the Avoidance Zones, which are under Rio Tinto QMM's direct management and subject to intensive management, it was estimated that the deforestation rate would be reduced by 100%—i.e. no further area would be lost. For the Ste Luce Forests offset, which is under Rio Tinto QMM's direct influence (unlike the other offset sites), it was estimated that deforestation could be reduced by 75%.

3.5.4 Credit claims

A number of Rio Tinto QMM's offset sites are co-funded by other organizations. To ensure that credit is apportioned appropriately, the following rule was used in these analyses when calculating biodiversity gains attributable to Rio Tinto QMM:

> If Rio Tinto QMM leads on a particular project and starts it up and maintains it, 100% of the resulting gains can be claimed. However, if Rio Tinto QMM joins and co-funds a pre-existing project being led by another organization, benefits are only attributed on a pro rata basis proportionate to investment.

This rule attributes gain in proportion to investment, whilst also providing an incentive to make the first move. Following this rule Rio Tinto QMM is able to claim 100% of gains at all offset sites except for Mahabo, where conservation measures had been started with funding from Missouri Botanical Gardens prior to the involvement of Rio Tinto QMM. In the case of Mahabo, annual management costs are c.US$65,000, of which 63% is provided by Rio Tinto QMM—consequently 63% of the annual biodiversity gains from the site can be attributed to Rio Tinto QMM (assuming the same proportion of investment continues in future).

3.6 Calculating species losses and gains for the periods 2004–2015 and 2004–2065

For species included in the analysis, losses and gains were calculated in Units of Global Distribution.

For species included in the analysis (High Priority species as defined in the Biodiversity Action Plan), losses and gains were calculated in Units of Global Distribution (UD). For most species, losses and gains were initially calculated in hectares. Each High Priority species was coded by occurrence at the following sites: Mandena, Petriky, Ste Luce Deposit, Ste Luce Avoidance Zone, Ste Luce Offsets (Ste Luce was sub-divided in this way because it is a larger site, and some species occur in e.g. the Ste Luce Offsets but not the other two sub-sites), Mahabo and Bemangidy. Area of distribution on the mining leases, and concomitant losses, were calculated assuming that a species was found throughout the whole surface area of forest at any site at which it occurred. Custom estimates of predicted loss, based on detailed field mapping and population estimates, were made for four locally endemic plant species at Petriky that were known to have particularly patchy or restricted distributions, such that this assumption would not be valid.[42] Custom estimates of predicted loss were also made for the Critically Endangered gecko *Phelsuma antanosy*.

To convert losses and gains in hectares to Units of Global Distribution, the total global Area of Occupancy (AOO) was estimated for all species. Different methods were used to estimate global AOO depending on the taxonomic group under consideration and the information available. For locally endemic plants, global distribution area was calculated based on the total area of known sites for most species[43] and custom estimates for certain Petriky species. For most birds, mammals, and amphibians, Extent of Occurrence (EOO) was measured based on the polygon area of GIS distribution maps from the IUCN Red List of Threatened Species (IUCN, 2009), and AOO was inferred as 10% of EOO (this is a very rough approximation that will not hold in all cases; the 10% relationship between AOO and EOO is implied by the thresholds set for Criterion B of the IUCN Red List). For some birds, mammals and amphibians, a more detailed estimate of AOO is given in the IUCN Red List (2009); this was used where available. For reptiles, estimates were based on draft maps provided by R. Jenkins and prepared for the January 2011 IUCN Global Reptile Assessment workshop held in Madagascar. For a very small number of High Priority species, it was not possible to measure losses and gains in UD as global range and/or population size could not be quantified based on existing data. For these species, losses and gains were simply measured in hectares.

[42] *Eligmocarpus cynometroides, Eulophia filifolia, Myrtus madagascariensis,* and *Peponium poissonii.* Note that *E. filifolia* may have recently been found at Mahabo (C. Birkinshaw pers. comm. 2010), but is precautionarily retained as a local endemic in the present analysis.

[43] This is arguably too generic a use of the term 'area of occupancy', which has a very specific definition in the IUCN Red List guidelines, and a different term might be more appropriate. The intention here is to provide an approximation, albeit rough, of the size of the distribution area where a species is actually found; it is well known that broad measures such as extent of occurrence typically overestimate (sometimes vastly so) the area occupied by each species (Jetz, Sekercioglu and Watson, 2008; Rodrigues, 2011).

4 RESULTS

4.1 Is Rio Tinto QMM on track to achieve a Net Positive Impact on biodiversity for the period 2004–2065?

4.1.1 Summary

Biodiversity losses and gains were calculated in two ways: using Quality Hectares and Units of Global Distribution.

Biodiversity losses and gains were calculated in two ways: using Quality Hectares as a metric (for forest, littoral forest and littoral forest sub-types); and using Units of Global Distribution as a metric (for High Priority species, i.e. Highly Threatened and restricted-range species).

Three offset sites were included in the quantitative analysis—Ste Luce Forests, Mahabo and Bemangidy. Two of these sites (Ste Luce Forests and Mahabo) already have active conservation programmes, the third (Bemangidy) has a draft management plan and is awaiting confirmation as an offset from Rio Tinto QMM and the Biodiversity Committee.

Two further sites (Ambatotsirongorongo and TGK I Direct Payments Project) have had active conservation projects, but are currently under review regarding whether they should be maintained as offset sites in the future. In the case of Ambatotsirongorongo, work at the site will continue in future[44], although this may be formally classed as an additional conservation action rather than an offset within the Rio Tinto mitigation hierarchy (in this case because of the high risk that even well-managed conservation projects may not deliver measurable biodiversity gains because of the very great pressure that the site is under – Ambatotsirongorongo is very small, fragmented, and degraded as a result of pre-existing threats). Consequently, these two sites have not been included as offset sites in the quantitative analysis presented here. Further details on each of the offset sites are given in the discussion.

Losses and gains were therefore calculated based on the following assumptions:

- Rio Tinto QMM will maintain three offset sites: Mahabo, Bemangidy and Ste Luce Forests.
- 225 ha of restoration will be carried out at Mandena, Petriky and Ste Luce, respectively (775 ha in total).
- Avoidance Zones at Mandena, Petriky and Ste Luce will be maintained and enhanced.[45]

[44] Rio Tinto QMM is currently contributing to two projects at Ambatotsirongorongo: a natural resources management project with UNDP and the local NGO FAFAFI; and a management plan for the Critically Endangered gecko *Phelsuma antanosy* with Fauna & Flora International and the national NGO Voakajy.

[45] 'Enhanced' means enhanced in quality rather than increased in area. This may involve e.g. enrichment planting of High Priority plant species, where this is deemed appropriate by botanical experts.

Additionally, a series of drop-out analyses were carried out to examine the impact on NPI of partial or total failure of restoration or offsets (e.g. removing the offsets component from the analysis or greatly reducing the magnitude of projected gains, and seeing whether NPI could still be reached based on restoration and Avoidance Zone gains alone). Rio Tinto QMM does not envisage that the restoration, Avoidance Zones or offset sites will fail, but it is important to consider this possibility when forecasting to ensure that there is a sufficient buffer to secure NPI even in the case of partial failure.

Based on the portfolio of offsets, restoration and Avoidance Zones described above, for the period 2004 to 2065 (the latter being the current mine closure date), Rio Tinto QMM is predicted to have a Net Positive Impact on the forests in general, and on the littoral forest in particular.

Loss of littoral forest caused by direct impacts of mining is predicted to be -428 QH. Total gain of littoral forest is predicted to be +778 QH. Consequently net impact is positive, at +350 QH, and the ratio of gain to loss (or compensation to impact) is approximately 2:1. Considering all forest types, loss remains constant at -428 QH; gain in all forest types (including Bemangidy humid forest) is +1,679 QH. In this case the ratio of gain to loss (or compensation to impact) is approximately 4:1. This information is particularly relevant given discussion in the biodiversity offsetting community around multipliers (BBOP Multipliers Consultation Working Group, 2008).

In terms of Units of Global Distribution, there is predicted to be a Net Positive Impact on all High Priority plants (54/54 species) and most High Priority animals (29/36) over the same time period.

Thus, if Net Positive Impact is to be achieved by 2065 overall, urgent research and action are necessary to mitigate the residual impacts on the remaining seven animal species, along with efforts to ensure the continued implementation of current mitigation measures for the rest of the region's species and habitats.

Table 1. Predicted net impact of Rio Tinto QMM for the period 2004–2065, based on Scenario 2 (0.9% annual deforestation rate, equivalent to the Madagascar average).

		2004-2065
Quality Hectares	1. All forest	+1,251
	2. Littoral forest	+350
	3. Fort Dauphin littoral forest (including Mandena, Petriky, Ste Luce; excluding Mahabo)	+216
Units of Global Distribution	1. All High Priority species	83/90 positive
	2. Priority plants only	54/54 positive
	3. Priority animals only	29/36 positive

4.1.2 Impacts on habitats—Quality Hectares

4.1.2.1 Results for 2004–2065

The results of this NPI forecast show that, in terms of Quality Hectares, Rio Tinto QMM is predicted to have a Net Positive Impact in the period 2004–2065, based on the conservative national average deforestation rate of 0.9% per year. Net Impact is predicted to be positive for littoral forest (Mandena, Petriky, Ste Luce and Mahabo; **Table 2**, **Figure 6**), and for all forest types combined (i.e. including the humid forests of the Bemangidy offset) (**Table 2**, **Appendix 3**).

Net impact on littoral forest is forecast to be +350 QH in 2065 (**Table 2**), representing an increase of 13% by comparison with 2004, when there were 2,747 QH of littoral forest in Fort Dauphin (Mandena, Petriky and Ste Luce) and Mahabo, collectively.

A similar result is seen if the analysis is simply based on hectares of littoral forest rather than Quality Hectares—in this case, by 2065, the net impact is an increase of 205 ha (an increase of 5% by comparison with 2004 forest cover, which was 4,352 ha in Fort Dauphin and Mahabo).

As can be seen in **Figure 6**, a similar magnitude of gains in QH is generated by restoration (collectively), averted loss in Avoidance Zones (collectively), quality gains in the Avoidance Zones (collectively) and averted loss in the Ste Luce and Mahabo offsets. Gains at Bemangidy are predicted to be of significantly greater magnitude; however as this is humid forest it is not a like-for-like offset for littoral forest (although there is significant overlap of species, c.50% for plants: Rabenantoandro *et al.*, 2007).

Based on the results per site presented in **Table 2**, it is possible to calculate net position for any individual site or combination of sites. For example, Petriky on its own (which is distinct from Mandena and Ste Luce, see Section 3.3.1.2), is forecast to be at a net position of -9 QH in 2065. Looking at Mandena, Ste Luce and Petriky together but excluding Mahabo (which may be relevant from a conservation perspective as Dumetz, 1999, classified these three forests as a unique type of littoral forest on sand), net position in 2065 is forecast to be +216 QH.

Table 2. **Losses and gains in QH predicted for 2004–2065 for each category of loss and gain and by forest type, based on counterfactual Scenario 2 for the Fort Dauphin region (i.e., 0.9% annual deforestation rate, equivalent to the Madagascar average).**

Type of loss/gain	Site	QH of forest lost / gained	Hectares of forest lost / gained
LOSSES	Mandena mining	-23	-208
LOSSES	Petriky mining	-98	-425
LOSSES	Ste Luce mining	-307	-417
RESTORATION GAINS	Mandena restoration	79	225
RESTORATION GAINS	Petriky restoration	45	225
RESTORATION GAINS	Ste Luce restoration	56	225
AVERTED LOSS IN AZs	Mandena Avoidance	56	97
AVERTED LOSS IN AZs	Petriky Avoidance	20	51
AVERTED LOSS IN AZs	Ste Luce Avoidance	92	116
INCREASED QUALITY IN AZs	Mandena Avoidance	92	0
INCREASED QUALITY IN AZs	Petriky Avoidance	24	0
INCREASED QUALITY IN AZs	Ste Luce Avoidance	56	0
AVERTED LOSS IN OFFSETS	Ste Luce Offset	124	147
AVERTED LOSS IN OFFSETS	Mahabo (littoral forest)	134	168
AVERTED LOSS IN OFFSETS	Bemangidy (humid forest)	901	1001
	Total all forest types	**1251**	**1206**
	Total Fort Dauphin littoral forest	**216**	**37**
	Total littoral forest habitat type (Mandena, Petriky, Ste Luce and Mahabo)	**350**	**205**

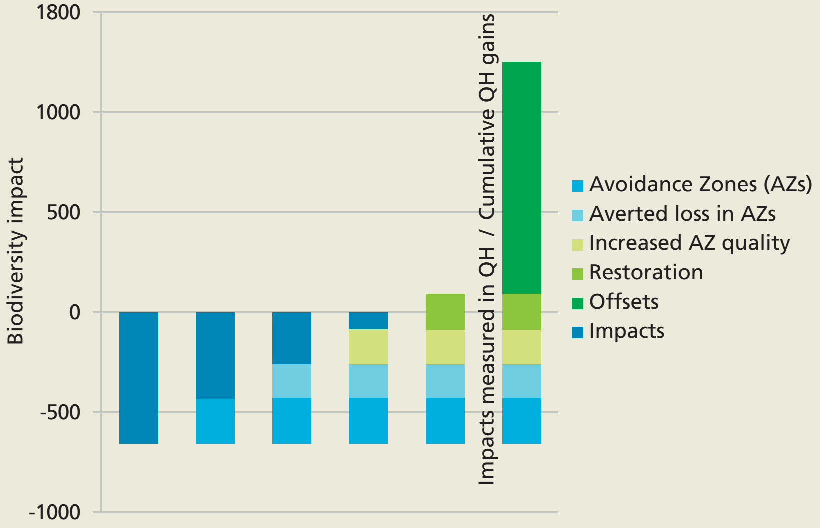


Figure 6. **Losses and gains of Quality Hectares of forest for the period 2004–2065. Note that 'offsets' includes both the littoral forest offsets of Ste Luce and Mahabo (+259 QH) and the humid forest offset of Bemangidy (+901 QH).**

4.1.2.2 Alternative scenarios

As explained in the discussion of the Methods, one assumption that makes a significant difference to the outcome of the NPI analysis is the background deforestation rate used for the Fort Dauphin region. The Madagascar national average from c.1990 – c.2000 (0.9% annual deforestation) was selected as the most appropriate precautionary baseline against which to forecast and measure Rio Tinto QMM's performance against the goal of reaching NPI.

