BHP Billiton Iron Ore Strategic Assessment: Cumulative Impact Assessment

Commonwealth Cumulative Impact Assessment Report

Revision 5

Prepared for
BHP Billiton Iron Ore

3 August 2015

eco logical AUSTRALIA

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Abbreviations

Abbreviation	Description
AATB	Assessment of Australia's Terrestrial Biodiversity
BRT	Boosted regression tree
CIA	Cumulative impact assessment
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DAFWA	Department of Agriculture and Food Western Australia
DEC	Department of Environment and Conservation (Western Australia)
DEH	Australian Government Department of Environment and Heritage
DEM	Digital elevation model
DER	Department of Environment Regulation (Western Australia)
DERM	Department of Environment and Resource Management (Queensland)
DoE	Australian Government Department of the Environment
EHU	Ecohydrological unit
EIA	Environmental impact assessment
EPA	Environmental Protection Authority (Western Australia)
EP Act	*Environmental Protection Act 1986* (WA)
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth)
ELA	Eco Logical Australia
GAM	Generalised additive model
GCM	Global Climate Model
GDM	Generalised dissimilarity modelling
GIS	Geographic information system
GLM	Generalised linear model
GRASP	Generalised regression analysis and spatial predictions
ha	Hectare
IBRA	Interim Biogeographic Regionalisation for Australia
IUCN	International Union for Conservation of Nature
km	Kilometre
m	Metre
MARS	Multivariate adaptive regression splines
MNES	Matter of National Environmental Significance
Parks and Wildlife	Department of Parks and Wildlife (Western Australia)

Abbreviation	Description
QLD	Queensland
RF	Random Forest
ROC	Receiver operating characteristic
SPRAT	Species Profiles and Threats
TDS	Total dissolved solids
TSSC	Threatened Species Scientific Committee
VM Act	*Vegetation Management Act 1999* (QLD)
WA	Western Australia

Glossary

Term	Definition
Asset	A specific component of the biophysical environment which supports one or more environmental and/or social values, such as Karijini National Park and Fortescue Marsh.
Base case	The initial extent of habitat suitability as modelled, prior to application of Scenario 1.
Baseline	A starting point that may be used for comparisons.
Conceptual modelling	A type of diagram which shows of a set of relationships between factors within a system.
Cumulative impact assessment	As assessment of the effects of multiple actions or impacts on the environment that may combine over time and space.
Full Development Scenario	The predicted or expected full extent of development of the Strategic Assessment at closure.
Landscape	A spatially heterogeneous area, scaled relative to the process of interest. Within landscapes it is usually possible to define a series of different ecosystems, landforms, habitats and natural or man-made features.
Operational hub	A location of mining activities on BHP Billiton Iron Ore tenure. The operational hub may contain one or more processing hubs within it, depending on the mining strategy.
Operations	Collective term for operational hubs.
Predictive modelling	A statistical technique used to expand on existing data and predict a greater spatial extent and future states.
Predictive habitat modelling	The use of predictive modelling (refer to definition) to model habitat, in this case on a regional scale.
Processing hub	A location within a BHP Billiton Iron Ore operational hub, where mined ore is processed, stockpiled and loaded for transport. Typically comprised of crushers, ore handling plant/s, stockyard/s, train load-out and/or conveyors.
Region	The range, area or scope relevant to a specific asset, value or factor of interest.
Regional scale	At the scale of the region (refer to definition).
Scenario 1	Application of existing mining (BHP Billiton Iron Ore and third party) and non-mining impacts to the base case.
Scenario 2	Application of Scenario 1 and impacts from reasonably foreseeable future third party iron ore mines.
Scenario 3	Application of Scenario 2 and impacts from the Full Development Scenario.
Strategic Assessment (the Proposal)	Represents approximately 100 years of BHP Billiton Iron Oreȇs proposed operations in the Pilbara bioregion and includes all greenfields mine development, involving resources in which BHP Billiton Iron Ore currently has an interest, or may acquire an interest in in the future, and brownfields development of existing assets.
Value	Any particular benefit of use of the environment that is important for a healthy ecosystem or for public benefit. Values are not quantifiable and cannot be directly monitored,

Term	Definition
	measured or assessed.

Executive Summary

INTRODUCTION

The Australian Government entered into an agreement (the Agreement) with BHP Billiton Iron Ore on 18 September 2012 to undertake a strategic environmental assessment under the *Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth) (EPBC Act) of the potential environmental impacts of BHP Billiton Iron Ore's Strategic Assessment (the Proposal). This cumulative impact assessment (CIA) report provides an assessment of the potential cumulative impacts at a regional scale of the Proposal to five Matters of National Environmental Significance (MNES) under the EPBC Act.

The strategic environmental assessment of the Proposal under the EPBC Act will be informed by two components: the MNES Program and the Impact Assessment Report (IAR). The purpose of the MNES Program and the IAR is to address the requirements of the Agreement. The CIA is a key component of the IAR and has been written to be considered as an appendix to the IAR.

The MNES Program sets out BHP Billiton Iron Ore's proposed approach to the application of the mitigation hierarchy to minimise impacts to relevant MNES to an acceptable level. The MNES Program details how BHP Billiton Iron Ore will embed application of the mitigation hierarchy during its internal project development, construction, operation and rehabilitation. The MNES Program outlines the requirement for implementation plans to address biodiversity, offsets, monitoring and reporting.

The IAR addresses in full the assessment requirements of the Terms of Reference under the Agreement, presents the findings of this CIA and other component studies and addresses the significance of potential impacts to relevant MNES when mitigation measures are taken into consideration.

The CIA is one of a number of inputs to the IAR. The CIA addressed and quantified potential cumulative impacts to five MNES using models of habitat suitability developed for each species by ELA (2015). The potential impact to habitat suitability was used in the CIA as a proxy to assess potential impacts to MNES. Each of the ELA (2015) models provided a GIS layer of predicted relative probability of potential habitat across the Pilbara bioregion, which ranged from zero to 100 per cent and can be thought of as broadly analogous to 'habitat suitability'.

The Proposal will also undergo a strategic environmental assessment under the *Environmental Protection Act 1986* (WA) (EP Act); a CIA to support the strategic environmental assessment of the Proposal under the EP Act is reported on separately.

CUMULATIVE IMPACT ASSESSMENT IN CONTEXT

CIA aims to consider the effects of multiple actions or impacts on the environment that may combine over time and space. This CIA focuses on:

- Space crowding, occurring when a system is disturbed by several similar activities, or by different activities producing a similar effect, in an area too small to assimilate the combined impacts (Rees 1995).
- Additive interactive effects, reflecting the interactive nature of ecosystems.

- Indirect impacts arising as a result of an action.

Time crowding (when impacts are so close in time that the impact of one action is not dissipated before the next occurs; CEARC 1986), and synergistic cumulative impacts were considered as part of the scoping of this assessment. Based on the available scientific knowledge and data for the region, it was determined that a credible analysis of these types of impacts was beyond the capacity of present analytical capabilities and the limitations of the best available data.

The approaches and methodologies applied in CIA tend to be less standardised than conventional environmental impact assessment practices; a customised approach is applied, addressing the location, scale and particular context of the action or proposal.

CIA provides insight into, rather than a definitive or final landing point, on the combined effects of projects. This CIA is a first of its kind for the Pilbara and represents a significant contribution by BHP Billiton Iron Ore to provide an analysis of the potential effects of iron ore mining development in the Pilbara. It also provides government and industry with a substantial foundation for undertaking further assessment of cumulative impacts in the future, as planning for, and understanding of, potential impacts develops.

OBJECTIVES OF THE CIA

The objectives of this CIA were to:

- present a base case of habitat suitability in the Pilbara bioregion for each of the five relevant MNES, from which potential cumulative impact increases could be measured;
- quantify the potential cumulative impacts to habitat suitability of both existing non-mining land use and activities and iron ore projects operating and proposed in the Pilbara bioregion; using a conservative approach without the inclusion of management and mitigation measures;
- determine the proportion of potential cumulative impact attributable to the Proposal;
- assess the implications of the potential cumulative impact attributable to the Proposal in the context of the total potential cumulative impact and the ecology of each MNES.

The key stages of this CIA were to (1) predict habitat suitability for each of the five relevant MNES, (2) identify key threats to these MNES and (3) quantify the area of potential change in habitat suitability under defined scenarios (**Figure ES1**).

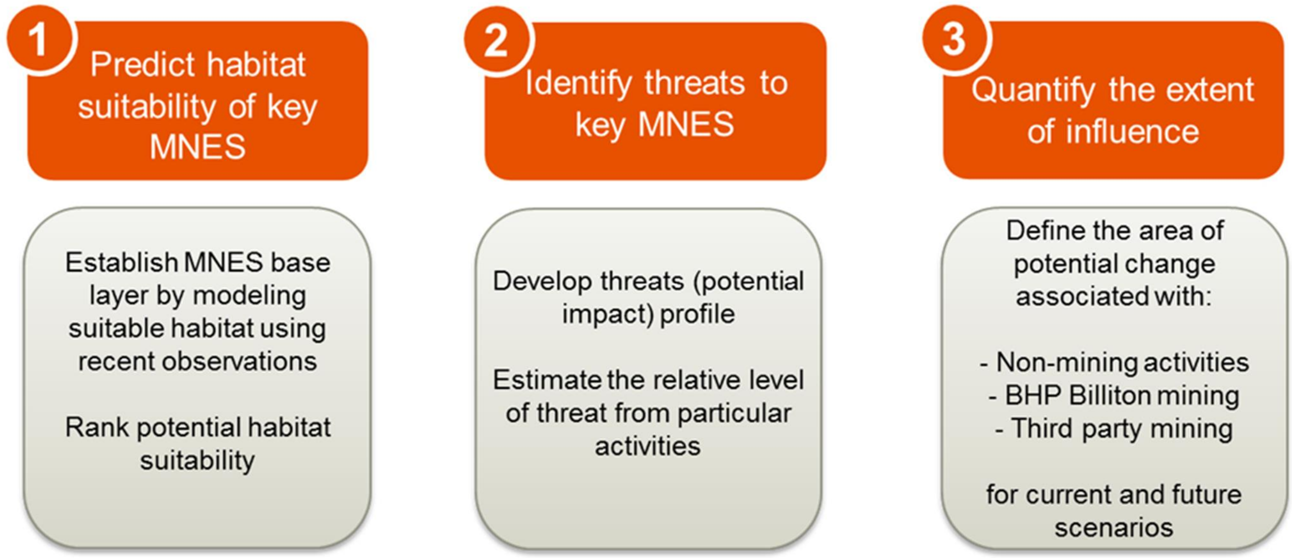

Figure ES1: Key stages of the CIA

SCOPE AND METHODS OF THE CIA

Cumulative impact scenarios

A scenario-based approach was used to examine different potential cumulative impact outcomes (**Figure ES2**). Each scenario was analysed independently, with the order of the scenarios not affecting analysis outcomes. The amount of the potential cumulative impact attributable to each individual component impact was determined through analysis of the change from one scenario to another scenario, or to the base case.