One assumption that makes a significant difference to the outcome of the NPI analysis is the background deforestation rate used for the Fort Dauphin region.

However, in order to fully understand the implications of selecting this baseline, alternative baselines were analysed for comparison. Littoral forest QH was calculated looking at three different scenarios: 0%, 0.9% (national average) and 3.89% (Fort Dauphin regional average 1995–2005). The method used was the same in each case (e.g. see Appendix 3; to recalculate NPI for different scenarios, the background deforestation rate for Mandena, Petriky and Ste Luce was changed; all other variables remained the same). Additionally, a scenario of 0.1% was calculated to clarify the relationship between NPI and deforestation rate, which is non-linear (**Figure 7**).

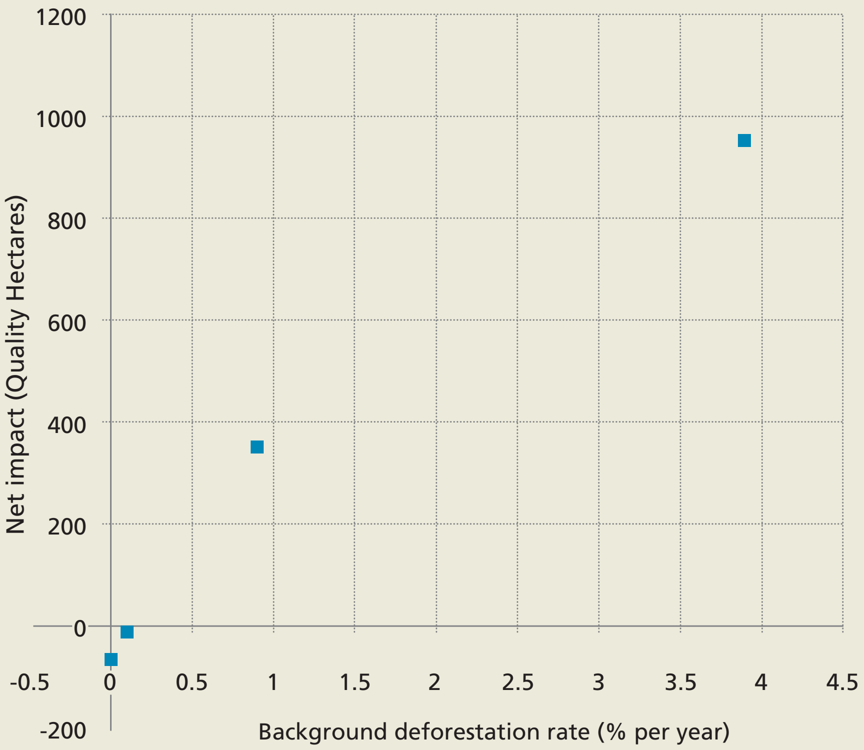


Figure 7. NPI forecast (net impact for 2004–2065) based on different presumed background annual deforestation rates (0%, 0.1%, 0.9%, 3.89%) for the Fort Dauphin region.

As can be seen in **Figure 7**, net impact from 2004 to 2065 is negative (-68 QH) if the background deforestation rate for the Fort Dauphin region is set at zero. This represents a reduction in littoral forest QH of 2% by comparison with 2004 levels. However, as soon as it is assumed that even a small degree of forest loss is likely to have occurred in the absence of Rio Tinto QMM between 2004 and 2065 (between 0.1% and 0.2%; the point shown just below the x axis on **Figure 7** is based on a background rate of 0.1%), net impact becomes positive. At the 1995–2005 measured regional background rate (3.89%), the Rio Tinto QMM project would have a major positive impact (952 QH, representing an increase of 35% by comparison with the 2004 littoral forest QH).

4.1.2.3 Risk of failure of offsets or restoration

A series of drop-out analyses was carried out to examine the impact upon NPI at 2065 of total or partial failure of offsets or restoration to deliver measurable gains. This could happen, for example, if external factors outside Rio Tinto QMM's control caused the deforestation rates at the off-site offsets to remain as high as before 2004 (e.g. major political or socio-economic problems that rendered Rio Tinto QMM and its partners' best conservation efforts ineffectual in reducing deforestation). In the case of restoration, no other organization has ever attempted to restore littoral forest and, although Rio Tinto QMM has made significant investment in research and restoration trials over the past 10 years, with good progress, there is a risk that restoration may not deliver even the conservatively estimated gains forecast by the present analysis. All drop-out analyses were based on a precautionary shifting baseline (0.9% annual deforestation rate, the Madagascar average).

If restoration completely fails, the net impact at 2065 is forecast to be +170 QH of littoral forest (a gain of 6% by comparison with 2004). If both off-site offsets (Mahabo and Bemangidy) fail, the net impact at 2065 is forecast to be +216 QH of littoral forest (a gain of 8% by comparison with 2004).

However, if both restoration and offsets fail completely (and only the Avoidance Zones are successful), the project would have a net negative impact of -88 QH (3% loss).

4.1.3 Impacts on species—Units of Global Distribution

4.1.3.1 Results for 2004–2065

Biodiversity losses and gains were also calculated in terms of Units of Global Distribution (UD) for High Priority species. This is essentially an extension of the Quality Hectares method that calibrates losses and gains in terms of % global range/population size. All High Priority species analyses were based on the Scenario 2 baseline (0.9% annual deforestation rate, the Madagascar average).

Of the 90 High Priority terrestrial species 83 are forecast to show a Net Positive Impact by 2065.

Of the 90 High Priority terrestrial species (54 plants, 26 invertebrates, 10 vertebrates; Appendices 4 and 5), 83 (92%) are forecast to show a Net Positive Impact by 2065. For 59 of these, area-based calculations predict that NPI will be reached. For a further 24 plant species, area-based calculations predict a moderate negative impact (-1.3% to -17.9%) but it is predicted that NPI can be reached by 2065 through enrichment of the AZs and restoration zones (e.g. planting species at a somewhat greater density than they currently occur in nature).[46] As Rio Tinto QMM tracks its progress towards achieving NPI over the coming years and decades, gains in priority plant species will be measured in terms of UD based on population size—this means that enrichment gains can be accounted for.

[46] Because some of the littoral forest at Mandena, Petriky and Ste Luce was already degraded prior to the arrival of QMM, it is considered likely that some priority plant species (especially late-succession species requiring a closed canopy) currently occur at a lower density than they would do in optimal conditions. Consequently 'enrichment planting' to increase the density of priority species in the AZs and restoration areas can be seen as restoring habitat to an optimal state, rather than creating an artificial landscape. QMM is being advised in these matters by experts in *in situ* and *ex situ* plant conservation from RBG Kew and MBG.

Seven animal species show residual negative impacts—four vertebrates (two frogs, two reptiles, including the Critically Endangered gecko *Phelsuma antanosy*) show residual negative impacts of up to 5.1%, and three invertebrates (all millipedes) show residual negative impacts of up to 17.9% (**Table 3**). It is not known whether enrichment or *ex situ* conservation would be feasible for these species. Research is underway to investigate options for achieving NPI for *Phelsuma antanosy*.

In the majority of cases, achievement of NPI for individual High Priority species is dependent upon the success of restoration efforts. Targeted restoration will be needed as it cannot be guaranteed that species will naturally colonize the restoration zones. At present, 27 of the 54 High Priority plant species are being propagated in a nursery, and it is intended that all High Priority species will be included in the near future; careful attention is needed in the next few years to check that all High Priority plants can be successfully propagated and planted out (e.g. into the Avoidance Zones; many are late-successional species and consequently cannot be planted in restoration zones until many years from now—trials in the AZs are recommended, so that any potential problems can be identified early).

Ex situ conservation measures such as seed banking and establishment of populations in botanical gardens are needed for all High Priority plant species.

Ex situ conservation measures (seed banking, establishment of populations in botanical gardens, etc.) are needed for all High Priority plant species. Currently 17 of the 54 High Priority plant species (31%) have been stored in seed banks; the aim is that seeds of all High Priority plant species should be banked by 2015 (Rio Tinto QMM, 2010). Some *ex situ* actions such as seed banking serve as a kind of 'insurance policy', others such as establishment of populations in botanic gardens can produce measurable gains in UD when reintroduced into the wild. These measures will help to ensure a net positive impact on all species, and in particular those species for which the NPI forecast predicts residual losses in wild populations in 2065. It is a general principle in conservation that *ex situ* conservation should not replace *in situ* conservation, although it is often an essential part of conservation strategies for very rare or threatened species. Because *ex situ* and *in situ* biodiversity gains are not the same, Rio Tinto QMM will account for these gains separately as it tracks its future performance towards NPI.

Further trials and monitoring are needed to determine whether High Priority animals will naturally colonize restoration zones or whether active measures (e.g. translocation or captive breeding and release) are needed and would be effective. *Phelsuma antanosy* shows a potential residual loss of 5.1% of its global population; further research is needed to determine the most appropriate conservation measures for this species and Rio Tinto QMM are supporting this research through a Phelsuma antanosy Management Plan project with Fauna & Flora International and the national NGO Voakajy. It has been protected at Ambatotsirongorongo forest through a joint Rio Tinto QMM-Wildlife Conservation Society (WCS) initiative[47]—however this site was already very small and degraded,

[47] WCS are no longer as active at Ambatotsirongorongo as they previously were; however Rio Tinto QMM retains engagement with the site in the form of two projects: a natural resources management project with UNDP and the local NGO FAFAFI; and a management plan for the Critically Endangered gecko *Phelsuma antanosy* with Fauna & Flora International and the national NGO Voakajy.

and further research is necessary to determine whether the local population is likely to be viable in the long term. 'Gains' from Ambatotsirongorongo are not included in the summary figures for *Phelsuma antanosy* presented here.

Table 3. **Animal species with a net negative impact at 2065.**

Group	Species	IUCN Red List category*	Net impact (UD)
Amphibians	*Guibemantis (Mantidactylus) bicalcaratus ?sp. nov.*	NE	-1.6
Amphibians	*Madecassophryne truebae*	EN	-0.3
Reptiles	*Pseudoxyrhopus kely*	EN	-3.0
Reptiles	*Phelsuma antanosy*	CR	-5.1
Giant pill-millipedes	*Zoosphaerium alluaudi*	NE	-17.9
Giant pill-millipedes	*Sphaeromimus splendidus*	NE	-12.7
Spirobolid millipedes	*Alluviobolus laticlavius*	NE	-17.9

*NE = Not Evaluated, EN = Endangered, CR = Critically Endangered

For all High Priority species together (note that individual results per species were presented at the beginning of this section), there is forecast to be a net gain of +1,256 UD. If site-endemic and Critically Endangered plants and animals that occur at the offset sites but not on the mining leases are also considered, there are additional gains of +493 UD (+60.3UD for animals and +432.7UD for plants; **Tables 4** and **5**). These comprise 19 plant species with gains of 10-25 UD and six vertebrate species with gains of 1-25 UD (**Tables 4** and **5**). Overall, the project is thus forecast to result in a gain of like-for-like and like-for-not-like High Priority species of c.+1,750 UD. The net losses and gains for all High Priority species are presented here for illustrative purposes and to highlight the additional benefits that the offset sites bring for High Priority species that are not found within the Rio Tinto QMM mining area. They should not be taken to imply that one species can be exchanged for another species.

If restoration fails completely to generate measurable gains in any of the High Priority species, there would be a deficit of -1,426 UD. The like-for-not like gains of +493 UD at Mahabo and Bemangidy provide a partial but insufficient buffer in case of complete failure. By expanding the size of the offset at Bemangidy (e.g. from the currently proposed 4,000 ha to c.10,000 ha) a more complete buffer could be provided, although it should be borne in mind that this would not be like-for-like. *Ex situ* conservation will also help to provide a backup and buffer in case of failure. Rio Tinto QMM intends to make its restoration a success, but it is important to consider the worst case scenario during planning.

Table 4. Like-for-not-like gains in site-endemic plant species that occur at offset sites but not on the mining leases.

Site	Species	Species distribution (ha)	Gains 2004–2065 (ha)	Gains 2065 as % global range
Bemangidy	*Lowryanthus rubens Pruski, gen. et sp. Nov., ined.*	4,000	1,001	25.03
Bemangidy	*Gnidia razakamalalana Z.S. Rogers*	4,000	1,001	25.03
Bemangidy	*Ixora bemangidiensis Guédès*	4,000	1,001	25.03
Bemangidy	*Micronychia bemangidiensis Randrian. & Lowry*	4,000	1,001	25.03
Bemangidy	*Diospyros bemangidiensis G.E. Schatz & Lowry, sp. nov. ined.*	4,000	1,001	25.03
Bemangidy	*Diosypros "Sclerophylla group" sp. 14, ined.*	4,000	1,001	25.03
Bemangidy	*Hyperacanthus gereaui Rakotonas. & A.P. Davis, sp. nov. inéd.*	4,000	1,001	25.03
Bemangidy	*Hyperacanthus rajeriarisoniae Rakotonas. & A.P. Davis, sp. nov. inéd.*	4,000	1,001	25.03
Bemangidy	*Ivodia anosiensis Rabarimanarivo et al., sp. nov. ined.*	4,000	1,001	25.03
Bemangidy	*Polyscias bemangidiensis Lowry & G.M. Plunkett, sp. nov. ined.*	4,000	1,001	25.03
Bemangidy	*Polyscias ericii Lowry & G.M. Plunkett, sp. nov. ined.*	4,000	1,001	25.03
Bemangidy	*Polyscias manonae Lowry & G.M. Plunkett, sp. nov. ined.*	4,000	1,001	25.03
Bemangidy	*Polyscias urceolata Lowry & G.M. Plunkett, sp. nov. ined.*	4,000	1,001	25.03
Bemangidy	*Schefflera bemangidiensis Lowry & G.M. Plunkett, sp. nov. ined.*	4,000	1,001	25.03
Bemangidy	*Schizolaena charlotteae Lowry et al., sp. nov. ined.*	4,000	1,001	25.03
Bemangidy	*Schrebera trifoliata C. Frasier & G.E. Schatz, sp. nov., ined.*	4,000	1,001	25.03
Mahabo	Brackenridgia sp. nov.	1,565	168	10.74
Mahabo	*Cassinopsis sp. nov.*	1,565	168	10.74
Mahabo	*Octolepis cf dioica*	1,565	168	10.74
				432.67

Table 5. **Like-for-not-like gains in site-endemic, Endangered and Critically Endangered animal species that occur at offset sites but not on the mining leases.**

Site	Higher taxon	Species	Priority	Strict endemic	Regional endemic	IUCN EN or CR?	Global distribution of species (ha)	Total area of site (ha)	Condition	Total QH at site	Gains 2004-2065 (ha)	Gains 2065 as % global range
Bemangidy	Amphibia	*Mantidactylus aff.grandidieri*	High	1			4,000	4,000	0.9	3,600	1,001	25.03
Bemangidy	Amphibia	*Boehmantis microtympanum*	High		1	EN	50,000	4,000	0.9	3,600	1,001	2.00
Mahabo	Amphibia	*Heterixalus sp. nov.*	High	1			1,565	1,565	0.8	1,252	166	10.74
Mahabo	Reptilia	*Phelsuma cf quadriocellata*	High	1			1,565	1,565	0.8	1,252	168	10.74
Mahabo	Reptilia	*Phelsuma sp. nov.*	High	1			1,565	1,565	0.8	1,252	168	10.74
Mahabo	Mammalia	*Eulemur cinereiceps*	High			EN	1,5613	1,565	0.8	1,252	168	1.08
												60.33

4.2 Is Rio Tinto QMM on track to achieve a Net Positive Impact on biodiversity for the period 2004–2015?

4.2.1 Impacts on habitats—Quality Hectares

4.2.1.1 Results for 2004–2015

The QH analysis was also carried out for the period 2004–2015, as 2015 is the first internal Rio Tinto benchmark date when all business units subject to the NPI target must measure their progress towards meeting this goal.

Rio Tinto QMM is predicted to have a Net Positive Impact on littoral forest QH in the period 2004–2015, based on the national average deforestation rate of 0.9% per year. NPI is predicted to be positive for littoral forest (Mandena, Petriky, Ste Luce and Mahabo), and for all forest types combined (i.e. including the humid forests of the Bemangidy offset as well).

Net impact on littoral forest is forecast to be +48 QH in 2015, representing an increase of 2% by comparison with 2004 levels. This comes primarily from avoided deforestation, as restoration will only recently have started.

4.2.2 Impacts on species—Units of Global Distribution

The UD analysis indicates that only 32 of the 90 High Priority species are likely to be at NPI by 2015, and some species show losses of up to 39 UD (two millipedes, Sphaeromimus inexpectatus and Riotintobolus mandensis, and one plant Eulophia palmicola show population reductions of this magnitude; all of these are Mandena endemics). This is because there will already have been major impacts by this date (particularly at Mandena), but restoration zones will not yet have reached sufficient maturity to count towards NPI. Carefully targeted restoration is critically important for minimizing residual losses and achieving NPI for High Priority species. However even at these sites, where research and trials of restoration techniques were instigated well in advance of the start of mining operations, it still takes time for restoration to create functioning natural habitat analogues. Furthermore, many of the High Priority species are late-successional species and cannot be planted out in restoration zones until the restored forest is reasonably mature. Consequently, even with the best possible conservation action, it is likely that the majority of High Priority species will not reach NPI by 2015, based on predicted losses and gains in their wild populations.

Carefully targeted restoration is critically important for minimizing residual losses and achieving NPI for High Priority species.

4.3 Is Rio Tinto QMM on track to achieve a Net Positive Impact on biodiversity throughout the lifecycle of the mine?

Temporal loss is recognized as a significant issue that needs to be tackled by biodiversity offsetting and 'no net loss' or 'net positive impact' initiatives.

Temporal loss is recognized as a significant issue that needs to be tackled by biodiversity offsetting and 'no net loss' or 'net positive impact' initiatives (ten Kate *et al.*, 2004; Burgin, 2008; Bekessy *et al.*, 2010). It can be said to occur when a loss occurs in advance of sufficient gains being accrued through restoration, averted loss at offsets, or other measures. To determine whether Rio Tinto QMM is forecast to be 'net negative' with respect to littoral forest habitat at any point during the lifecycle of the mine, losses and gains were calculated using the same methods and assumptions as above and displayed on a year-by-year cumulative basis (**Figure 8**). To calculate losses on a year-by-year basis, some additional assumptions had to be made. These were (i) that Mandena, Ste Luce and Petriky would be mined sequentially (this is the current plan), (ii) that a constant number of QH will be lost to mining every year of 'active' mine life (during the last few years of mine life, the 'closure phase', there will be no further mining activity; activities such as decommissioning and restoration and rehabilitation are carried out during this phase); and (iii) that mining will stop c.12 years before final closure (this is the current plan). Assumption (ii) is simplistic, first because although the dredge moves steadily and more-or-less constantly through the landscape, covering c.100 ha per year (Rio Tinto QMM, 2001), the forest cover is patchy both in terms of quantity and quality. Second, the extent of forest QH at Ste Luce is greater than that at Petriky, so the timing of losses depends on whether Ste Luce or Petriky is mined after Mandena. However, despite these caveats, better predictive data are not yet available and it was felt that a year-by-year cumulative analysis would provide useful additional information. This analysis was carried out for forest habitats only, measured in Quality Hectares, because it would have been very significantly more complex to carry out an analogous analysis for High Priority species.

The results (**Figure 8**) suggest that there will be no temporal loss of littoral forest, and that Rio Tinto QMM will remain net positive in terms of littoral forest QH throughout mine life.

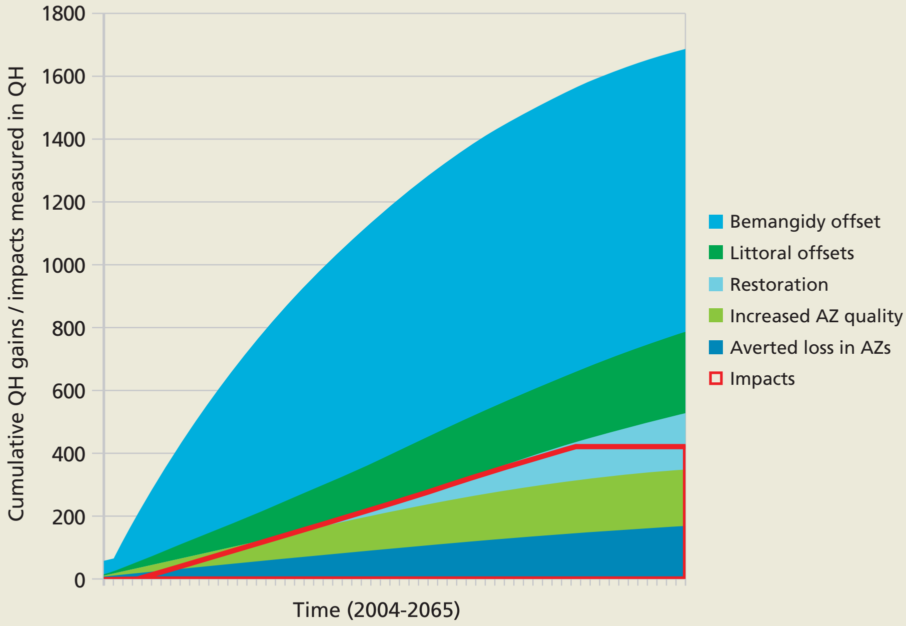


Figure 8. Cumulative gains in littoral forest over time (measured in QH) compared to cumulative impacts from mining (measured in QH).

5 CONCLUSIONS AND NEXT STEPS

5.1 Summary

Detailed analyses based on the best available scientific information were carried out to project biodiversity losses and gains over the life of the mine (2004–2065) and to determine whether Rio Tinto QMM will have a Net Positive Impact at closure. Biodiversity losses and gains were calculated in two ways: using Quality Hectares as a metric (for forest habitats); and using Units of Global Distribution as a metric (for High Priority species, e.g. threatened and restricted-range species). Rio Tinto QMM's Biodiversity Committee has approved the use of these metrics. Results show that Rio Tinto QMM is anticipated to have a Net Positive Impact on biodiversity, both in terms of Quality Hectares of littoral forest and Units of Global Distribution for the majority (83/90) of High Priority species, if the mitigation measures outlined in this report are successfully implemented.

The mitigation portfolio proposed by Rio Tinto QMM is as follows:

Offsets: at (i) Mahabo, (ii) Tsitongambarika III Bemangidy, (iii) Ste Luce Forests. Ambatotsirongorongo and the Tsitongambarika (TGK I) Direct Payments project are currently under review as formal offsets, so gains from these two sites are not included in the quantitative analysis presented here. Each of these sites is discussed in more detail later in the report.

Restoration: 225 ha of restoration each at Mandena, Petriky, Ste Luce. Restoration zones will be located adjacent to the Avoidance Zones, to provide a buffer, improve connectivity and facilitate natural regeneration and recolonization.

Avoidance Zones: at Mandena, Petriky, Ste Luce.

The project is predicted to have a Net Positive Impact on littoral forest in 2065, and a significant Net Positive Impact on regional forest types.

The project is predicted to have a Net Positive Impact on littoral forest in 2065 (+350 QH), and a significant Net Positive Impact on regional forest types, including Bemangidy humid forest (+1,251 QH).

The project is predicted to have a Net Positive Impact on 83/90 High Priority species, comprising a total of +1,256 UD (including like-for-like species only) and +c.1,750 UD (including like-for-not-like High Priority species that are found in the offsets but not on the mine site). For individual High Priority species, area-based predictions indicate that 59/90 will experience net gains by 2065; for the remaining 31 (24 plants and seven animals: four vertebrates and three invertebrates), it is intended that NPI will be met by a combination of enrichment (e.g. by restoring species towards presumed natural densities from their currently depleted densities; this may be more feasible for plants than for animals; trials are needed) and *ex situ* conservation measures such as propagation in botanical gardens. Based on area-based predictions, no plant or invertebrate is predicted to have a residual decline greater than 18% and no vertebrate species is predicted to have a residual decline greater than 5% of its global distribution (i.e. 5 UD) requiring compensation through enrichment and insurance through *ex situ* conservation measures.

These calculations are based on a number of assumptions; they are based on the best data available at present although there is significant uncertainty around any prediction of what will happen 55 years hence.

A key assumption that makes a significant difference to the analysis is the counterfactual scenario considered. We propose that a precautionary counterfactual scenario (0.9%, the Madagascar national average) is the most appropriate to use. The analyses presented here show that, even if only a very low rate of deforestation is presumed (**Figure 7**), the Rio Tinto QMM project will have a Net Positive Impact on littoral forest over the life of the mine based on the proposed mitigation portfolio.

5.2 Achieving NPI—what does it mean for Rio Tinto QMM?

One of the original reasons for carrying out this analysis was to provide transparent quantification of likely losses and gains.

One of the original reasons for carrying out this analysis was to provide transparent quantification of likely losses and gains, in order to inform debate and allow a consensus to be reached between Rio Tinto QMM and the Biodiversity Committee regarding what ‘achieving NPI’ means for Rio Tinto QMM.

Following discussion of an earlier draft version of this report at the Biodiversity Committee Meeting held on 3-6 May 2010 in Fort Dauphin, Madagascar, the Biodiversity Committee recommended that ‘achieving NPI’ means achieving a Net Positive Impact on littoral forest[48] (using QH as a metric) and achieving a Net Positive Impact on species (using UD of High Priority species as a metric). The target is to achieve NPI for each High Priority species individually. Measures of UD should be based on population size as well as distribution area where appropriate; it is likely that population information will become available for more species as time goes on. It is assumed that QH will provide an adequate surrogate for other species. Rio Tinto QMM accepted these recommendations.

It is important to note that QH and UD are the main metrics used to forecast NPI over the mine life, and to plan for the type and scale of interventions required, but they are not the only metric or indicator that will be used at Rio Tinto QMM. In addition, to track progress against broader conservation goals

[48] I.e. offsets in a different forest type, such as the humid forest offset at Tsitongambarika, can act as an ‘insurance policy’ and a kind of additional benefit (as well as providing key ecosystem services such as water for local communities), but it was agreed that a loss of littoral forest cannot be compensated for by a gain in a different habitat type. This decision was made at QMM based on the local context; however at other sites a different decision might be made.

as outlined in the Biodiversity Action Plan (Rio Tinto QMM, 2010), Rio Tinto QMM and partners will be monitoring a number of indicators of e.g. ecosystem integrity, diversity of common species, forest regeneration, presence/absence and numbers of invasive species, etc. Further details can be found in the Biodiversity Action Plan and in specific monitoring protocols developed (or currently under development) in consultation with the Biodiversity Committee.