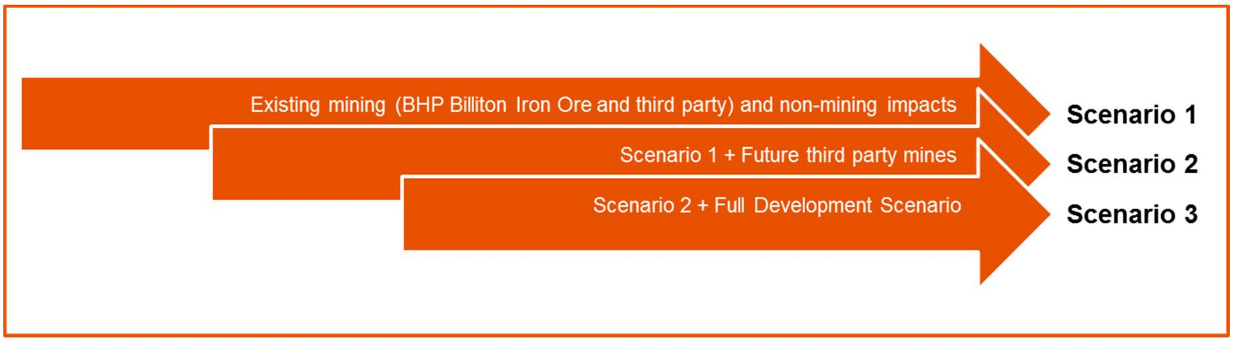

Figure ES2: Scenarios used in the CIA

Based on current available resource knowledge, the Proposal represents approximately 100 years of BHP Billiton Iron Ore's proposed operations in the Pilbara bioregion. However, this could vary in the future due to changes in the economic climate and resource knowledge. The Full Development Scenario represents the predicted or expected full extent of development of the Proposal at closure.

The Proposal comprises construction, operation and eventual closure of a number of new operational iron ore hubs, expansion (and eventual closure) of existing operational iron ore hubs, and capacity upgrades to the main Newman to Port Hedland rail line and associated spur lines to existing and proposed hubs. The Proposal specifically excludes existing and approved BHP Billiton Iron Ore operations and infrastructure (but includes their proposed expansions), future development of BHP

Billiton Iron Ore northern Pilbara operations at Yarrie and Goldsworthy and associated infrastructure; and development and operations at Port Hedland, including rail to the 26 kilometre chainage mark. With regard to the former, while existing BHP Billiton Iron Ore operations and infrastructure are excluded from the Proposal, they have been included in Scenario 1 of the CIA (**Figure ES2**) to enable the assessment of cumulative impacts of existing iron ore and non-mining activities, and proposed future iron ore mining activities.

Matters of National Environmental Significance

Loss or degradation of modelled habitat suitability caused by a number of potential impacts attributable to existing or proposed mining activity and to historical development was predicted for the following MNES: *Macrotis lagotis* (Greater Bilby), *Lepidium catapycnon* (Hamersley Lepidium), *Dasyurus hallucatus* (Northern Quoll), *Rhinonicteris aurantia* (Pilbara Leaf-nosed Bat) and *Liasis olivaceus barroni* (Pilbara Olive Python).

Relevant potential impacts

The assessment considered a range of potential impacts and how these may combine in a cumulative sense. The sources of potential impacts considered were the Full Development Scenario, existing mining projects and non-mining activities and land use for which data were available, and reasonably foreseeable future third party iron ore projects. Relevant impacts to each MNES and biodiversity group were determined on a case by case basis according to their attributes, values and likely sensitivity to different types of impacts.

Species-specific impacts were identified for each MNES through review of available scientific and other literature, and were informed by the outcomes of workshops which specifically identified key threats to species and identified knowledge gaps and further research priorities. For each species, impacts applied comprised a subset of the following (further detailed in Section 3 to Section 7 of this report):

- removal of habitat;
- fragmentation of habitat;
- predation;
- mortality from collision with vehicles;
- grazing;
- introduction or spread of weeds;
- change in hydrology/hydrogeology.

Potential impacts were applied to each habitat model as spatial layers using numerical values to represent the potential effect of each impact. Spatial layers were generated separately to account for the potential effect of each impact on its own, independent of other impacts, and then consolidated into an óall impactsô spatial layer for each CIA scenario.

Data used in the CIA

The assessment used the best available data for the study region. The main sources of data were from BHP Billiton Iron Ore (including data for third party iron ore disturbance footprints derived by BHP Billiton Iron Ore) and Geoscience Australia.

Detailed engineering design has not yet been undertaken for all of the elements of the Proposal. The Full Development Scenario footprint used in the CIA is an indicative and non-exhaustive delineation of likely hub configurations in respect to currently known resources. The location of mines and rail corridors may change in the future, for example in response to newly identified resources, as a result of technology advances or to avoid environmental impacts. This level of information is considered appropriate for a regional scale assessment.

The key study commissioned by BHP Billiton Iron Ore to support the assessment of potential cumulative impacts to MNES was species habitat modelling conducted by ELA (2015). The study utilised a considerable number of datasets from multiple sources and produced models that were used as base layers (in a Geographic Information System; GIS) to which datasets representing potential impacts were applied to quantify cumulative impacts.

KEY OUTCOMES OF THE CIA

The potential cumulative impact to Greater Bilby habitat suitability in the Pilbara was a decrease in the extent of the most suitable habitat of approximately 1.4 million hectares (85 per cent of the modelled extent in the base case). Existing impacts were the main contributor to this potential impact. The substantial decrease in habitat suitability from existing impacts is likely due to a combination of grazing pressure and extensive development of roads and human settlements (resulting in increased habitat fragmentation, predation and mortality from collision with vehicles) around and to the east and south-east of Marble Bar, and in the area around 170 kilometres south of Port Hedland. The modelled potential impact of the Full Development Scenario to the most suitable Greater Bilby habitat was less than one per cent. The contributions of future third party mines and the Full Development Scenario to the overall potential cumulative impact to Greater Bilby habitat suitability were minor as a percentage of the total area of the Pilbara bioregion and in comparison to the effect of existing impacts.

The potential cumulative impact to Hamersley Lepidium habitat suitability was a decrease in the extent of the most suitable habitat of approximately 61,000 hectares (seven per cent of the modelled extent in the base case), predominantly as a result of the Full Development Scenario.

The potential cumulative impact to Northern Quoll habitat suitability in the Pilbara was a decrease in the extent of the most suitable habitat of approximately 1.4 million hectares (90 per cent of the modelled extent in the base case). Existing impacts were the main contributor to this potential impact. The substantial decrease in habitat suitability from existing impacts is likely due mainly to fragmentation of habitat and to a lesser extent predation and mortality from collision with road vehicles as a result of extensive development of roads and human settlements in the northern Pilbara. The modelled potential impact of the Full Development Scenario to the most suitable Northern Quoll habitat was less than one per cent. The contributions of future third party mines and the Full Development Scenario to the overall potential cumulative impact to Northern Quoll habitat suitability were minor as a percentage of the total area of the Pilbara bioregion and in comparison to the effect of existing impacts.

The potential cumulative impact to Pilbara Leaf-nosed Bat habitat suitability was a decrease in the extent of the most suitable habitat of approximately 39,000 hectares (two per cent of the modelled extent in the base case), mostly as a result of existing impacts. The modelled potential impact of the Full Development Scenario to the most suitable Pilbara Leaf-nosed Bat habitat was less than one per cent.

The potential cumulative impact to Pilbara Olive Python habitat suitability was a decrease in the extent of the most suitable habitat of approximately 841,000 hectares (75 per cent of the modelled extent in the base case). Existing impacts were the main contributor to this potential impact. The substantial decrease in habitat suitability from existing impacts was predominantly a downgrading of habitat throughout and to the north of the Hamersley Ranges, and to the west of Marble Bar. This was likely due to a combination of development of roads, human settlements, or mines in these areas, contributing to habitat fragmentation, predation and mortality from collision with vehicles. The modelled potential impact of the Full Development Scenario to the most suitable Pilbara Olive Python habitat was less than one per cent. The contributions of future third party mines and the Full Development Scenario to the overall potential cumulative impact to Pilbara Olive Python habitat suitability were minor as a percentage of the total area of the Pilbara bioregion and in comparison to the effect of existing impacts.

The distributions of the Greater Bilby and Northern Quoll extend beyond the Pilbara bioregion and this assessment therefore may overstate the potential impacts to these species if considered across the speciesôentire range. The Greater Bilby also occurs in the Tanami Desert in the Northern Territory, and the Great Sandy and Gibson Deserts and south-western Kimberley in Western Australia (DoE 2013b). The Northern Quoll also occurs in the Kimberley in Western Australia, the Top End of the Northern Territory, and eastern Queensland (Biota 2009; DoE 2013b). The conclusions drawn in this report should be considered in the context of each speciesôcomplete distribution.