5.3 Rio Tinto QMM's biodiversity offsets

Figure 8 shows sites that are current Rio Tinto QMM biodiversity offsets, or that are under consideration as Rio Tinto QMM offsets. Three offset sites were included in the quantitative analysis in this report; two of these sites (Ste Luce Forests and Mahabo) already have active conservation programmes, while the third (Bemangidy) is awaiting confirmation as an offset by Rio Tinto QMM and the Biodiversity Committee.

Two further potential offset sites are discussed below (Ambatotsirongorongo and TGK I Direct Payments Project)—both of these sites have had active conservation projects funded by Rio Tinto QMM over several years, but review is ongoing regarding whether they should be maintained as offset sites in the future. Consequently they have not been included in the quantitative NPI forecast in this report.

Ste Luce Forests are 500 ha of littoral forest, adjacent to (but not overlapping) the Ste Luce ilmenite deposit. They are very similar to forests on the Rio Tinto QMM deposits, and so are a like-for-like offset for both habitat type and species. They are part of the mining leases so Rio Tinto QMM has greater control than at other offset sites (reducing uncertainty). A conservation programme has been operating at this site since before 2004, initiated, funded and managed by Rio Tinto QMM.

Mahabo is a 1,500 ha littoral forest offset site located several hundred kilometres north of Fort Dauphin. In collaboration with Missouri Botanical Gardens it was chosen as a 'like-for-like' offset site for littoral forest as a habitat type. Its distant location is not ideal but it represents the best option, after Ste Luce, for a littoral forest habitat offset through averted deforestation and degradation. A conservation and development programme with local communities has been operating since 2004 at this site (jointly funded and managed by Rio Tinto QMM and Missouri Botanical Gardens).

Bemangidy provides important ecosystem service benefits such as water provision and carbon sequestration.

Bemangidy (Tsitongambarika III) is a c.4,000 ha parcel of lowland humid forest within the larger c.60,000 ha Tsitongambarika forest. It is a like-for-not-like offset for locally endemic species, and a like-for-like offset for more widespread species. Additionally, it provides important ecosystem service benefits such as water provision and carbon sequestration. Bemangidy currently has the status of a proposed offset site—a Management Plan has been drafted for the site. As a large parcel of remaining forest, even though it is not a 'like-for–like' offset, it provides a crucial 'insurance policy' in case conservation at some of the smaller sites is less successful than hoped in the long term. Even with active conservation intervention, small parcels of forest can be difficult to protect and manage in the long term.

In 2004, through discussions with BirdLife International and Asity Madagascar (the BirdLife partner in Madagascar), the value of the whole Tsitongambarika unprotected area of humid forest was identified as a strategic priority for Rio Tinto QMM. It was clear the area had the potential to act as an offset site for many littoral forest species and also had huge value as the regional ecosystem services hub for water, soil fertility, non-timber forest products, littoral forest pollination and seed dispersal, and local climate regulation. Significant conservation activities have already been implemented with the involvement and support of Rio Tinto QMM that benefit the whole forest.

1. Policy and legislation: protected area designation under national law. Rio Tinto QMM and Asity Madagascar have carried out the preparatory work necessary to have Tsitongambarika designated a new national protected area, within the Système des Aires Protegées de Madagascar. This work was funded by Rio Tinto QMM. Tsitongambarika currently has temporary protection status N°21480 of 02/12/2008, pending political processes.
2. Long-term planning: a Tsitongambarika Conservation Management Plan. A coalition of agents including government, CBOs, NGOs and local communities has collaboratively developed a long-term management plan for the forest.
3. A community-based forest conservation project has been implemented in Tsitongambarika 1 by Asity Madagascar (funded by Rio Tinto QMM); this is described further under 'Tsitongambarika 1' below.
4. Ongoing surveys of flora and fauna since 2003.

Rio Tinto QMM is currently deciding where in Tsitongambarika its offset activities should be focused. At present, the most likely strategy is that Rio Tinto QMM's offset activities will be focused in a particular area within Tsitongambarika (e.g. Bemangidy or similar), but that Rio Tinto QMM will seek partner organizations (such as Asity Madagascar, which is the lead responsible party for the whole protected area under government policy) and co-financing to carry out conservation activities throughout the whole of Tsitongambarika.

Tsitongambarika 1 is the southern part of the large forest massif that also encompasses Bemangidy. A Direct Payments community-based avoided deforestation programme was operated by Asity Madagascar in six villages in this area from 2007 to 2009, funded by Rio Tinto and QMM. It is an incentive-based community conservation project whereby forest integrity is conserved in exchange for local community development such as schools and clinics. This was a pilot project and longer-term involvement of Rio Tinto QMM in Tsitongambarika as a whole is currently under review, as described above.

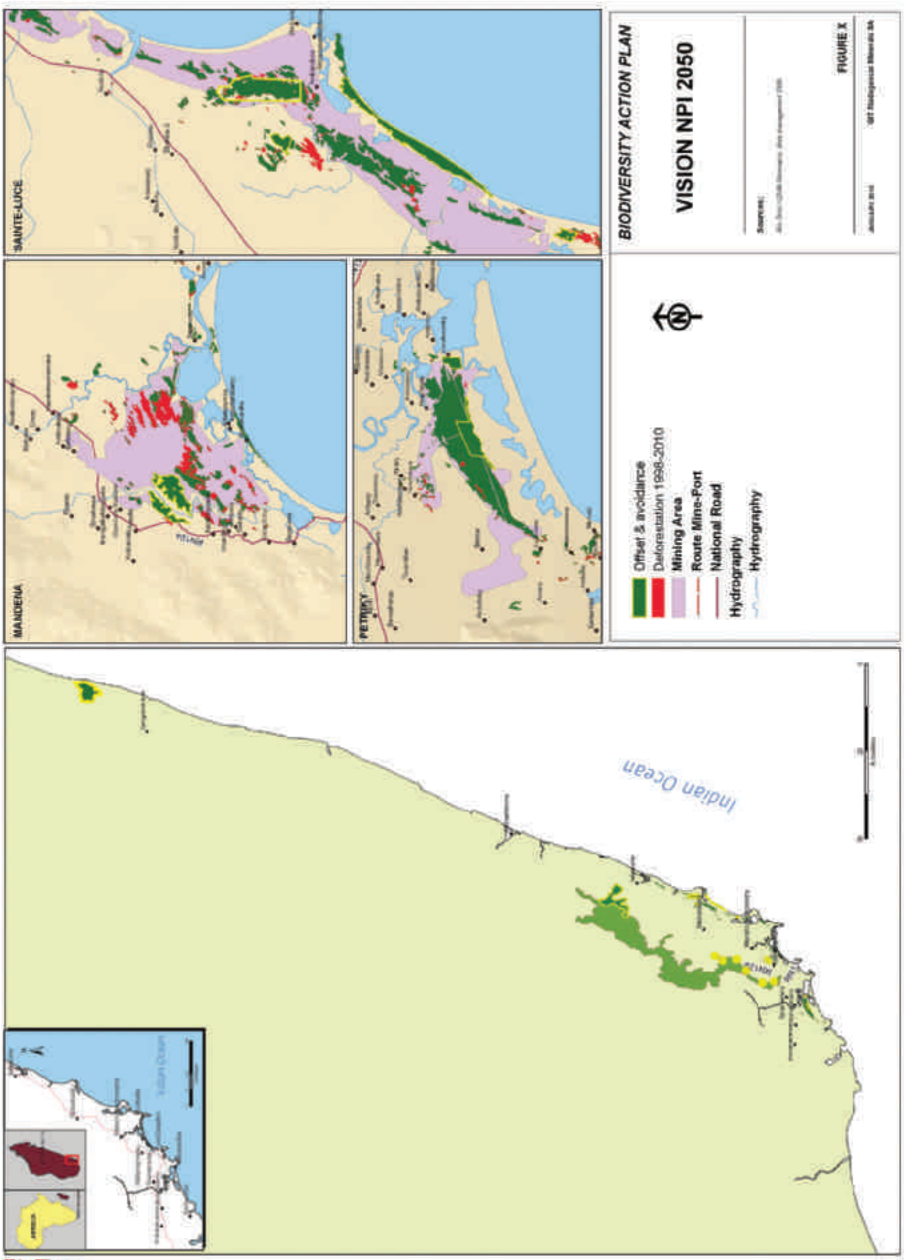
Ambatotsirongorongo is an area of transitional forest to the west of Petriky which has suffered a high rate of deforestation. The forest is home to a significant population of *Phelsuma antanosy* (Critically Endangered) currently only otherwise found in the littoral forests in Ste Luce (including the Ste Luce Forests offset). This small gecko was previously also observed in Petriky, but background habitat loss through subsistence agriculture appears to have eliminated this population. The Ambatotsirongorongo programme is a partnership between Rio Tinto QMM, the Wildlife Conservation Society and local communities.

5.4 Monitoring forest loss

Measuring averted deforestation will be a key piece of NPI accounting in the future, and needs to be given careful thought at an early stage in project planning.

A significant proportion of biodiversity gains for Rio Tinto QMM will accrue through averted loss. For Rio Tinto QMM to be able to credibly claim these gains in 2065, a robust and consistent monitoring system will be needed to document rates of forest loss across the mining leases and all the offset sites, to show that real measurable averted loss is occurring. It would also be advisable to measure rates of loss in the wider region over the same period to provide context and to help monitor Rio Tinto QMM's success in tackling potential secondary impacts such as habitat conversion resulting from in-migration. Measuring averted deforestation will be a key piece of NPI accounting in the future, and needs to be given careful thought at an early stage in project planning. Whatever method is chosen, care must be taken that it does not provide a 'perverse incentive' for Rio Tinto QMM to encourage (or fail to help reduce) forest loss in the wider region.

Figure 9. Current biodiversity offset sites or sites that are under consideration as offsets.



RioTinto

5.5 The broader context—drivers of biodiversity loss in southeastern Madagascar

Forest conservation in southeastern Madagascar will only be successful in the long term if the underlying drivers of biodiversity loss are addressed.

As in other parts of the world, forest conservation in southeastern Madagascar will only be successful in the long term if the underlying drivers of biodiversity loss are addressed. Prior to the arrival of Rio Tinto QMM in the 1990s, the littoral forest was already in rapid decline (Vincelette *et al.*, 2007b). Apart from mining, other major causes of current forest loss are unsustainable levels of charcoal production and tavy (slash-and-burn agriculture). People using forests in these ways do so because they have no other option—82% of Anosy inhabitants live below the poverty line (US1$/day; Vincelette *et al.*, 2007a).

Many of Rio Tinto QMM's Additional Conservation Actions seek to address these underlying causes of biodiversity loss, for example by setting up plantations of fast-growing non-native trees to reduce charcoal production pressure on native forest, or providing alternative livelihoods by training local people in skills such as blacksmithing, crop production and diversification, vetiver grass production and planting, improved rice production, animal breeding, handicrafts, etc. However, southeastern Madagascar's social and environmental problems cannot be solved by the actions of a single company; broader initiatives are needed involving multiple agencies and stakeholders.

5.6 NPI analysis updates and adaptive management

As part of Rio Tinto QMM's biodiversity action planning process, this analysis and forecast should be periodically revisited to take into account changes such as newly discovered or described species, new listings (and up- or down-listings) on the IUCN Red List, and methodological improvements that can be made as the state of knowledge and best practice in relevant fields such as biodiversity metrics and biodiversity offsetting evolve. This will help Rio Tinto QMM to track progress and will contribute to adaptive management. It will also allow the assumptions made in the present analysis to be tested based on empirical data (e.g. is it reasonable to assume that deforestation can be completely stopped in the Avoidance Zones? Is it reasonable to assume that conservation actions will improve the quality score of the Avoidance Zone in Petriky by 0.05 every 15 years?). It is recommended that this analysis should be revisited at least every five years (the same periodicity is recommended for revisiting the Biodiversity Action Plan: Rio Tinto QMM, 2010). Section 7 details lessons learned in carrying out the present analysis and recommends areas for future research—subsequent iterations of this NPI forecast should take into account these lessons, as well as any relevant new research findings.

6 LESSONS LEARNED AND DIRECTIONS FOR FUTURE RESEARCH

6.1 Potential impacts of climate change

An important point to consider in the future is how Rio Tinto QMM can factor the potential impacts of climate change into biodiversity action planning and implementation of restoration and offsets. The impact sites, avoidance and restoration zones, and littoral forest offset sites are all close to the coast and at very low altitudes. Consequently, by 2065, they may plausibly be impacted by sea level rise (especially when associated with storm surges), and will face increased temperatures and decreased rainfall. This could pose problems for the long-term viability of Rio Tinto QMM's littoral forest conservation areas. Among many other things it may affect the ease and effectiveness of restoration, and could wipe out other gains in Quality Hectares as the climate becomes less suitable for littoral forest or the coast is inundated. There may be a need to secure and re-vegetate areas that are further inland or upslope, and to think about buffers and corridors for existing sites. This underlines the importance of Rio Tinto QMM's ongoing monitoring of the habitats and species and adaptive management to changing conditions as they occur (Rio Tinto QMM, 2010).

Recent research modelling species range shifts in Madagascar in response to future climate change predicted that the littoral forest will disappear.

Recent research modelling species range shifts in Madagascar in response to future climate change predicted that the littoral forest will disappear (Hannah *et al.*, 2008), and palaeoecological reconstruction indicates that littoral forest in the Fort Dauphin region has been highly dynamic in response to climatic changes in the past (Virah-Sawmy *et al.*, 2010). Given that the Rio Tinto QMM mine is planning for the 2004–2065 time period, it would be useful to evaluate the vulnerability of the conservation actions described in this report to different climate change scenarios (i.e. less rain, warmer temperatures, higher sea level, increased frequency of storms) to determine how resilient the proposed activities would be. It would also be informative to supplement the broad-scale modelling of Hannah *et al.* (2008) with a more detailed study at the regional level.

6.2 Defining a standard set of species to be included in NPI accounting

At present, Rio Tinto's guidance on which species to include in NPI accounting is not prescriptive, although it does state that this decision should be based on the classic conservation priority-setting principles of vulnerability and irreplaceability, and should be done in consultation with relevant experts and stakeholders (Ekstrom and Anstee, 2007; Rio Tinto, 2010). For this analysis, and following these principles, Rio Tinto QMM (in consultation with the biodiversity committee and other experts) determined that High Priority species as defined in the Biodiversity Action Plan (Rio Tinto QMM, 2010) should be included. These include globally Critically Endangered and Endangered species and species with a highly restricted distribution (see Rio Tinto QMM, 2010 for a definition), but excluded Vulnerable species.

One of the lessons learned from this process is that it may be valuable for Rio Tinto to define a standard set of species to be included in NPI accounting, based on criteria that are applied in the same way to all Rio Tinto sites globally. This should likely include Vulnerable species as well as those listed as Endangered and Critically Endangered on the IUCN Red List. It may also be valuable to establish standard definitions for what constitutes 'restricted range'. If Rio Tinto develops such standard guidelines, they should be used in subsequent iterations of the present analysis.

6.2.1 Undescribed species

When it comes to defining a standard set of species for inclusion in NPI accounting, undescribed species present an interesting conundrum.

When it comes to defining a standard set of species for inclusion in NPI accounting, undescribed species present an interesting conundrum. The present analysis includes a number of possible new species that have yet to be formally described. Many of these will be described over the course of the project, and Rio Tinto QMM arguably has a responsibility to support the taxonomic research to allow this. However, it is debatable whether it is appropriate to include such taxa in formal NPI calculations. Based on experience from carrying out this analysis, we would recommend that Rio Tinto develops a standard policy for dealing with undescribed species.

6.3 Counterfactual scenarios, baselines, and calculating biodiversity gains from averted loss

This is a particularly fertile and fast-moving field of research at the moment given interest in REDD (Reducing Emissions from Deforestation and Degradation) and growing interest in biodiversity offsets. It will be important to keep abreast of developments in this field, and evaluate their relevance to calculation of biodiversity offset gains at the site level, to ensure that NPI accounting and forecasting is as robust as possible. Specific questions raised elsewhere in this report include how to ensure that calculation methods do not inadvertently create perverse incentives, and how best to monitor deforestation and measure gains going forward.

6.4 Calculating Units of Global Distribution—methods for measuring species distribution area

In the present analysis, in cases where UD was measured based on distribution rather than population (e.g. where population data were unavailable at the global and site level), it was necessary to estimate the global distribution area for each species. Different methods were used depending on the taxon in question. For example, for some mammals and birds area of occupancy (AOO) was calculated by measuring extent of occurrence (EOO) based on maps from the IUCN Red List of Threatened Species (IUCN, 2009), and inferring AOO based on a very rough 'rule of thumb' of 10% of EOO (this relationship between AOO and EOO is implied by the thresholds set for Criterion B of the IUCN Red List). EOO cannot be used without some modification because it typically overestimates (sometimes vastly) the area occupied by each species (Jetz *et al.*, 2008; Rodrigues, 2011). However, for future analyses of this type, it could be worth exploring whether other metrics such as Extent of Suitable Habitat (ESH) offer a useful alternative. ESH is the area of potentially suitable vegetation types within the altitudinal preferences of the species (Rondinini, *et al.*, 2005; Buchanan *et al.*, 2008). In a recent study using the ESH method, species' range was restricted on average to 28% of its original EOO (Beresford *et al.*, 2011). However, the ESH method is not without its problems, as detailed by Rodrigues *et al.* (2011); a recent ground-truthing exercise suggested that the ESH method had very little capacity to distinguish between occupied and non-occupied parts of species' EOOs (Beresford *et al.*, 2011; Rodrigues *et al.*, 2011).

7 BIBLIOGRAPHY

BBOP Multipliers Consultation Working Group. 2008. Business and Biodiversity Offsets Program (BBOP) Consultation paper: The use of multipliers to deal with risk, uncertainty, time discounting and landscape conservation targets in biodiversity offset design. Unpublished report.

Business and Biodiversity Offsets Programme (BBOP). 2009. Biodiversity Offset Cost-Benefit Handbook. BBOP, Washington, DC. www.forest-trends.org/biodiversityoffsetprogram/guidelines/cbh.pdf.

Bekessy, S.A., Wintle, B.A., Lindenmayer, D.B., Mccarthy, M.A., Colyvan, M., Burgman, M.A. and Possingham, H.P. 2010. The biodiversity bank cannot be a lending bank. Conservation Letters, 3: 151–158.

Beresford, A.E., Buchanan, G.M., Donald, P.F., Butchart, S.H.M., Fishpool, L.D.C. and Rondinini, C. 2011. Poor overlap between the distribution of protected areas and globally threatened birds in Africa. Animal Conservation, 14: 99–107.

Buchanan, G.M., Butchart, S.H.M., Dutson, G., Pilgrim, J.D., Steininger, M.K., Bishop, K.D. and Mayaux, P. 2008. Using remote sensing to inform conservation status assessment: estimates of recent deforestation rates on New Britain and the impacts upon endemic birds. Biol. Conserv., 141: 56–66.

Burgin, S. 2008. BioBanking: an environmental scientist's view of the role of biodiversity banking offsets in conservation. Biodiversity and Conservation, 17: 807–816.

Consiglio, T., Schatz G.E., McPherson G., Lowry, P.P., Rabenantoandro, J., Rogers, Z.S., Rabevohitra, R. and Rabehevitra, R. 2006. Deforestation and plant diversity of Madagascar's littoral forests. Conservation Biology, 20: 1799–1803.

Comité Régional pour le Développement de l'Anosy (CRD). 2003. Schéma de Développement Régional (SRD) de l'Anosy. Rapports Phases 1 à 4. Dobbin International Inc. Washington, DC.

Du Puy, D. and Moat, J. 1998. Vegetation Mapping and Classification in Madagascar (Using GIS): Implications and Recommendations for the Conservation of Biodiversity. Pp. 97-–117 in: Huxley, R., Lock, J.M. and Cutler, D.F. (eds.). Chorology, Taxonomy and Ecology of the Floras of Africa and Madagascar. Royal Botanic Gardens Kew, Richmond.

Dumetz, N. 1999. High plant diversity of lowland rainforest vestiges in eastern Madagascar. Biodiversity and Conservation, 8: 273–315.

Ekstrom, J.M.M. and Anstee, S. 2007. The Rio Tinto Biodiversity Values Identification and Prioritisation System. (Unpublished internal Rio Tinto guidance note).

Ganzhorn, J.B. 1998. Nested patterns of species composition and its implications for lemur biogeography in Madagascar. Folia Primatologica, 69: 332–341.

Ganzhorn, J.U., Lowry II, P.P., Schatz. G.E. and Sommer, S. 2001. The biodiversity of Madagascar: one of the world's hottest hotspots on its way out. Oryx, 35: 346–348.

Ganzhorn, J.U., Goodman, S.M. and Vincelette, M. (eds.). 2007. Biodiversity, ecology and conservation of littoral ecosystems in southeastern Madagascar, Tolagnaro (Fort Dauphin). Smithsonian Institution, Washington, DC.

Goodman, S.M., Pigeon, M., Hawkins, A.F.A. and Schulenberg, T.S. 1997. The birds of southeastern Madagascar. Fieldiana: Zoology, new series, 87: 1–132.

Goodman, S.M. and Ramanamanjato J.-B. 2007. A perspective on the paleo-ecology and biogeography of extreme southeastern Madagascar, with special reference to animals. Pp. 25–48 in: Ganzhorn, J.U., Goodman, S.M. and Vincelette, M. (eds.). Biodiversity, ecology and conservation of littoral ecosystems in southeastern Madagascar, Tolagnaro (Fort Dauphin). Smithsonian Institution, Washington, DC.

de Gouvenain, R.C. and A.J. Silander Jr. 2000. Diversité et Endémisme a Madagascar. Pp. 45–62 in: Lourenço, W.R. and Goodman, S.M. (eds.). Mémoires de la Société de Biogéographie. Paris.

Hannah, L., Dave R., Lowry P.P. *et al.* 2008. Climate change adaptation for conservation in Madagascar. Biology Letters, 4: 590–594.

Harper, G.J., Steininger, M.K., Tucker, C.J., Juhn, D. and Hawkins, F. 2007. Fifty years of deforestation and forest fragmentation in Madagascar. Environmental Conservation, 34: 325–333.

Henderson, S. 1999. Relationship between structure and composition in the littoral forests of southeast Madagascar. PhD thesis, Environmental Change Unit, Oxford University.

International Monetary Fund (IMF). 2011. World Economic Outlook Database–April 2011, International Monetary Fund [Data refer to the year 2010]. Accessed on 11 April 2011. http://imf.org/external/pubs/ft/weo/2011/01/weodata/index.aspx.

Ingram, J.C. and Dawson, T.P. 2005. Climate change impacts and vegetation response on the island of Madagascar. Philosophical Transactions of the Royal Society, London, A, 363: 55–59.

Ingram, J.C., Dawson, T.P. and Whittaker, R.J. 2005a. Mapping tropical forest structure in southeastern Madagascar using remote sensing and artificial neural networks. Remote Sensing of Environment, 94: 491–507.

Ingram J.C., Whittaker, R.J. and Dawson, T.P. 2005b. Tree structure and diversity in human-impacted littoral forests, Madagascar. Environmental Management, 35: 779–798.

Ingram, J.C. and Dawson, T.P. 2006. Forest cover, condition, and ecology in human-impacted forests, south-eastern Madagascar. Conservation and Society, 4: 194–230.

IUCN. 2009. 2009 IUCN Red List of Threatened Species. International Union for Conservation of Nature, Gland, Switzerland and Cambridge, UK.

Jacques Whitford Inc. 2007. Marine Environmental Monitoring of Ehoala Port. Unpublished report for Rio Tinto QMM.

Jetz, W., Sekercioglu, C.H. and Watson, J.E.M. 2008. Ecological correlates and conservation implications of overestimating species geographic ranges. Conservation Biology, 22: 110–119.

Langhammer, P.F., Bakarr, M.I., Bennun, L.A., Brooks, T.M., Clay, R.P., Darwall, W., De Silva, N., Edgar, G.J., Eken, G., Fishpool, L.D.C., Fonseca, G.A.B. da, Foster, M.N., Knox, D.H., Matiku, P., Radford, E.A., Rodrigues, A.S.L., Salaman, P., Sechrest, W. and Tordoff, A.W. 2007. Identification and Gap Analysis of Key Biodiversity Areas: Targets for Comprehensive Protected Area Systems. IUCN, Gland, Switzerland.

Lowry II, P.P. and Faber-Langendoen, D. 1991. Overall flora and vegetation study. In: Ilmenite Project. Social and Environmental Impact Assessment. Supporting Document no. 4. Unpublished document presented by QIT Madagascar Minerals S.A. (QMM S.A.) to the Madagascar National Environment Office in May 2001.

Lowry II, P.P., Smith, P.P. and Rabevohitra, R. 2001. Review of MIR Télédétection Inc.: Deforestation Study in the region of Fort Dauphin (Tolagnaro) Madagascar. In: Ilmenite Project. Social and Environmental Impact Assessment. Supporting Document no. 9. Unpublished document presented by QIT Madagascar Minerals S.A. to the Madagascar National Environment Office in May 2001.

McKenney, B. and Kiesecker J.M. 2010. Policy Development for Biodiversity Offsets: A Review of Offset Frameworks. Environmental Management, 45: 165–176

Mittermeier, R.A., Robles Gil, P., Hoffmann, M., Pilgrim, J., Brooks, T., Mittermeier, C.G., Lamoreux, J. and da Fonseca, G.A.B. 2004. Hotspots Revisited. CEMEX, Mexico City.

Nussbaum, R.A., Raxworthy, C.J., Raselimanana, A.P. and Ramanamanjato, J.-B. 1999. Amphibians and reptiles of the Réserve Naturelle Intégrale d'Andohahela, Madagascar. In: Goodman, S.M. (ed.). A floral and faunal inventory of the Réserve Naturelle Intégrale d'Andohahela, Madagascar: With reference to elevational variation. Fieldiana: Zoology, 94: 155–173.

Parkes, D., Newell, G. and Cheal, D. 2003. Assessing the quality of native vegetation: the 'habitat hectares' approach. Ecological Management and Restoration, 4: S29–S38.

Rabenantoandro, J. 2001. Floral, structural and dendrometric analysis of low altitude humid forest on the western slopes of the Masaola National Park [Analyse floristique, structurale et dendrométrique de la forêt dense humide de basse altitude du Parc National Masoala sur le versant occidental selon la méthode de la parcelle permanente.] Dissertation study, Faculty of Sciences, Antananarivo University.

Rabenantoandro, J., Randriatafika, F. and Lowry II, P.P. 2007. Floristic and Structural Characteristics of Remnant Littoral Forest Sites in the Tolagnaro Area. Pp. 65-93 in: Ganzhorn, J.U., Goodman, S.M. and Vincelette, M. (eds.). Biodiversity, Ecology and Conservation of Littoral Ecosystems in Southeastern Madagascar; Tolagnaro (Fort Dauphin). Smithsonian Institution, Washington DC.

Rabevohitra, R., Wilmé, L., Lowry II, P.P. and Schatz, G.E. 1998. Pp. 65–99 in: Ratsirarson, J. and Goodman, S.M. (eds.). Biological inventory of the littoral forest of Tampolo. Volume 14. [Inventaire biologique la Foret Littorale de Tampolo.] Volume 14. Centre d'Information et de Documentation Scientifique et Technique, Antananarivo, Madagascar.