The significance of the potential impacts to each of the relevant MNES has been assessed as part of the IAR.

1 Introduction

1.1 PURPOSE AND OBJECTIVES OF THIS REPORT

This cumulative impact assessment (CIA) report provides an assessment of the potential cumulative impacts at a regional scale of BHP Billiton Iron Ore's Strategic Assessment (the Proposal) to five Matters of National Environmental Significance (MNES) under the *Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth) (EPBC Act). The CIA is one of a number of inputs to the Impact Assessment Report (IAR), which is one of two components of the strategic environmental assessment under the EPBC Act of the Proposal. The IAR addresses in full the assessment requirements of the Terms of Reference under the strategic environmental assessment agreement. The IAR presents the findings of this CIA and other component studies and addresses the significance of potential impacts to relevant MNES when mitigation measures are taken into consideration.

The objectives of this CIA were to:

- present a base case of habitat suitability in the Pilbara bioregion for each of the five relevant MNES, from which potential cumulative impact increases could be measured;
- quantify the potential cumulative impacts to habitat suitability of both existing non-mining land use and activities and iron ore projects operating and proposed in the Pilbara bioregion; using a conservative approach without the inclusion of management and mitigation measures;
- determine the proportion of potential cumulative impact attributable to the Proposal;
- assess the implications of the potential cumulative impact attributable to the Proposal in the context of the total potential cumulative impact and the ecology of each MNES.

1.2 BACKGROUND TO THE PROPOSAL

The Australian Government entered into an agreement (the Agreement) with BHP Billiton Iron Ore on 18 September 2012 to undertake a strategic environmental assessment under the EPBC Act of the potential environmental impacts of the Proposal The Proposal will also undergo a strategic environmental assessment under the *Environmental Protection Act 1986* (WA) (EP Act); a CIA to support the strategic environmental assessment of the Proposal under the EP Act is reported on separately.

The Proposal is proposed for development within BHP Billiton's mining operation tenure in the Pilbara bioregion of Western Australia (**Figure 1**). The CIA has been undertaken for existing iron ore mining (BHP Billiton Iron Ore and third party) and non-mining impacts in the Pilbara bioregion of Western Australia and two future iron ore development scenarios: future third party mines only, and future third party mines plus the Full Development Scenario (**Figure 2**). Based on current available resource knowledge, the Proposal represents approximately 100 years of BHP Billiton Iron Ore's proposed operations in the Pilbara bioregion; however, this could vary in the future due to changes in the economic climate and resource knowledge. The Full Development Scenario represents the predicted or expected full extent of development of the Proposal at closure.

The Proposal comprises construction, operation and eventual closure of a number of new operational iron ore hubs, expansion (and eventual closure) of existing operational iron ore hubs, and capacity upgrades to the main Newman to Port Hedland rail line and associated spur lines to existing and proposed hubs (**Figure 2**). Disturbance associated with each operational hub ranges from 1,000 to 9,000 hectares. The total disturbance footprint of the Full Development Scenario is approximately 106,000 hectares. The Proposal includes infrastructure typically used in Pilbara iron ore operations including crushers, conveyors, ore handling and screening plants, stockpiles and train load-out facilities, rail loops, workshops, warehousing, concrete batching plants, administration facilities, refuelling facilities, laydown and storage areas, power and water distribution infrastructure, waste disposal, wastewater treatment, dangerous goods and hazardous materials storage facilities, water treatment facilities and surface water management infrastructure. Beneficiation facilities with associated tailings dams may also be proposed for some operations. Road and rail networks to access these operations and allow the transportation of ore will also be required.

Proposal operations included in the CIA were associated with the Area C, Caramulla, Coondiner, Gurinbiddy, Jimblebar, Jinidi, Marillana, Mindy, Ministers North, Mudlark, Munjina/Upper Marillana, Newman, Opthalmia/Prairie Downs, Rocklea, Roy Hill, South Flank, Tandanya and Yandi hubs (**Figure 2**). Further information about the Proposal is provided in Section 2.5.

Subject to express exclusions outlined in the IAR, the Proposal includes all of BHP Billiton Iron Ore's proposed greenfields mine development, involving resources in which BHP Billiton Iron Ore currently has an interest, or may acquire an interest in in the future, and brownfields development of BHP Billiton Iron Ore's existing assets.

BHP Billiton Iron Ore's existing and approved operations and infrastructure are excluded from the Proposal; however, they have been included in the CIA to enable the assessment of cumulative impacts of existing and proposed development.

1.3 CUMULATIVE IMPACT ASSESSMENT IN CONTEXT

CIA aims to consider the effects of multiple actions or impacts on the environment. The cumulative impacts of multiple actions may combine over time and space and can be generalised as:

- Space crowding, occurring when a system is disturbed by several similar activities, or by different activities producing a similar effect, in an area too small to assimilate the combined impacts (Rees 1995). 'Nibbling' is an incremental form of space crowding and is the gradual disturbance or loss of land and habitat (Court et al. 1994).
- Time crowding, occurring when impacts are so close in time that the impact of one action is not dissipated before the next occurs (CEARC 1986).
- Interactive effects that may be additive or synergistic, reflecting the interactive nature of ecosystems.
- Indirect impacts arising as a result of an action.

This CIA focused on space crowding, additive interactive effects and indirect effects. Time crowding and synergistic cumulative impacts were considered as part of the scoping of this assessment. Based on the available scientific knowledge and data for the region, it was determined that a credible analysis of these types of impacts was beyond the capacity of present analytical capabilities and the limitations of the best available data.

While sharing some common perspectives with conventional 'project specific' environmental impact assessment, CIA can provide a spatial and temporal extension. The approaches and methodologies applied in CIA tend to be less standardised than conventional environmental impact assessment practices; a customised approach is applied, addressing the location, scale and particular context of the action or proposal (**Appendix B**). The additional spatial and temporal dimensions make CIA complex and challenging, requiring due consideration of the activities to include in the assessment, the impacts to be addressed and data to be used, along with the results of the CIA.

CIA provides insight into, rather than a definitive or final landing point on the combined effects of projects, as it is typically undertaken within a larger setting with variable levels of data. This CIA is a first of its kind for the Pilbara and represents a significant contribution by BHP Billiton Iron Ore to provide an analysis of the potential effects of iron ore mining in the Pilbara. It also provides government and industry with a substantial foundation for undertaking further assessment of cumulative impacts in the future, as planning for, and understanding of, potential impacts develops.

1.4 SCOPE OF THE CUMULATIVE IMPACT ASSESSMENT

The scope of the CIA was defined in terms of the spatial boundary, development scenarios, impacts considered and MNES targeted (**Table 1**). Each component of the CIA scope is described further in Section 2.2.

Table 1: Summary of key elements defining the scope of the CIA

Scope component	Description
Spatial boundary	• Pilbara bioregion of Western Australia.
Development scenarios	• Existing mining and non-mining impacts (Scenario 1). • Scenario 1 plus reasonably foreseeable future third party iron ore mines (Scenario 2). • Scenario 2 plus the Full Development Scenario (Scenario 3).
Potential impacts	• Removal of habitat. • Fragmentation of habitat. • Predation. • Mortality from collision with vehicles. • Grazing. • Introduction or spread of weeds. • Change in hydrology/hydrogeology.
Environmental receptors	• MNES: ○ *Macrotis lagotis* (Greater Bilby). ○ *Lepidium catapycnon* (Hamersley Lepidium). ○ *Dasyurus hallucatus* (Northern Quoll). ○ *Rhinonicteris aurantia* (Pilbara Leaf-nosed Bat). ○ *Liasis olivaceus barroni* (Pilbara Olive Python).

1.5 STRUCTURE OF THIS REPORT

This report documents the approach to the CIA and provides the outcomes of the assessment of potential cumulative impacts to each MNES. The report is structured as follows:

- Section 1: Introduction ï outlines the context for the CIA and defines the scope and objectives of the CIA.
- Section 2: Methods ï describes the methods used to assess potential cumulative impacts and specifies the impacts and MNES considered.
- Section 3: Greater Bilby ï provides an overview of the ecology of the Greater Bilby, the impacts applied and the results of the CIA for the Greater Bilby.
- Section 4: Hamersley Lepidium ï provides an overview of the ecology of Hamersley Lepidium, the impacts applied and the results of the CIA for Hamersley Lepidium.
- Section 5: Northern Quoll ï provides an overview of the ecology of the Northern Quoll, the impacts applied and the results of the CIA for the Northern Quoll.
- Section 6: Pilbara Leaf-nosed Bat ï provides an overview of the ecology of the Pilbara Leaf-nosed Bat, the impacts applied and the results of the CIA for the Pilbara Leaf-nosed Bat.
- Section 7: Pilbara Olive Python ï provides an overview of the ecology of the Pilbara Olive Python, the impacts applied and the results of the CIA for the Pilbara Olive Python.
- Section 8: Key information gaps ï provides the key information gaps related to GIS base layers, impact data and methods.
- Section 9: Key outcomes and significance assessment ï provides the key outcomes of the CIA for the MNES considered and a brief preliminary discussion of their significance.
- Section 10: References.

The following appendices provide detailed information to support the main body of the report:

- **Appendix A**: Studies undertaken to support the CIA ï a summary of studies undertaken to support the CIA and the outputs produced by these studies that were utilised directly in the CIA.
- **Appendix B**: Literature review ï cumulative environmental effects ï introduces and defines the concept of cumulative environmental effects and discusses CIA as a process by which to assess and report on the impacts of cumulative environmental effects.
- **Appendix C**: Sensitivity analysis ï a summary of the results of a sensitivity analysis undertaken to test the robustness of assignment of levels of potential impact and determine the degree to which minor changes in levels of impact may affect results.
- **Appendix D**: MNES viability summary ï a summary of peer reviewer species matter expertsô assessment of the cumulative impact of the Proposal to the viability of the five relevant MNES considered in the CIA.