Ramsar Convention Secretariat. 2004. Designating Ramsar Sites. Strategic Framework and Guidelines for the Future Development of the List of Wetlands of International Importance. Second edition. Ramsar Convention Secretariat, Gland, Switzerland.

Ramanamanjato, J.B., Mcintyre, P.B. and Nussbaum, R.A. 2002. Reptile, amphibian and lemur diversity of the Malahelo Forest, a biogeographical transition zone in southeastern Madagascar. Biodiversity and Conservation, 11: 1791–1807.

Rarivoson, C. and Mara, R. 2007. Testing of Fast Growing Tree Species for the Rehabilitation of Mine Sites. Pp. 323–331 in: Ganzhorn, J.U., Goodman, S.M. and Vincelette, M. (eds.). Biodiversity, Ecology and Conservation of Littoral Ecosystems in Southeastern Madagascar; Tolagnaro (Fort Dauphin). Smithsonian Institution, Washington DC.

Raxworthy, C.J. 2003. Introduction to the Reptiles. Pp. 934–949 in: Goodman, S.M. and Benstead, J.P. (eds.). The Natural History of Madagascar. (Chicago Press, Chicago.)

Rio Tinto. 2004. Rio Tinto's biodiversity strategy: Sustaining a natural balance. Rio Tinto, London and Melbourne. Unpublished document available at: www.riotinto.com/documents/ReportsPublications/RTBidoversitystrategyfinal.pdf.

Rio Tinto. 2008a. Rio Tinto and biodiversity: Achieving results on the ground. Rio Tinto, London and Melbourne. Unpublished document available at: www.riotinto.com/documents/ReportsPublications/RTBidoversitystrategyfinal.pdf.

Rio Tinto. 2008b. Standard E9—Land Use Stewardship. Unpublished document available at: www.riotinto.com/documents/ReportsPublications/LandUseStewardship.pdf.

Rio Tinto. 2008c. A biodiversity case study of Rio Tinto Madagascar / QMM: Achieving a Net Positive Impact on Biodiversity.

Rio Tinto. 2009. The Way We Work: our global code of business conduct. Unpublished document available at: www.riotinto.com/documents/The_way_we_work.pdf.

Rio Tinto. 2010. Biodiversity Action Planning Guidance Note. Unpublished document.

Rio Tinto QMM. 2001. Social and Environmental Impact Assessment "Ilmenite Project" (Office National d'Environnement 2001).

Rio Tinto QMM. 2008. Biodiversity Offsets Strategy—QMM Rio Tinto Madagascar: Draft working paper and issues for discussion. Unpublished document.

Rio Tinto QMM. 2010. Rio Tinto QMM Biodiversity Action Plan. Unpublished document.

Rodrigues, A.S.L. 2011. Improving coarse species distribution data for conservation planning in biodiversity-rich, data-poor, regions: no easy shortcuts. Animal Conservation, 14: 108–110.

Rondinini, C., Stuart, S. and Boitani, L. 2005. Habitat suitability models and the shortfall in conservation planning for African vertebrates. Conservation Biology, 19: 1488–1497.

Schütte, K. 2007. An inventory of the Mantodea and Phasmatodea in the littoral forests near Tolagnaro (Fort-Dauphin) / Inventaire des Mantodea et des Phasmatodea dans les forêts littorales des environs de Tolagnaro (Fort-Dauphin). Pp. 155–162 in: Ganzhorn, J.U., Goodman, S.M. and Vincelette, M. (eds.).

Biodiversity, Ecology and Conservation of Littoral Ecosystems in Southeastern Madagascar; Tolagnaro (Fort Dauphin). Smithsonian Institution, Washington DC.

Schütte, K. and Razafindraibe, P. 2007. Checklist of dragonflies of the littoral forests near Tolagnaro (Fort-Dauphin) / Liste de contrôle des libellules des forêts littorales des environs de Tolagnaro (Fort-Dauphin). Pp. 163–166 in: Ganzhorn, J.U., Goodman, S.M. and Vincelette, M. (eds.). Biodiversity, Ecology and Conservation of Littoral Ecosystems in Southeastern Madagascar; Tolagnaro (Fort Dauphin). Smithsonian Institution, Washington DC.

Society for Ecological Restoration International Science & Policy Working Group. 2004. The SER International Primer on Ecological Restoration. Society for Ecological Restoration International, Tucson, USA.

TEEB. 2010. The Economics of Ecosystems and Biodiversity: Mainstreaming the Economics of Nature: Chapter 4 Scaling down biodiversity and ecosystem risks to business www.teebweb.org/LinkClick.aspx?fileticket=tcneop1kys4%3d&tabid=1021&language=en-US.

ten Kate, K., Bishop, J. and Bayon, R. 2004. Biodiversity offsets: Views, experience, and the business case. IUCN, Gland, Switzerland and Cambridge, UK and Insight Investment, London.

van Aarde, R.J., Ferreira, S.M., Kritzinger, J.J., van Dyk, P.J., Vogt, M. *et al.* 1996. An evaluation of habitat rehabilitation on coastal dune forests in northern KwaZulu-Natal, South Africa. Restoration Ecology, 4: 334–345.

Vincelette, M., Dean, L. and Ganzhorn, J.U. 2007a. The QMM/Rio Tinto project history in Tolagnaro and its social and environmental concepts. Pp. 1–8 in: Ganzhorn, J.U., Goodman, S.M. and Vincelette, M. (eds.). Biodiversity, Ecology and Conservation of Littoral Ecosystems in Southeastern Madagascar; Tolagnaro (Fort Dauphin). Smithsonian Institution, Washington DC.

Vincelette, M. Theberge, M. and Randrihasipara, L. 2007b. Evaluations of forest cover at regional and local levels in the Tolagnaro region since 1950. Pp. 49–59 in: Ganzhorn, J.U., Goodman, S.M. and Vincelette, M. (eds.). Biodiversity, Ecology and Conservation of Littoral Ecosystems in Southeastern Madagascar; Tolagnaro (Fort Dauphin). Smithsonian Institution, Washington DC.

Vincelette, M., Dumouchel, J., Giroux, J. and Heriarivo, R. 2007c. The Tolagnaro (Fort Dauphin) region: a brief overview of the geology, hydrology and climatology. Pp. 9–18 in: Ganzhorn, J.U., Goodman, S.M. and Vincelette, M. (eds.). Biodiversity, Ecology and Conservation of Littoral Ecosystems in Southeastern Madagascar; Tolagnaro (Fort Dauphin). Smithsonian Institution, Washington DC.

Vincelette, M. Rabenantoandro, J., Randrihasipara, L., Randriatafika, F. and Ganzhorn, J. 2007d. Results from Ten Years of Restoration Experiments in the Southeastern Littoral Forests of Madagascar. Pp. 337–354 in: Ganzhorn, J.U., Goodman, S.M. and Vincelette, M. (eds.). Biodiversity, Ecology and Conservation of Littoral Ecosystems in Southeastern Madagascar; Tolagnaro (Fort Dauphin). Smithsonian Institution, Washington DC.

Virah-Sawmy, M. and Ebeling, J. 2010. The difficult road toward real-world engagement: conservation science and mining in southern Madagascar. Conservation Letters, 3: 288–289.

Virah-Sawmy, M., Willis, K.J. and Gillson, L. 2010. Evidence for drought and forest declines during the recent megafaunal extinctions in Madagascar. Journal of Biogeography, 37(3): 506–519.

Watson, J.E.M., Whittaker, R.J. and Dawson, T.P. 2005. The importance of littoral forest remnants for indigenous bird conservation in southeastern Madagascar. Biodiversity and Conservation, 14: 523–545.

Watson, J.E.M. 2007. Conservation of Bird Diversity in Madagascar's Southeastern Littoral Forests. Pp. 186–208 in: Ganzhorn, J.U., Goodman, S.M. and Vincelette, M. (eds.). Biodiversity, Ecology and Conservation of Littoral Ecosystems in Southeastern Madagascar; Tolagnaro (Fort Dauphin). Smithsonian Institution, Washington DC.

Wesener, T. 2009. Unexplored richness: discovery of 31 new species of Giant Pill-Millipedes endemic to Madagascar, with a special emphasis on microendemism (Diplopoda, Sphaerotheriida). Zootaxa, 2097: 3–134.

Wesener, T. and Wägele, J.W. 2007. Giant Pill-Millipedes (Diplopoda: Sphaerotheriida) in the Littoral Forest Fragments of Southeastern Madagascar. Pp. 147–154 in: Ganzhorn, J.U., Goodman, S.M. and Vincelette, M. (eds.). Biodiversity, Ecology and Conservation of Littoral Ecosystems in Southeastern Madagascar; Tolagnaro (Fort Dauphin). Smithsonian Institution, Washington DC.

Wesener, T., Enghoff, H. and Sierwald, P. 2009. Review of the Spirobolida on Madagascar, with descriptions of twelve new genera, including three genera of 'fire millipedes' (Diplopoda). Zookeys, 19: Special Issue.

APPENDIX 1

QMM Biodiversity Committee

QMM invited external biodiversity experts to participate in a formal Biodiversity Committee in 2003. The Committee had operated informally for several years prior to this. The Committee operates with full autonomy, being free to publically criticize Rio Tinto QMM (either individually or collectively), and receiving no remuneration for time spent on Committee meetings.[49]

The purpose of the Committee is to advise QMM on how best to conserve and enhance biodiversity within the project area before, during and after mining. The Committee also advises QMM and the regional authorities on biodiversity issues within the Fort Dauphin area. The Committee assists QMM with the implementation of its Biodiversity Programme, for example by critically reviewing and providing input to the draft Biodiversity Action Plan (Rio Tinto QMM, 2010) and the present report, and assisting with the preparation of the biodiversity monograph (Ganzhorn *et al.*, 2007).

The Guiding Principles of operation for the Biodiversity Committee include:

- Open and honest communication;
- Non-attribution of discussions;
- Full access to social and environmental information;
- Information and Committee process accessible to public;
- Members retain freedom to communicate, singly or collectively, about Committee activities and the project.

The Committee meets once a year; additional ad hoc meetings may be arranged between some or all members at other times. Meetings normally last three days, and include a mixture of technical and strategic issues. The Committee provides expert advice to QMM and can identify its own topics of interest and agenda priorities. The last day of each meeting includes a 'closed session' that only the Committee can attend (e.g. no Rio Tinto QMM staff may be present). The Committee typically gives Rio Tinto QMM a set of formal comments and recommendations at the end of each meeting, to which QMM must respond. QMM provides for any additional work requested by the Committee and mutually agreed upon.

Committee meetings are hosted by QMM; travel and living expenses related to meetings are reimbursed by QMM; however Committee members are not remunerated for their time and contribution to Committee meetings.

[49] Travel and living expenses are reimbursed, and committee members (or their institutions) may at times be engaged to deliver specific pieces of work which are financed either as separate contracts, or through the existing partnership frameworks (e.g. Rio Tinto has formal partnership programmes with a number of NGOs including RBG Kew), as appropriate.

APPENDIX 2

Quality Hectares and Units of Global Distribution

Quality Hectares (QH)

Quality Hectares are Rio Tinto's standard metric for tracking progress towards the NPI target at the global and site level. They are conceptually related to the 'habitat hectares' metric used in Victoria, Australia (Parkes *et al.*, 2003). A wide range of biodiversity values, including threatened species, rare habitats or non-timber forest products, may be expressed in terms of their quantity and quality. This is expressed as an 'Area × Quality' metric, referred to here as Quality Hectares (QH). For example, 100 hectares of forest in pristine condition would count as 100 Quality Hectares (100 ha × 100% quality = 100 QH), whereas 100 hectares of fairly degraded forest at 40% 'optimal quality' would be expressed as 40 Quality Hectares (100 ha × 40% quality = 40 QH).

Quality or condition can be measured in a variety of different ways, depending upon the habitat in question. Rio Tinto does not have a single 'one-size-fits-all' global method for measuring habitat quality because it is so context dependent, but rather recommends using established and accepted methods where these are available at the regional (e.g. national or state) level. Because there was no established methodology for evaluating habitat condition in Madagascar, QMM has developed its own classification method, with input from Missouri Botanical Garden (MBG), Royal Botanic Gardens (RBG Kew), FOFIFA,[50] and other experts. This method is described in Vincelette *et al.*, (2007b) and Rabenantoandro *et al.* (2007).

Units of Global Distribution (UD)

Units of Global Distribution are a novel metric, developed for this analysis, but conceptually related to Quality Hectares. A Unit of Global Distribution is equivalent to 1% of a species' global population (or 1% of its global distribution, in the event that population data are unavailable). Units of Global Distribution are calculated as follows: if a species has a global population of 1,000 individuals, and 10 of those are lost, that would be a loss of 1% of the global population or 1 'Unit of Global Distribution' (UD). Similarly, if a species has a global distribution of 100 ha, and 1 ha of its distribution is lost as a result of habitat loss caused by mining, that is a loss of 1% of its global distribution or 1 'Unit of Global Distribution' (UD).

A precedent for the use of this kind of metric can be found in the quantitative thresholds used to identify sites of global significance for biodiversity conservation. Under the Convention on Wetlands (Ramsar Convention, 1971), sites are

[50] The National Centre for Applied Research into Rural Development, www.fofifa.mg.

selected for the List of Wetlands of International Importance according to a suite of criteria adopted by the Conference of Parties, one of these being Criterion 6: "A wetland should be considered internationally important if it regularly supports 1% of the individuals in a population of one species or subspecies of waterbird" (Ramsar Convention Secretariat, 2004). Similarly, the criteria for the identification of Key Biodiversity Areas (KBAs) use thresholds of 1% or 5% of the species' global population (depending on the type of species in question) to identify Key Biodiversity Areas (Langhammer *et al.*, 2007).