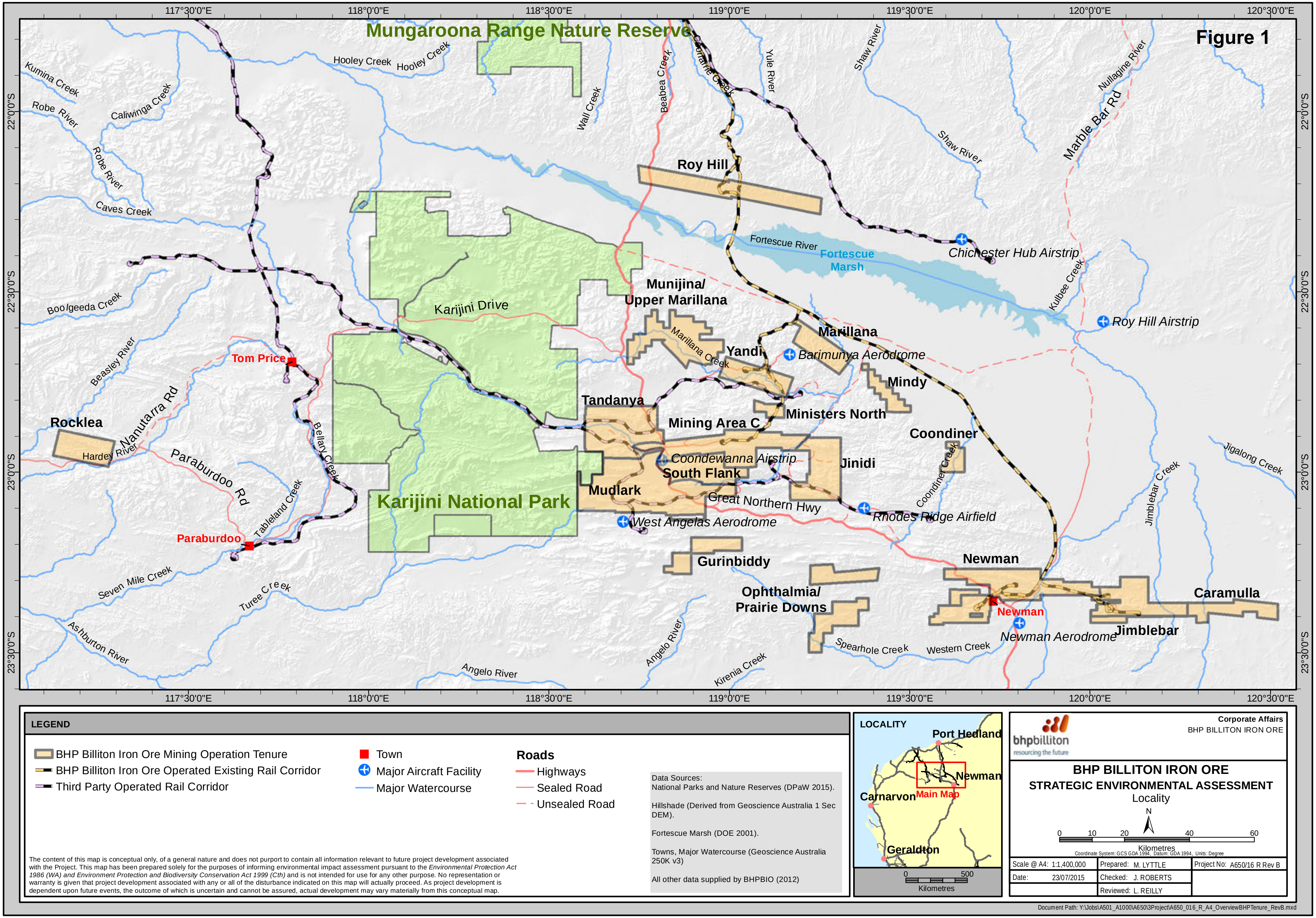
Figure 1
Mungaroona Range Nature Reserve
Karijini National Park
Karijini Drive
Roy Hill
Munijina/
Upper Marillana
Marillana
Yandi
Mindy
Ministers North
Mining Area C
Tandanya
Rocklea
Coondiner
Jinidi
South Flank
Mudlark
Gurinbiddy
Ophthalmia/
Prairie Downs
Newman
Caramulla
Jimblebar
Tom Price
Paraburdoo
Newman
Fortescue Marsh
Chichester Hub Airstrip
Roy Hill Airstrip
Barimunya Aerodrome
Coondewanna Airstrip
West Angelas Aerodrome
Rhodes Ridge Airfield
Newman Aerodrome
Great Northern Hwy
Marble Bar Rd
Nanutarra Rd
Paraburdoo Rd
Fortescue River
Hooley Creek
Kumina Creek
Robe River
Caliwinga Creek
Caves Creek
Boolgeeda Creek
Beasley River
Hardey River
Bellary Creek
Tableland Creek
Seven Mile Creek
Turee Creek
Ashburton River
Angelo River
Kirienia Creek
Spearhole Creek
Western Creek
Marillana Creek
Coondiner Creek
Jimblebar Creek
Jigalong Creek
Kulbee Creek
Nullagine River
Shaw River
Yule River
Beabea Creek
Wall Creek
117°30'0"E
118°0'0"E
118°30'0"E
119°0'0"E
119°30'0"E
120°0'0"E
120°30'0"E
22°0'0"S
22°30'0"S
23°0'0"S
23°30'0"S
LEGEND
BHP Billiton Iron Ore Mining Operation Tenure
BHP Billiton Iron Ore Operated Existing Rail Corridor
Third Party Operated Rail Corridor
Town
Major Aircraft Facility
Major Watercourse
Roads
Highways
Sealed Road
Unsealed Road
Data Sources:
National Parks and Nature Reserves (DPaW 2015).
Hillshade (Derived from Geoscience Australia 1 Sec DEM).
Fortescue Marsh (DOE 2001).
Towns, Major Watercourse (Geoscience Australia 250K v3)
All other data supplied by BHPBIO (2012)
The content of this map is conceptual only, of a general nature and does not purport to contain all information relevant to future project development associated with the Project. This map has been prepared solely for the purposes of informing environmental impact assessment pursuant to the Environmental Protection Act 1986 (WA) and Environment Protection and Biodiversity Conservation Act 1999 (Cth) and is not intended for use for any other purpose. No representation or warranty is given that project development associated with any or all of the disturbance indicated on this map will actually proceed. As project development is dependent upon future events, the outcome of which is uncertain and cannot be assured, actual development may vary materially from this conceptual map.
LOCALITY
Port Hedland
Newman
Carnarvon
Main Map
Geraldton
0
500
Kilometres
Corporate Affairs
BHP BILLITON IRON ORE
bhpbilliton
resourcing the future
BHP BILLITON IRON ORE
STRATEGIC ENVIRONMENTAL ASSESSMENT
Locality
N
0 10 20 40 60
Kilometres
Coordinate System: GCS GDA 1994, Datum: GDA 1994, Units: Degree
Scale @ A4: 1:1,400,000
Prepared: M. LYTTLE
Project No: A650/16 R Rev B
Date: 23/07/2015
Checked: J. ROBERTS
Reviewed: L. REILLY
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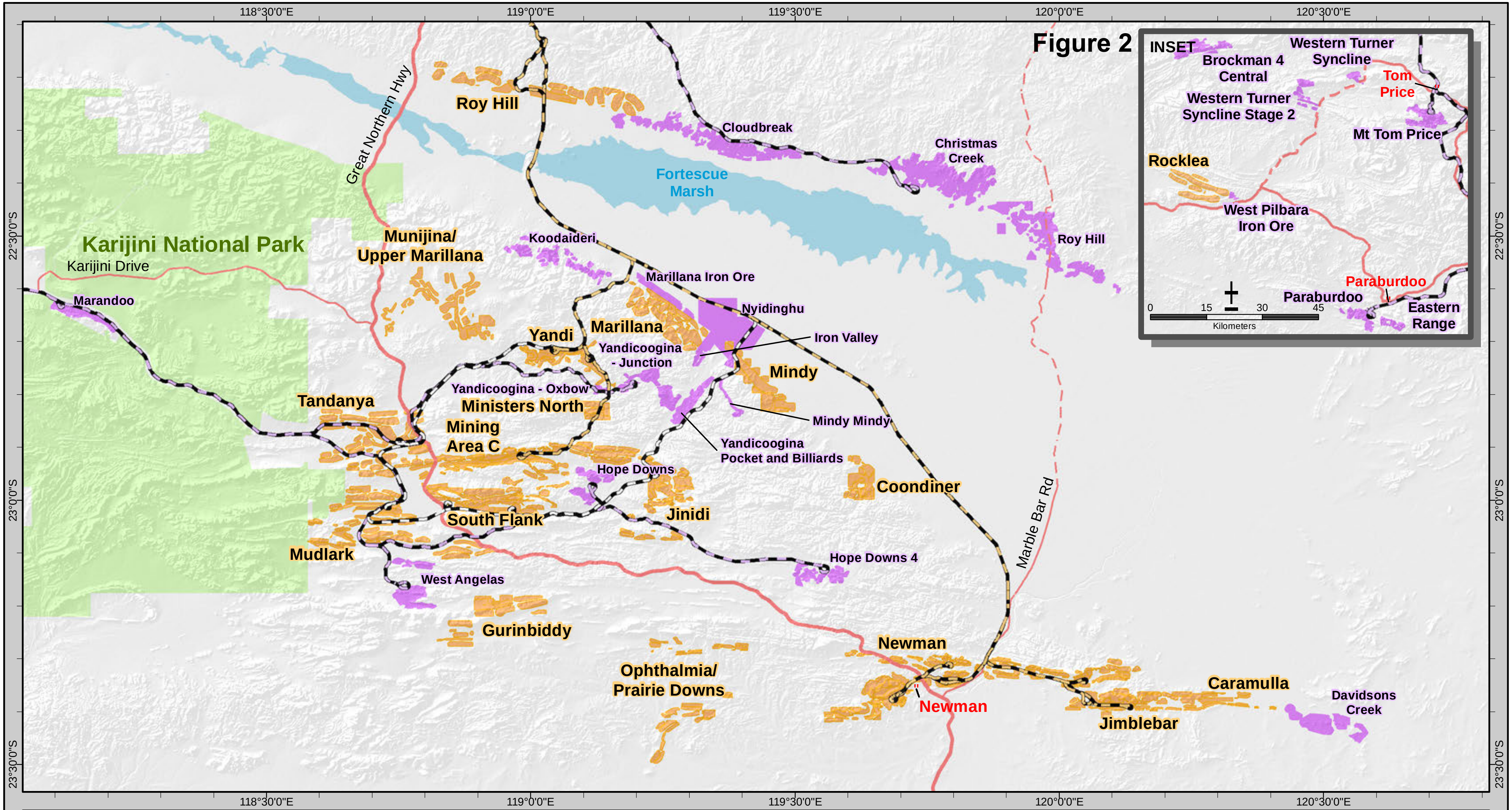