This is the first offsets analysis to use Units of Global Distribution (UD) as a metric or currency, so their use warrants a brief discussion. Crucially, the use of the 'Units of Global Distribution' metric should not be seen to imply that different species are directly exchangeable. It will never be acceptable to simply state that it is permissible to render a species of plant extinct so long as one protects in perpetuity the entire global range of a particular frog species. Rather, it gives an idea of the scale of losses, and the concomitant scale of gains required to give a Net Positive Impact.

The advantage of Units of Global Distribution is that this metric is much more closely linked to the extinction risk[51] faced by a species than is simple hectares (or even Quality Hectares). For example, a loss of 80 ha of habitat would be catastrophic for a species with a total global distribution of 100 ha, but would be of negligible significance for a species with a total global distribution of 1,000,000 ha. The disadvantage is that it is slightly more difficult and time-consuming to calculate, although as demonstrated by the present analysis it is feasible. Essentially, Units of Global Distribution are a way of calibrating losses/gains measured in hectares (or Quality Hectares) so that they take into account the total global area of distribution of a particular biodiversity value. UD can be calculated for species, habitats, or other types of biodiversity value (e.g. non-timber forest products).

[51] Indeed, a reduction in Units of Global Distribution is essentially the same as what is measured by Criterion A of the IUCN Red List of Threatened Species. Under Criterion A, if a species loses >80% of its global population in 10 years/3 generations (which can be inferred based on reduction in distribution), it would be classed as Critically Endangered. Similarly, a reduction of >50% would render a species Endangered and a reduction of >30% would render a species Vulnerable (IUCN, 2001).

APPENDIX 3

Losses and gains in Quality Hectares (QH) of littoral forest

Type of loss/gain	Site	Forest cover in 2004	Background deforestation rate	Estimated forest cover remaining in 2065 given no mine	Quality in 2004	Total QH Lost	HA forest cover AZ or Offset	Quality in 2004	QH in 2004
LOSSES	Mandena Mining	330	0.009	208	0.11	23			
LOSSES	Petriky Mining	674	0.009	425	0.23	98			
LOSSES	Ste Luce Mining	661	0.009	417	0.74	307			
RESTORATION GAINS	Mandena restoration								
RESTORATION GAINS	Petriky restoration								
RESTORATION GAINS	Ste Luce restoration								
AVERTED LOSS IN AZs	Mandena Avoidance (AZ)						230	0.57	132
AVERTED LOSS IN AZs	Petriky Avoidance (AZ)						120	0.39	46
AVERTED LOSS IN AZs	Ste Luce Avoidance (AZ)						274	0.80	218
INCREASED QUALITY IN AZs	Mandena Avoidance (AZ)						230	0.57	132
INCREASED QUALITY IN AZs	Petriky Avoidance (AZ)						120	0.39	46
INCREASED QUALITY IN AZs	Ste Luce Avoidance (AZ)						274	0.80	218
AVERTED LOSS IN OFFSETS	Ste Luce Offset						498	0.84	420
AVERTED LOSS IN OFFSETS	Mahabo						1565	0.80	1252
AVERTED LOSS IN OFFSETS	Bemangidy						4000	0.90	3600
	Total All forest Types								
	Total Fort Dauphin Littoral Forest								
	Total Littoral Forest								

Quality in 2065	Area in 2065	QH in 2065	Deforestation rate	Reduced deforestation rate	Years of Intervention since 2004 baseline	QH remaining after 61 years @ background rate	QH remaining after 61 years @ 50%/75%/100% background rate	What proportion of offset gains can be claimed by Rio Tinto?	Net QH of Forest Gained through QMM investment
									-23.3
									-97.7
									-307.1
0.35	225	79							79
0.20	225	45							45
0.25	225	56							56
			0.009	0	61	76.1	132.1	1.00	56.0
			0.009	0	61	26.6	46.3	1.00	19.6
			0.009	0	61	125.6	218.1	1.00	92.4
0.97	230	224						1.00	92.0
0.59	120	70						1.00	24.0
1.00	274	274						1.00	55.9
			0.009	0.0023	61	242.0	366.1	1.00	124.1
			0.008	0.0040	61	767.0	980.4	0.63	134.5
			0.0255	0.0128	61	744.7	1645.7	1.00	901.0
									1251.4
									215.9
									350.4

APPENDIX 4

Characteristics of High Priority species for which losses and gains were calculated in Units of Global Distribution (UD)

Higher taxon 2	Scientific name	Non-endemic species with no like-for-like offset
Amphibians	*Guibemantis (Mantidactylus) bicalcaratus nov. sp.*	
Amphibians	*Guibemantis (Mantidactylus) cf pulcher nov. sp.*	
Amphibians	*Guibemantis (Mantidactylus) punctatus nov. sp.*	
Amphibians	*Madecassophryne truebae*	
Amphibians	*Stumpffia cf tridactyla nov. sp.*	
Reptiles	*Pseudoxyrhopus kely*	
Reptiles	*Phelsuma antanosy*	
Birds	*Anas melleri*	
Birds	*Ardea humbloti*	Yes
Terrestrial mammals	*Microcebus cf rufus nov. sp.*	
Giant pill-millipedes	*Zoosphaerium alluaudi*	
Giant pill-millipedes	*Zoosphaerium arborealis*	
Giant pill-millipedes	*Zoosphaerium sp. 'Sainte-Luce'*	
Giant pill-millipedes	*Sphaeromimus inexpectatus*	
Giant pill-millipedes	*Sphaeromimus splendidus*	
Spirobolid millipedes	*Riotintobolus mandensis*	
Spirobolid millipedes	*Riotintobolus minutus*	
Spirobolid millipedes	*Granitobolus sp.'black'*	
Spirobolid millipedes	*Alluviobolus laticlavius*	
Mantises (Mantodea)	*Nesogalepsus sp.*	
Mantises (Mantodea)	*"Tarachodinae" sp.*	
Mantises (Mantodea)	*Apterocorypha sp.*	
Mantises (Mantodea)	*Platycalymma sp.*	
Mantises (Mantodea)	*Tarachomantis sp.*	
Mantises (Mantodea)	*Tisma freyi*	
Mantises (Mantodea)	*Tisma pauliani*	
Mantises (Mantodea)	*Danuriella irregularis*	

Endemism status	IUCN Red List Status	Unit of measure-ment	Bespokeloss/gain measurements needed?	Global population size (number of individuals) - estimated for endemic plants	Global range (hectares)
Regional or local endemic	LC (G. bicalcaratus)	UD			1,595
Regional or local endemic	NE	UD			2,093
Regional or local endemic	DD (G. punctatus)	UD			2,093
Regional endemic	EN B1ab(iii)	UD			36,373
Regional or local endemic	DD	UD			2,093
Regional endemic (found only at two forest sites)	EN B2ab(ii,iii)	UD			11,660
Regional endemic (found only at two forest sites)	CR B2ab(ii,iii,iv)	UD	Yes		788
Country endemic	EN C2a(ii)	UD			2,111,126
Country endemic	EN C2a(ii)	UD			285,554
Regional or local endemic	LC (M. rufus)	UD			1,355
Regional or local endemic	NE	UD			890
Regional or local endemic	NE	UD			2,093
Regional or local endemic	NE	UD			498
Regional or local endemic	NE	UD			738
Regional or local endemic	NE	UD			857
Local endemic	NE	UD			738
Regional or local endemic	NE	UD			196
Local endemic	NE	UD			2,093
Local endemic	NE	UD			890
Regional or local endemic	NE	UD			2,093
Regional or local endemic	NE	UD			2,093
Regional or local endemic	NE	UD			2,093
Regional or local endemic	NE	UD			2,093
Regional or local endemic	NE	UD			2,093
Regional or local endemic	NE	UD			2,093
Regional or local endemic	NE	UD			2,093
Regional or local endemic	NE	UD			2,093

Higher taxon 2	Scientific name	Non-endemic species with no like-for-like offset
Stick insects (Phasmatodea)	*"Antongiliinae" sp.*	
Stick insects (Phasmatodea)	*Cirsia sp.*	
Stick insects (Phasmatodea)	*Pseudodatames sp.*	
Stick insects (Phasmatodea)	*Parectatosoma cf. cervinum*	
Stick insects (Phasmatodea)	*Leiophasma sp.1*	
Stick insects (Phasmatodea)	*Leiophasma sp.2*	
Stick insects (Phasmatodea)	*Xerantherix sp.1*	
Stick insects (Phasmatodea)	*Xerantherix sp.2*	
Stick insects (Phasmatodea)	*Anareolatae sp 1*	
Plants	*Acalypha vulneraria*	
Plants	*Aloe helenae Danguy*	Yes
Plants	*Asteropeia micraster Hallier f.*	
Plants	*Astrotrichilia elliotii (Harms) Cheek*	
Plants	*Beccariophoenix madagascariensis Jum. & H. Perrier*	
Plants	*Croton trichotomus Geiseler*	
Plants	*Cynorkis elata Rolfe*	
Plants	*Dalbergia delphinensis Bosser & Rabevohitra.*	Yes
Plants	*Dalbergia maritima R. Vig.*	
Plants	*Dombeya mandenensis Arènes*	
Plants	*Dombeya rariflora Arènes*	
Plants	*Dracaena bakeri Scott-Elliot*	
Plants	*Dypsis mananjarensis Jum & H.Perr*	
Plants	*Dypsis saintelucei Beentje*	
Plants	*Eligmocarpus cynometroides Capuron*	
Plants	*Enterospermum sp 30*	
Plants	*Erythroxylum myrtoides Bojer*	
Plants	*Eulophia filifolia Bosser & Morat*	
Plants	*Eulophia palmicola H. Perr.*	
Plants	*Euphorbia elliotii Leandri*	Yes
Plants	*Euphorbia francoisii Leandri*	

Endemism status	IUCN Red List Status	Unit of measure-ment	Bespokeloss/gain measurements needed?	Global population size (number of individuals) - estimated for endemic plants	Global range (hectares)
Local endemic	NE	UD			2,093
Local endemic	NE	UD			2,093
Local endemic	NE	UD			2,093
Local endemic	NE	UD			2,093
Local endemic	NE	UD			2,093
Local endemic	NE	UD			2,093
Local endemic	NE	UD			2,093
Local endemic	NE	UD			2,093
Local endemic	NE	UD		<10,000	2,093
Local endemic		UD		>10,000	890
	CR D	Ha		n/a (non-endemic)	
Local near-endemic (Mahabo)	EN A3cd	UD		n/a (non-endemic)	3,658
Local near-endemic (Mahabo)		UD		n/a (non-endemic)	3,887
	CR B1+2cd	Ha		n/a (non-endemic)	
Local endemic		UD		>10,000	1,628
Local endemic		UD		>10,000	2,093
	EN A2cd, B1+2bcde	Ha		n/a (non-endemic)	
	EN A1cd+2cd	Ha		n/a (non-endemic)	
Local endemic		UD		>10,000	2,093
Local endemic		UD		1,035,636	890
Local endemic		UD		>10,000	2,093
Local endemic	VU D1	UD		>10,000	2,093
Local endemic	CR D	UD		>10,000	1,355
Local endemic		UD	Yes	2,545	100
Local endemic		UD		<10,000	934
Local endemic		UD		<10,000	498
Local near-endemic (Mahabo)		UD	Yes	n/a (non-endemic)	1,615
Local endemic		UD		<10,000	738
	EN B1ab(iii)+2ab(iii)	Ha		n/a (non-endemic)	
Local endemic	CR B1ab(iii,v)	UD		>10,000	1,628

Higher taxon 2	Scientific name	Non-endemic species with no like-for-like offset
Plants	*Euphorbia lophogona Lam.*	
Plants	*Flagenium arboreum Wernham*	
Plants	*Grewia flavicans Boivin ex Baill.*	
Plants	*Hyperacanthus mandenensis Rakotonas. & A.P. Davis ined.*	
Plants	*Leptolaena delphinensis G.E. Schatz & Lowry*	
Plants	*Leptolaena pauciflora Baker*	
Plants	*Malleastrum mandenense J.-F. Leroy*	
Plants	*Meineckia websteri Brunel & J. Roux*	
Plants	*Millettia taolanaroensis Du Puy & Labat*	
Plants	*Myrtus madagascariensis H. Perrier*	
Plants	*Ocotea brevipes Kosterm.*	
Plants	*Oeceoclades longebracteata Bosser & Morat*	
Plants	*Paederia taolagnarensis Razafim. & C.M. Taylor*	
Plants	*Peponium poissonii Keraudren*	
Plants	*Phyllanthus nummulariifolius subsp. vinanibeae Brunel & J.P. Roux*	
Plants	*Phyllarthron ilicifolium (Pers.) H. Perrier*	
Plants	*Polyalthia madagascariensis Cavaco & Keraudren*	
Plants	*Polyalthia pendula Capuron ex G.E. Schatz & Le Thomas*	
Plants	*Pseudocatha sp nov*	
Plants	*Pyrostria sp.nov*	
Plants	*Rinorea pauciflora var. pauciflora (Thouars.) Baill.*	
Plants	*Senecio antandroi Scott-Elliot*	
Plants	*Sideroxylon beguei var. saboureaui Aubrev.*	
Plants	*Suregada baronii (S. Moore) Croizat*	
Plants	*Tricalysia cryptocalyx Baker*	
Plants	*Vitex bracteata Scott-Elliot*	
Plants	*Vitex grandidiana W. Piep.*	
Plants	*Vitex tristis Scott-Elliot*	