LEGEND

BHP Billiton Iron Ore Full Development Scenario Disturbance

- BHP Billiton Iron Ore Conceptual Direct Disturbance
- BHP Billiton Iron Ore Operated Existing Rail Corridor
- BHP Billiton Iron Ore Operated Conceptual Rail Corridor

Third Party Reasonably Foreseeable Disturbance

- Third Party Reasonably Foreseeable Disturbance
- Third Party Operated Rail Corridor

" Town

Roads

- Highways
- Sealed Road
- Unsealed Road

Data Sources:
National Parks (DPaW 2015).

Hillshade (Derived from Geoscience Australia 1 Sec DEM).

Third Party Disturbamce digitised from Aerial Imagery (Aug - Sept 2013) & Approval Documentations.

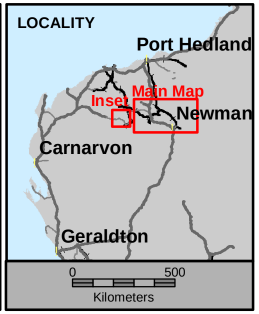
Fortescue Marsh (DOE 2001).

Towns (Geoscience Australia 250K v3)

All other data supplied by BHPBIO (2012)

The content of this map is conceptual only, of a general nature and does not purport to contain all information relevant to future project development associated with the Project. This map has been prepared solely for the purposes of informing environmental impact assessment pursuant to the *Environmental Protection Act 1986 (WA) and Environment Protection and Biodiversity Conservation Act 1999 (Cth)* and is not intended for use for any other purpose. No representation or warranty is given that project development associated with any or all of the disturbance indicated on this map will actually proceed. As project development is dependent upon future events, the outcome of which is uncertain and cannot be assured, actual development may vary materially from this conceptual map.

LOCALITY



Corporate Affairs
BHP BILLITON IRON ORE

CENTRAL PILBARA
STRATEGIC ENVIRONMENTAL ASSESSMENT
BHP Billiton Iron Ore Full Development Scenario and Third Party Reasonably Foreseeable Disturbance Areas

0 10 20 40 60
Kilometres
Coordinate System: GCS GDA 1994, Datum: GDA 1994, Units: Degree

Scale @ A4: 1:1,100,000	Prepared: M. LYTTLE	Project No: A650/13 R Rev A
Date: 8/05/2015	Checked: J. ROBERTS	
	Reviewed: L. REILLY	

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2 Methods

2.1 OVERVIEW

This CIA focused on BHP Billiton Iron Oreâs Full Development Scenario, other existing iron ore mining and non-mining impacts and reasonably foreseeable future iron ore mining impacts in the Pilbara bioregion of Western Australia. It addressed and quantified potential cumulative impacts to potential relative habitat suitability modelled in the Pilbara bioregion by ELA (2015) for five MNES: Greater Bilby, Hamersley Lepidium, Northern Quoll, Pilbara Leaf-nosed Bat and Pilbara Olive Python.

The key stages of this CIA were to (1) predict habitat suitability for each of the five relevant MNES, (2) identify key threats to these MNES and (3) quantify the area of potential change in habitat suitability under defined scenarios (**Figure 3**).

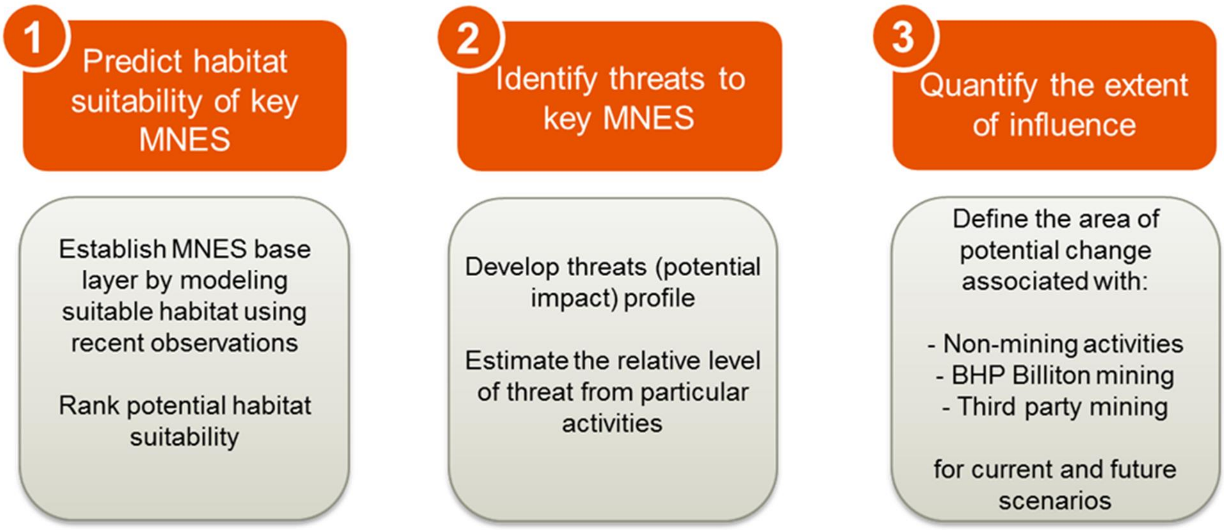


Figure 3: Key stages of the CIA

The assessment used the best available data for the study region (Section 2.5). This report provides:

1. a definition of the scope and boundaries of the assessment;
2. a description of the best available data collated for MNES and potential impacts, which included customised modelling;
3. a description of the rationale and approach for the assessment;
4. cumulative application of impacts;
5. analysis and presentation of results.

These are described in the following sections.

2.2 SCOPE AND BOUNDARIES OF THE CIA

2.2.1 Spatial boundary

The scope of the CIA was defined spatially by the Pilbara bioregion as per the Department of the Environment (DoE) Interim Biogeographic Regionalisation of Australia (IBRA; DoE 2013a). The IBRA classifies Australia's landscapes into 89 geographically distinct bioregions based on common climate, geology, landform, native vegetation and species information (DoE 2013a). The IBRA bioregions (and their subregions) are typical reporting units for assessment of the status of native ecosystems and their protection in the national reserve system. It is noted that the distributions of two of the five MNES considered, the Greater Bilby and Northern Quoll, extend beyond the bioregion and this assessment therefore may overstate the potential impacts to these species if considered across the speciesôentire range.

2.2.2 Cumulative impact scenarios

A scenario-based approach was used to examine different potential cumulative impact outcomes (**Figure 4**). Each scenario was analysed independently, with the order of the scenarios not affecting analysis outcomes. Scenarios included were:

- Scenario 1: Application of existing mining and non-mining impacts.
- Scenario 2: Application of Scenario 1 and impacts from reasonably foreseeable future third party iron ore mines.
- Scenario 3: Application of Scenario 2 and impacts from the Full Development Scenario.

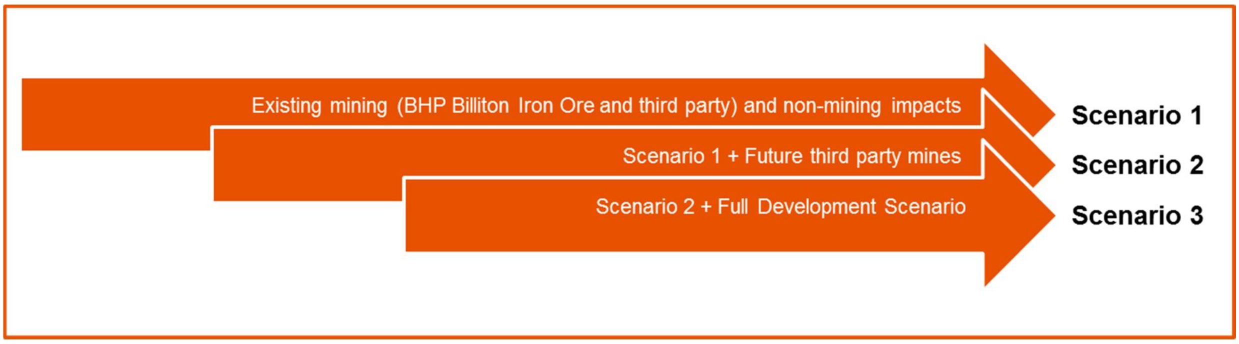


Figure 4: Scenarios used in the Commonwealth CIA

2.2.3 Matters of National Environmental Significance

The following five MNES were identified as being appropriate for regional-scale assessment of the Proposal:

- Greater Bilby ï listed as Vulnerable under the EPBC Act.
- Hamersley Lepidium ï listed as Vulnerable under the EPBC Act.
- Northern Quoll ï listed as Endangered under the EPBC Act.
- Pilbara Leaf-nosed Bat ï listed as Vulnerable under the EPBC Act.

- Pilbara Olive Python ï listed as Vulnerable under the EPBC Act.

Identification of these five MNES was based on a desktop assessment that considered the availability of potential habitat, known distribution and records within the Proposal area and the potential for future development to lead to significant impacts. This information is provided in the IAR. Other threatened and migratory species listed under the EPBC Act were not considered appropriate for regional-scale assessment of the Proposal due to:

- lack of overlap between their known distributions and the Proposal area;
- lack of suitable, species-specific preferred habitats within the Proposal area;
- lack of appropriate regional data;
- cosmopolitan distributions of some species where the species are widely distributed beyond the Proposal area.

2.3 HABITAT SUITABILITY

For each of the Greater Bilby, Hamersley Lepidium, Northern Quoll, Pilbara Leaf-nosed Bat and Pilbara Olive Python., the CIA involved prediction of loss or degradation of modelled habitat suitability caused by a number of potential impacts attributable to existing or proposed mining activity and to historical development. The CIA considered a base case model of habitat suitability developed for each MNES by ELA (2015), which modelled relative habitat suitability values from zero to 100 per cent across the Pilbara bioregion (**Appendix A**). The potential impact to habitat suitability was used in the CIA as a proxy to assess potential impacts to MNES.

Given the limitations of obtaining a comprehensive inventory of species locations in such a large and remote area as the Pilbara, the objective of the habitat suitability modelling was to provide a basis for assessment of potential cumulative impacts to each species by identifying locations most likely to be favoured by the species. Mining and other impacts within these regions would likely have greater consequence for species prevalence than in less favoured areas. The output from species habitat modelling was a predictive model surface across the Pilbara bioregion illustrating the relative probability of potential habitat for each target species (ELA 2015); this can be thought of as broadly analogous to óhabitat suitabilityô

The species habitat models developed by ELA (2015) are indicative and highlight those parts of the landscape where there is potentially a higher probability of species habitat being present. The models do not indicate the potential utilisation of these habitats by the species, nor the relative abundance of the species.

The use of species habitat models was considered the best available means to assess potential cumulative impacts to each of the MNES at a regional scale given the available data for the Pilbara bioregion. This approach was preferred over possible alternatives, such as an individual-, or population-based approach (whereby the impact to each species could be assessed based on known records as determined from on-ground investigations and surveys) because insufficient survey effort has been undertaken to enable an accurate estimate of key parameters for each species, such as distribution, population size, and population density, across all areas of the Pilbara bioregion.

For use in the CIA, the ELA (2015) models of habitat suitability were categorised into four Habitat Ranks based on the relative probability of the habitat being suitable to each species as follows:

- Habitat Rank 4: Highest probability of potential habitat (model value 70 to 100 per cent); this habitat is considered to probably be suitable for the species.
- Habitat Rank 3: Model value 30 to 70 per cent; this habitat is considered to possibly be suitable for the species.
- Habitat Rank 2: Model value 10 to 30 per cent; this habitat is considered to be marginally suitable for the species.
- Habitat Rank 1: Lowest probability of potential habitat (model value zero to 10 per cent); this habitat is considered to be unsuitable for the species.

2.4 APPLICATION OF POTENTIAL IMPACTS

The assessment considered a range of potential impacts and how these may combine in a cumulative sense. The sources of potential impacts considered were the Full Development Scenario, existing mining projects and non-mining activities and land use for which data were available, and reasonably foreseeable future third party iron ore projects. Relevant impacts were determined on a case by case basis according to each the attributes, values and likely sensitivity to different types of impacts of each MNES. Relevant potential impacts to MNES were informed by the outcomes of workshops facilitated by the Western Australian Department of Parks and Wildlife (Parks and Wildlife) in 2013, which specifically identified key threats to each species, knowledge gaps and further research priorities.

Species-specific impacts were identified for each species through review of available scientific and other literature, and from the outcomes of workshops facilitated by Parks and Wildlife in 2013. For each species, potential impacts applied comprised a subset of the following impacts as summarised in **Table 2** and further described in Section 3 to Section 7:

- removal of habitat;
- fragmentation of habitat;
- predation;
- mortality from collision with vehicles;
- grazing;
- introduction or spread of weeds;
- change in hydrology/hydrogeology.

Impacts that may also be relevant but were not modelled in the CIA due to inadequate or unsuitable datasets include fire, Cane Toads, noise, vibration and light. These potential impacts are discussed in Section 8. The potential effect of climate change on habitat suitability was considered and modelled; however, the level of uncertainty associated with the modelling outcomes was considered by peer reviewers to be too high.

Spatial data used as surrogates for the aforementioned impacts are outlined in **Table 4**. Impacts applied for each species are outlined in Section 3.3.2 (Greater Bilby), Section 4.3.2 (Hamersley Lepidium), Section 5.3.2 (Northern Quoll), Section 6.3.2 (Pilbara Leaf-nosed Bat) and Section 7.3.2 (Pilbara Olive Python).

Potential impacts were applied to each habitat model as spatial layers using numerical values to represent the potential effect of each impact. Application of impacts as numerical values in this way affected habitat suitability through multiplication of the impact value with the underlying species habitat model value when the spatial layers were overlaid against each other. A potential impact of 100 per cent was applied as the potential effect of habitat removal and for other impacts expected to reduce habitat suitability to essentially zero. This level of potential impact was classified as óHighô Similarly, potential impacts of 50 and 20 per cent were applied for impacts classified as óMediumô and óLowô respectively.

Levels of potential impact were set based on the best available literature, data and specialist expertise and knowledge. Information was not always available for the particular species in question and, in these cases, was often obtained from studies on other species (occasionally, but not always in the same genus or family), or in other parts of Australia or the world. The information used was considered the best available and was evaluated for relevance to the MNES in question before use in the CIA and consideration in the development of levels of potential impact.

Spatial layers were generated separately to account for the potential effect of each impact on its own, independent of other impacts, and then consolidated into an óall impactsô spatial layer for each CIA scenario. Operationally, the spatial layers for potential impacts effect change in habitat suitability through multiplication of the impact value with the underlying species habitat model value when the spatial layers are overlaid against each other in a GIS program.

For example, for potential impact spatial layers representing High (100 per cent impact), Medium (50 per cent impact) and Low (20 per cent impact) impacts respectively, the effect on a particular location in the landscape with a habitat suitability value of 65 per cent (Habitat Rank 3) would be as follows:

- High (100 per cent) impact: 0.65 (starting habitat model value; Habitat Rank 3) x 0.00 (impact value[1]) = 0.00 (resulting habitat model value; Habitat Rank 1) (**Figure 5**).
- Medium (50 per cent) impact: 0.65 (starting habitat model value; Habitat Rank 3) x 0.50 (impact value) = 0.32 (resulting habitat model value; Habitat Rank 3) (**Figure 5**).
- Low (20 per cent) impact: 0.65 (starting habitat model value; Habitat Rank 3) x 0.80 (impact value) = 0.52 (resulting habitat model value; Habitat Rank 3) (**Figure 5**).

As another example, if three Medium impact spatial layers were overlaid at the same location in the landscape (again, with a habitat suitability value of 65 per cent; Habitat Rank 3), the effect on habitat suitability would be as follows:

- Three Medium (50 per cent) impacts: 0.65 (starting habitat model value; Habitat Rank 3) x 0.50 (impact value 1) x 0.50 (impact value 2) x 0.50 (impact value 3) = 0.08 (resulting habitat model value; Habitat Rank 1) (**Figure 6**).

[1] The óimpact valueô is mathematically derived as: (100 minus the level of impact) divided by 100, i.e. High impact value = (100 - 100)/100 = 0; Medium impact value = (50 - 100)/100 = 0.5; Low impact value = (100 - 20)/100 = 0.8.

- Within areas where only two of the Medium (50 per cent) impacts overlap: 0.65 (starting habitat model value; Habitat Rank 3) x 0.50 (impact value 1) x 0.50 (impact value 2) = 0.16 (resulting habitat model value; Habitat Rank 2) (**Figure 6**).