Endemism status	IUCN Red List Status	Unit of measure-ment	Bespokeloss/gain measurements needed?	Global population size (number of individuals) - estimated for endemic plants	Global range (hectares)
Local endemic	VU B1ab(iii,v)	UD		>10,000	2,093
Local endemic		UD		>10,000	890
Local endemic		UD		364	890
Local near-endemic (Mahabo)		UD		n/a (non-endemic)	4,458
Local endemic	CR A3cd	UD		>10,000	2,093
	EN A3cd	Ha		n/a (non-endemic)	
Local endemic		UD		>10,000	2,983
Local endemic		UD		70,909	890
	EN B1+2abc	Ha	Yes	n/a (non-endemic)	
Local endemic		UD	Yes	727	13
Local endemic		UD	Yes	2,545	31
Local endemic		UD		>10,000	890
Local endemic		UD		>10,000	1,628
Local endemic		UD	Yes	727	6
Local endemic		UD		602,909	890
Local endemic		UD		>10,000	2,983
Local endemic		UD		<10,000	1,595
Local endemic		UD		26,545	890
Local endemic		UD		>10,000	934
Local endemic		UD		>10,000	1,236
Local endemic		UD		408,000	1,628
Local endemic		UD		21,455	890
Local endemic		UD		>10,000	1,432
Local near-endemic (Mahabo)		UD		n/a (non-endemic)	1,761
Local endemic		UD		>10,000	2,983
Local endemic		UD		20,364	890
Local endemic		UD		>10,000	2,093
Local endemic		UD		>10,000	2,093

APPENDIX 5

Net impact in terms of Units of Global Distribution for High Priority species: like-for-like species only

Group	Scientific name	Global range (hectares)	Net impact (ha) excl. restoration
Amphibians	*Guibemantis (Mantidactylus) bicalcaratus sp nov*	1,595	-476.2
Amphibians	*Guibemantis (Mantidactylus) cf pulcher sp nov*	2,093	-329.0
Amphibians	*Guibemantis (Mantidactylus) punctatus sp nov*	2,093	-329.0
Amphibians	*Madecassophryne truebae*	36,373	-333.9
Amphibians	*Stumpffia cf tridactyla ?sp nov*	2,093	-329.0
Reptiles	*Pseudoxyrhopus kely*	11,660	-796.4
Reptiles	*Phelsuma antanosy*	788	-40.4
Birds	*Anas melleri*	2,111,126	25.8
Birds	*Ardea humbloti*	285,554	-142.3
Terrestrial mammals	*Microcebus cf rufus ?sp nov*	1,355	-186.7
Giant pill-millipedes	*Zoosphaerium alluaudi*	890	-384.3
Giant pill-millipedes	*Zoosphaerium arborealis*	2,093	-329.0
Giant pill-millipedes	*Zoosphaerium sp. 'Sainte-Lucé'*	498	147.2
Giant pill-millipedes	*Sphaeromimus inexpectatus*	738	-142.3
Giant pill-millipedes	*Sphaeromimus splendidus*	857	-333.9
Spirobolid millipedes	*Riotintobolus mandensis*	738	-142.3
Spirobolid millipedes	*Riotintobolus minutus*	196	83.1
Spirobolid millipedes	*Granitobolus sp. 'black'*	2,093	-329.0
Spirobolid millipedes	*Alluviobolus laticlavius*	890	-384.3
Mantises (Mantodea)	*Nesogalepsus sp.*	2,093	-329.0
Mantises (Mantodea)	*"Tarachodinae" sp.*	2,093	-329.0
Mantises (Mantodea)	*Apterocorypha sp.*	2,093	-329.0
Mantises (Mantodea)	*Platycalymma sp.*	2,093	-329.0
Mantises (Mantodea)	*Tarachomantis sp.*	2,093	-329.0
Mantises (Mantodea)	*Tisma freyi*	2,093	-329.0
Mantises (Mantodea)	*Tisma pauliani*	2,093	-329.0
Mantises (Mantodea)	*Danuriella irregularis*	2,093	-329.0
Stick insects (Phasmatodea)	*"Antongiliinae" sp.*	2,093	-329.0
Stick insects (Phasmatodea)	*Cirsia sp.*	2,093	-329.0
Stick insects (Phasmatodea)	*Pseudodatames sp.*	2,093	-329.0
Stick insects (Phasmatodea)	*Parectatosoma cf. cervinum*	2,093	-329.0

Net impact (UD) excl. restoration	Net impact (ha) incl. restoration	Net impact (UD) incl. restoration	NPI achieved? 1=Yes; 0=No	Is NPI achievable (given proposed offsets & restoration portfolio)?
-29.9	-26.2	-1.6	0	?
-15.7	121.0	5.8	1	Yes
-15.7	121.0	5.8	1	Yes
-0.9	-108.9	-0.3	0	?
-15.7	121.0	5.8	1	Yes
-6.8	-346.4	-3.0	0	?
-5.1	-40.4	-5.1	0	?
0.0	250.8	0.0	1	Yes
0.0	82.7	0.0	1	Yes
-13.8	38.3	2.8	1	Yes
-43.2	-159.3	-17.9	0	?
-15.7	121.0	5.8	1	Yes
29.6	147.2	29.6	1	Yes
-19.3	82.7	11.2	1	Yes
-39.0	-108.9	-12.7	0	?
-19.3	82.7	11.2	1	Yes
42.4	308.1	157.2	1	Yes
-15.7	121.0	5.8	1	Yes
-43.2	-159.3	-17.9	0	?
-15.7	121.0	5.8	1	Yes
-15.7	121.0	5.8	1	Yes
-15.7	121.0	5.8	1	Yes
-15.7	121.0	5.8	1	Yes
-15.7	121.0	5.8	1	Yes
-15.7	121.0	5.8	1	Yes
-15.7	121.0	5.8	1	Yes
-15.7	121.0	5.8	1	Yes
-15.7	121.0	5.8	1	Yes
-15.7	121.0	5.8	1	Yes
-15.7	121.0	5.8	1	Yes
-15.7	121.0	5.8	1	Yes

Group	Scientific name	Global range (hectares)	Net impact (ha) excl. restoration
Stick insects (Phasmatodea)	*Leiophasma sp.1*	2,093	-329.0
Stick insects (Phasmatodea)	*Leiophasma sp.2*	2,093	-329.0
Stick insects (Phasmatodea)	*Xerantherix sp.1*	2,093	-329.0
Stick insects (Phasmatodea)	*Xerantherix sp.2*	2,093	-329.0
Stick insects (Phasmatodea)	*Anareolatae sp 1*	2,093	-329.0
Plants	*Acalypha vulneraria*	890	-384.3
Plants	*Aloe helenae Danguy*		-384.3
Plants	*Aspidostemun parvifolium*	890	-384.3
Plants	*Asteropeia micraster Hallier f.*	3,658	-160.9
Plants	*Astrotrichilia elliotii (Harms) Cheek*	3,887	-128.2
Plants	*Beccariophoenix madagascariensis Jum. & H. Perrier*		88.0
Plants	*Cadia commersoniana*	890	-384.3
Plants	*Capurodendron delphinensis*	890	-384.3
Plants	*Claoxylon flavum*	890	-384.3
Plants	*Coffea comersoniana*	2983	-713.3
Plants	*Croton trichotomus Geiseler*	1,628	-526.6
Plants	*Cynorkis elata Rolfe*	2,093	-329.0
Plants	*Dalbergia delphinensis Bosser & Rabevohitra.*		-142.3
Plants	*Dalbergia maritima R. Vig.*		-329.0
Plants	*Dombeya mandenensis Arènes*	2,093	-329.0
Plants	*Dombeya rariflora Arènes*	890	-384.3
Plants	*Dracaena bakeri Scott-Elliot*	2,093	-329.0
Plants	*Dypsis mananjarensis Jum & H.Perr*	2,093	-329.0
Plants	*Dypsis saintelucei Beentje*	1,355	-186.7
Plants	*Eligmocarpus cynometroides Capuron*	100	-0.3
Plants	*Enterospermum sp 30*	934	-59.2
Plants	*Erythroxylum myrtoides Bojer*	498	147.2
Plants	*Eulophia filifolia Bosser & Morat*	1,615	153.7
Plants	*Eulophia palmicola H. Perr.*	738	-142.3
Plants	*Euphorbia elliotii Leandri*		-443.5
Plants	*Euphorbia francoisii Leandri*	1,628	-526.6
Plants	*Euphorbia lophogona Lam.*	2,093	-329.0
Plants	*Flagenium arboreum Wernham*	890	-384.3
Plants	*Grewia flavicans Boivin ex Baill.*	890	-384.3
Plants	*Hyperacanthus mandenensis Rakotonas. & A.P. Davis ined.*	4,458	-545.2

Net impact (UD) excl. restoration	Net impact (ha) incl. restoration	Net impact (UD) incl. restoration	NPI achieved? 1=Yes; 0=No	Is NPI achievable (given proposed offsets & restoration portfolio)?
-15.7	121.0	5.8	1	Yes
-15.7	121.0	5.8	1	Yes
-15.7	121.0	5.8	1	Yes
-15.7	121.0	5.8	1	Yes
-15.7	121.0	5.8	1	Yes
-43.2	-159.3	-17.9	0	Provisional yes
n/a	-159.3	n/a	0	Provisional yes
-43.2	-159.3	-17.9	0	Provisional yes
-4.4	289.1	7.9	1	Yes
-3.3	546.8	14.1	1	Yes
n/a	538.0	n/a	1	Yes
-43.2	-159.3	-17.9	0	Provisional yes
-43.2	-159.3	-17.9	0	Provisional yes
-43.2	-159.3	-17.9	0	Provisional yes
-23.9	-38.3	-1.3	0	Provisional yes
-32.3	-76.6	-4.7	0	Provisional yes
-15.7	121.0	5.8	1	Yes
n/a	82.7	n/a	1	Yes
n/a	121.0	n/a	1	Yes
-15.7	121.0	5.8	1	Yes
-43.2	-159.3	-17.9	0	Provisional yes
-15.7	121.0	5.8	1	Yes
-15.7	121.0	5.8	1	Yes
-13.8	38.3	2.8	1	Yes
-0.3	163.7	163.7	1	Yes
-6.3	390.8	41.8	1	Yes
29.6	147.2	29.6	1	Yes
9.5	212.3	13.1	1	Yes
-19.3	82.7	11.2	1	Yes
n/a	231.5	n/a	1	Yes
-32.3	-76.6	-4.7	0	Provisional yes
-15.7	121.0	5.8	1	Yes
-43.2	-159.3	-17.9	0	Provisional yes
-43.2	-159.3	-17.9	0	Provisional yes
-12.2	129.8	2.9	1	Yes

Group	Scientific name	Global range (hectares)	Net impact (ha) excl. restoration
Plants	*Leptolaena delphinensis G.E. Schatz & Lowry*	2,093	-329.0
Plants	*Leptolaena pauciflora Baker*		840.2
Plants	*Malleastrum mandenense J.-F. Leroy*	2,983	-713.3
Plants	*Meineckia websteri Brunel & J. Roux*	890	-384.3
Plants	*Millettia taolanaroensis Du Puy & Labat*		-62.5
Plants	*Myrtus madagascariensis H. Perrier*	13	3.5
Plants	*Ocotea brevipes Kosterm.*	31	13.2
Plants	*Oeceoclades longebracteata Bosser & Morat*	890	-384.3
Plants	*Paederia taolagnarensis Razafim. & C.M. Taylor*	1,628	-526.6
Plants	*Peponium poissonii Keraudren*	6	2.6
Plants	*Phyllanthus nummulariifolius subsp. vinanibeae Brunel & J.P. Roux*	890	-384.3
Plants	*Phyllarthron ilicifolium (Pers.) H. Perrier*	2,983	-713.3
Plants	*Polyalthia madagascariensis Cavaco & Keraudren*	1,595	-476.2
Plants	*Polyalthia pendula Capuron ex G.E. Schatz & Le Thomas*	890	-384.3
Plants	*Pseudocatha sp nov*	934	-59.2
Plants	*Pyrostria sp.nov*	1,236	4.9
Plants	*Rinorea pauciflora var. pauciflora (Thouars.) Baill.*	1,628	-526.6
Plants	*Senecio antandroi Scott-Elliot*	890	-384.3
Plants	*Sideroxylon beguei var. saboureaui Aubrev.*	1,432	88.0
Plants	*Suregada baronii (S. Moore) Croizat*	1,761	251.2
Plants	*Tricalysia cryptocalyx Baker*	2,983	-713.3
Plants	*Vitex bracteata Scott-Elliot*	890	-384.3
Plants	*Vitex grandidiana W. Piep.*	2,093	-329.0
Plants	*Vitex tristis Scott-Elliot*	2,093	-329.0

Net impact (UD) excl. restoration	Net impact (ha) incl. restoration	Net impact (UD) incl. restoration	NPI achieved? 1=Yes; 0=No	Is NPI achievable (given proposed offsets & restoration portfolio)?
-15.7	121.0	5.8	1	Yes
n/a	1290.2	n/a	1	Yes
-23.9	-38.3	-1.3	0	Provisional yes
-43.2	-159.3	-17.9	0	Provisional yes
n/a	0.0	n/a	1	Yes
28.2	29.9	239.1	1	Yes
42.4	86.5	276.8	1	Yes
-43.2	-159.3	-17.9	0	Provisional yes
-32.3	-76.6	-4.7	0	Provisional yes
42.4	17.3	276.8	1	Yes
-43.2	-159.3	-17.9	0	Provisional yes
-23.9	-38.3	-1.3	0	Provisional yes
-29.9	-26.2	-1.6	0	Provisional yes
-43.2	-159.3	-17.9	0	Provisional yes
-6.3	390.8	41.8	1	Yes
0.4	229.9	18.6	1	Yes
-32.3	-76.6	-4.7	0	Provisional yes
-43.2	-159.3	-17.9	0	Provisional yes
6.1	538.0	37.6	1	Yes
14.3	476.2	27.0	1	Yes
-23.9	-38.3	-1.3	0	Provisional yes
-43.2	-159.3	-17.9	0	Provisional yes
-15.7	121.0	5.8	1	Yes
-15.7	121.0	5.8	1	Yes

Rio Tinto

IUCN