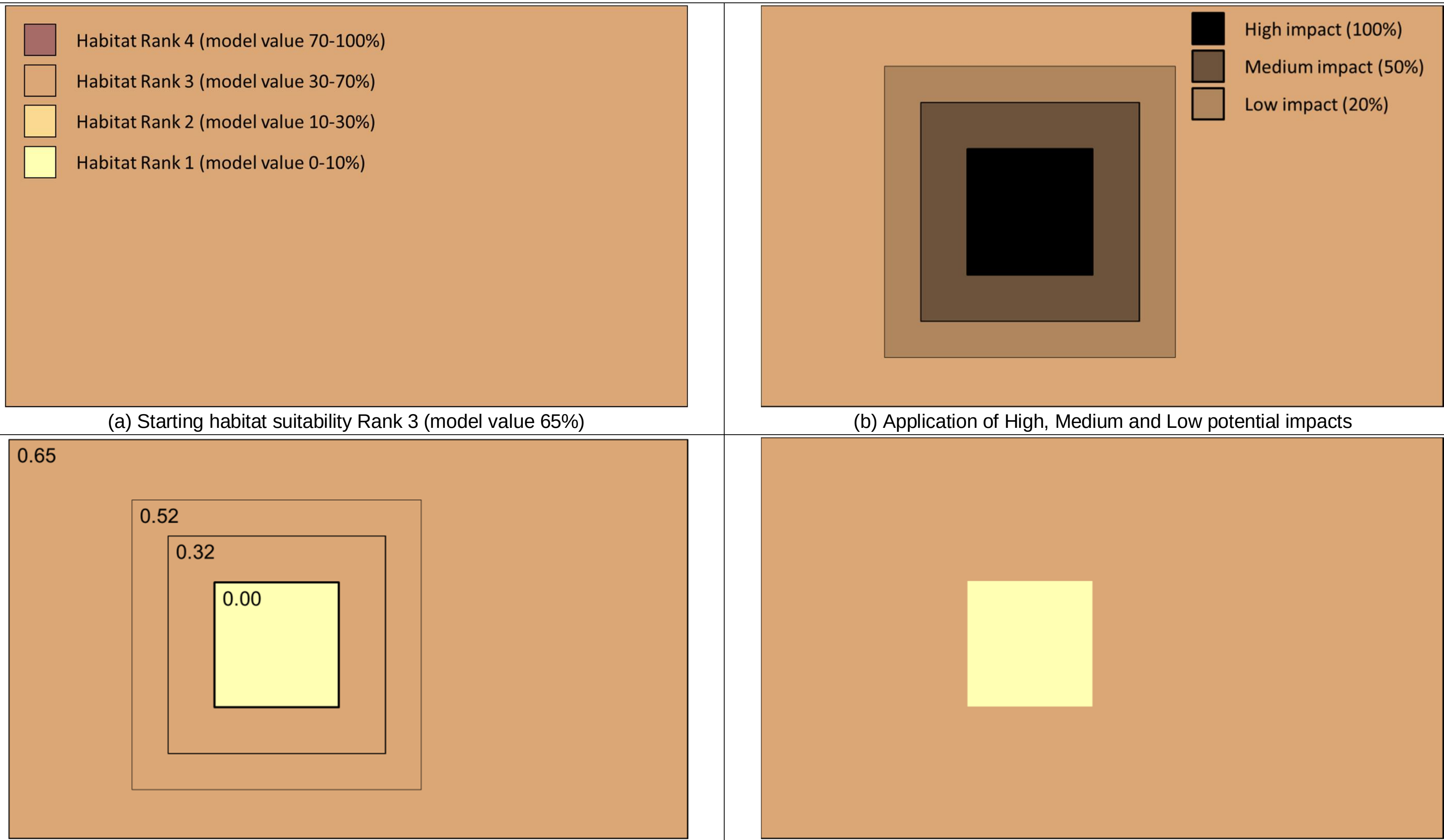
A summary of the potential impacts applied to each MNES is provided in **Table 2**. The rationale for the levels of potential impact applied is provided in Section 3.3.2 (Greater Bilby), Section 4.3.2 (Hamersley Lepidium), Section 5.3.2 (Northern Quoll), Section 6.3.2 (Pilbara Leaf-nosed Bat) and Section 7.3.2 (Pilbara Olive Python). A potential impact may have only one level (for example, all removed habitat was classified as a High level impact), or may have more than one. Multiple levels of potential impact represent variable application of a potential impact according to distance or area. For example, mortality from collision with vehicles was applied as either a Medium or Low impact to the Greater Bilby (Section 3.3.7), Northern Quoll (Section 5.3.7) and Pilbara Olive Python (Section 7.3.7) depending on proximity to roads and rail. Therefore, **Table 2** shows both levels.

Table 2: Summary of levels of potential impact applied in the CIA to each MNES

Potential impact	Greater Bilby	Hamersley Lepidium	Northern Quoll	Pilbara Leaf-nosed Bat	Pilbara Olive Python
Removal of habitat	🔴	🔴	🔴	🔴	🔴
Fragmentation of habitat	🟡/🟠/🔴	-	🟡/🟠/🔴	-	🟡/🟠/🔴
Predation	🟡	-	🟡	-	🟡
Mortality from collision with vehicles	🟡/🟠	-	🟡/🟠	🟡	🟡/🟠
Grazing	🟡/🟠/🔴	-	🟡/🟠	-	🟡
Weeds	-	🟡	-	-	-
Surface water change	-	-	-	🟡	🟡
Groundwater change	-	-	-	🟡	🟡

🟡 Low impact (20%) 🟠 Medium impact (50%) 🔴 High impact (100%)

A sensitivity analysis using the Pilbara Olive Python as an example was undertaken to test the robustness of assignment of levels of potential impact and determine the degree to which minor changes in levels of impact may affect results. Based on the results of the sensitivity analysis, it was concluded that the CIA approach in designating levels of potential impacts was robust and fit for purpose for a regional-scale assessment, with minor variations in levels of potential impact unlikely to significantly affect the outcome (**Appendix C**).



(a) Starting habitat suitability Rank 3 (model value 65%)

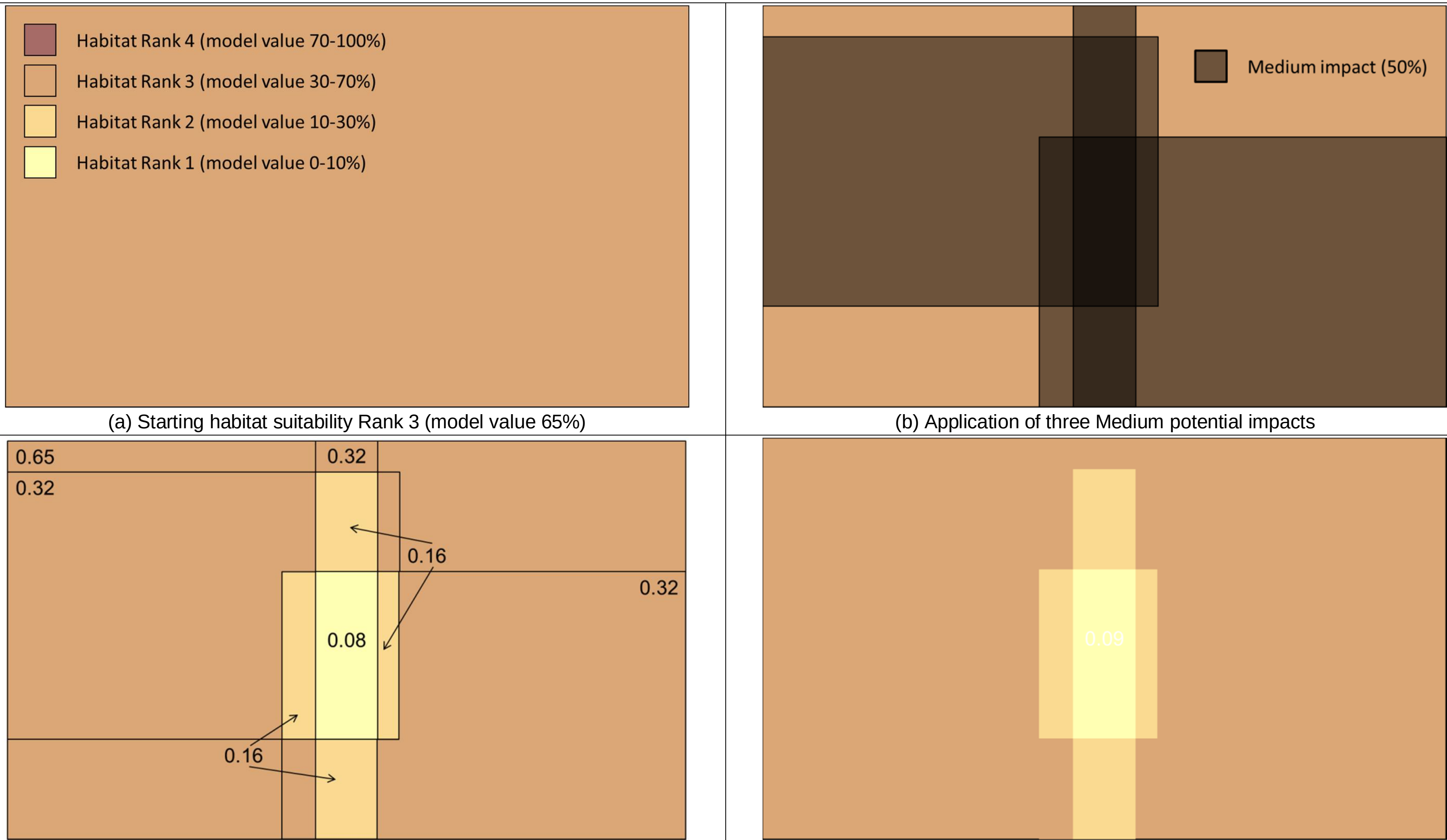
(b) Application of High, Medium and Low potential impacts

(c) Multiplication of potential impact values with underlying habitat model values

(d) Resulting habitat suitability: Habitat Ranks 1 and 3

At a particular location in the landscape classified as Habitat Rank 3 with a habitat model value of 65% (a), application of High, Medium and Low potential impacts via spatial overlay in GIS software (b) results in multiplication of the potential impact values with underlying habitat model values (c), resulting in modification of habitat suitability (d).

Figure 5: Commonwealth CIA methodology example No. 1



(a) Starting habitat suitability Rank 3 (model value 65%)

(b) Application of three Medium potential impacts

(c) Multiplication of potential impact values with underlying habitat model values

(d) Resulting habitat suitability: Habitat Ranks 1, 2 and 3

At a particular location in the landscape classified as Habitat Rank 3 with a habitat model value of 65% (a), application of three Medium potential impacts via spatial overlay in GIS software (b) results in multiplication of the potential impact values with underlying habitat model values (c), resulting in modification of habitat suitability (d).

Figure 6: Commonwealth CIA methodology example No. 2

2.5 DATA USED IN THE CIA

The assessment used the best available data for the study region. The main sources of data were from BHP Billiton Iron Ore (including data for third party iron ore disturbance footprints derived by BHP Billiton Iron Ore) and Geoscience Australia.

Data used in the CIA comprised:

- Disturbance footprint data for existing BHP Billiton Iron Ore operations (Section 2.5.1) and existing third party iron ore operations (Section 2.5.2).
- Disturbance footprint data and location data for existing non-mining impacts (Section 2.5.3).
- Disturbance footprint data for the Full Development Scenario (Section 2.5.4).
- Disturbance footprint data for reasonably foreseeable future third party iron ore operations (Section 2.5.6).
- Data for the predicted spatial extent of potential ecohydrological impacts of existing BHP Billiton Iron Ore and third party iron ore operations, the Full Development Scenario and reasonably foreseeable future third party iron ore operations (Section 2.5.7).
- Base layer data for modelled MNES habitat suitability (Section 2.5.8).

There is generally a lower level of confidence or precision associated with data for third party operations compared to BHP Billiton Iron Ore's data for its own operations; however, the data used in the CIA for third party operations is considered fit for purpose for regional-scale assessment of cumulative impacts.

2.5.1 Disturbance footprint data for existing BHP Billiton Iron Ore operations

The spatial data layer for existing BHP Billiton Iron Ore disturbance footprints was derived by BHP Billiton Iron Ore from analysis of aerial imagery and was current as at 6 December 2013. The layer included disturbance associated with the Area C, Jimblebar, Newman and Yandi mining operations (**Figure 7**). Some non-process infrastructure was excluded from the existing disturbance footprint, such as power lines and accommodations camps. This level of footprint accuracy is not likely to materially affect the key outcomes of the CIA. The disturbance footprint provided by the layer represents the extent of ground disturbance as at 6 December 2013 and may be less than that approved under existing environmental approvals.

2.5.2 Disturbance footprint data for existing third party iron ore operations

The spatial data layer for existing third party iron ore disturbance footprints was derived by BHP Billiton Iron Ore from analysis of aerial imagery (current as at 16 September 2013) and included disturbance associated with (**Figure 7**):

- Brockman Syncline 4, Hope Downs 1, Hope Downs 4, Marandoo, Mt Tom Price, Paraburdoo, Paraburdoo – Eastern Range, West Angelas, Western Turner Syncline Section 10, Western Turner Syncline Stage 2 and Yandicoogina (Junction Central, Junction SE, Junction SW and Oxbow, and Pocket and Billiards South and Infrastructure) (Rio Tinto Iron Ore; including Hamersley Iron, Hamersley HMS and Robe River Mining Co.);

- Cloudbreak, Christmas Creek and Nyidinghu (Fortescue Metals Group);
- Davidsons Creek DSO (Atlas Iron);
- Hardey Proposal (API);
- Iron Valley Iron Ore Project (Iron Ore Holdings);
- Phil's Creek (Mineral Resources);
- Roy Hill Iron Ore Project – Stage 1 and 2 (Hancock Prospecting).

Consideration of existing third party projects was limited to those within 50 kilometres of a Proposal mining operation. This was considered fit for purpose for this regional-scale CIA and was determined from an analysis conducted by BHP Billiton of the farthest reasonable distance that potential impacts from any given Proposal mining operation could occur. The exception was the Roy Hill Iron Ore Mine (Roy Hill Iron Ore Holdings Pty Ltd), which was included because of its close proximity to Fortescue Marsh.

Third party operations considered for the existing disturbance footprint were those that had been approved and were under development as at September 2014 as determined from aerial imagery. Haul roads, rail and accommodation camps that were not located within the main third party footprint were excluded from the existing third party iron ore disturbance footprint as these were considered to be of minor disturbance at a regional scale and not required for the CIA.

2.5.3 Disturbance footprint data and location data for existing non-mining impacts

A review of BHP Billiton Iron Ore and publicly available datasets was undertaken to identify the best available data to derive potential impacts from existing non-mining sources. The review determined that the Geoscience Australia Global Map 2001 (1:1 million) dataset was the best publicly available source of data to apply non-mining impacts in the CIA. Individual data layers for roads, power lines, airfields, railway yards, human settlements and built-up areas were obtained from this dataset and used in the CIA (**Figure 8**). Buffers were applied to point and line features to derive impact footprints based on reasoned estimates of the size of such features. Roads and power lines were line data and were buffered 12.5 metres either side of the line to generate a disturbance area 25 metres wide. Airfields, railway yards and human settlements were point data and were buffered 100 metres to create a circular disturbance area with a 100 metre radius. Publicly available data provided by BHP Billiton Iron Ore for use in the CIA for existing non-mining impacts comprised a single consolidated data layer containing point locations for existing Aboriginal communities, homesteads and roadhouses (**Figure 8**). Each point was buffered 100 metres to create a circular disturbance area with a 100 metre radius.

2.5.4 Disturbance footprint data for the Full Development Scenario

Proposal operations included in the CIA were associated with the Area C, Caramulla, Coondiner, Gurinbiddy, Jimblebar, Jinidi, Marillana, Mindy, Ministers North, Mudlark, Munjina/Upper Marillana, Newman, Opthalmia/Prairie Downs, Rocklea, Roy Hill, South Flank, Tandanya and Yandi hubs (**Figure 2**). The spatial data layer for the Full Development Scenario disturbance footprint was developed by BHP Billiton Iron Ore and represents the predicted or expected full extent of development of the Proposal at closure. Detailed engineering has not yet been undertaken for all of the elements of the Proposal. The Full Development Scenario footprint used in the CIA (**Figure 2**) is an indicative and non-exhaustive delineation of likely hub configuration in respect to currently known resources. The location of mines and rail corridors may change in the future, for example in response to newly identified resources, as a result of technology advances or to avoid environmental impacts. This level of information is considered appropriate for a regional scale assessment. Some non-process infrastructure, such as power lines and accommodation camps, was excluded from the Full Development Scenario disturbance footprint. This level of footprint accuracy is not required for the purposes of the CIA.

The rail alignments presented in this CIA report are located within BHP Billiton Iron Ore's tenure and based on linking the respective regions to existing rail infrastructure. The alignments are indicative only and would be confirmed at a local scale at a later stage, when sufficient resource knowledge would exist to support final project decisions. A 50 metre buffer was applied on each side of rail alignments included in the Full Development Scenario to provide an estimate of disturbance.

Existing road and rail infrastructure not owned by BHP Billiton Iron Ore intersects some parts of the Full Development Scenario footprint. Adjustments to these intersections have not been made for the purposes of the CIA.

2.5.5 Closure

In defining the nature of the Full Development Scenario, BHP Billiton Iron Ore recognises there are multiple potential scenarios that could be applied, including the status of mining activity and the associated infrastructure for both BHP Billiton Iron Ore and third party mines. Given uncertainty around the potential commencement and closure dates for future third party mines, this assessment has chosen a conservative scenario where all future third party mines were considered operational for Scenarios 2 and 3. All BHP Billiton Iron Ore operations were considered to have ceased operations in Scenario 3 (**Table 3**).

The scenario configurations used in the CIA (**Table 3**) are not intended to imply a higher or lower temporal contribution by either third party or BHP Billiton Iron Ore mines, but rather to enable an assessment of the relative contribution of BHP Billiton Iron Ore operations to potential impacts to MNES. While it was assumed that operations had ceased at BHP Billiton Iron Ore mines in Scenario 3, a range of direct and indirect impacts were still applied in the scenario, where these impacts might be sustained, without mitigation, beyond cessation of operations. The following impacts were applied to BHP Billiton Iron Ore operations is Scenario 3:

- removal of habitat;
- fragmentation of habitat;
- grazing;
- change in hydrology/hydrogeology.

The potential impacts that were not applied for BHP Billiton Iron Ore operations in Scenario 3 were:

- predation for the Greater Bilby, Northern Quoll and Pilbara Olive Python;
- mortality from collision with vehicles for the Greater Bilby, Northern Quoll, Pilbara Leaf-nosed Bat and Pilbara Olive Python;
- introduction or spread of weeds for Hamersley Lepidium.

The potential relative contribution of the impacts excluded from BHP Billiton Iron Ore operations in Scenario 3 is considered to be low. Based on the spatial extent and magnitude of the potential impacts of predation, mortality from collision with vehicles, and introduction or spread of weeds that were applied in the CIA, it is considered that the contribution of these impacts to the total amount of modelled change in habitat suitability in the CIA is likely to have been relatively minor compared to the impact of habitat removal. If they had been included for BHP Billiton Iron Ore operations in Scenario 3, the combined effect of the excluded impacts would usually have resulted in either no change in habitat rank, or a change of only one habitat rank. A change of two habitat ranks would have been possible in very few instances (within 50 metres of some rail infrastructure or some highly trafficked roads[2]) and was therefore relatively restricted in its spatial extent.

Table 3: Summary of closure status of mines for Scenarios 1, 2 and 3

Scenario	Existing BHP Billiton mines	Existing third party mines	Future third party mines	Full Development Scenario mines
1	All operational	All operational	-	-
2	All operational	All operational	All operational	-
3	All closed	All operational	All operational	All closed

2.5.6 Disturbance footprint data for reasonably foreseeable future third party iron ore operations

The spatial data layer for reasonably foreseeable future third party iron ore mining operations was derived by BHP Billiton Iron Ore from publicly available data for projects referred to the Western Australian Environmental Protection Authority (EPA). The layer included projects already approved, but not yet implemented (or partially implemented), and projects referred to the EPA as at September 2014. The disturbance footprint does not take into account any expansions that third party operators may propose to undertake in the future, nor any new projects that third party operators may refer in the future, as this information is not publicly available. The CIA therefore in all likelihood understates the potential impact from future third party mines; however, this limitation of the CIA is unavoidable given the data available.

The primary assumption for the disturbance area was that all projects approved or referred to the EPA as at September 2014 will be implemented in full for both Scenario 2 and Scenario 3 of the CIA. Consideration of future third party projects was limited to those within 50 kilometres of a Proposal mining operation as determined from an analysis conducted by BHP Billiton of the farthest reasonable distance that potential impacts from any given Proposal operation could occur. This was considered fit for purpose for this regional-scale CIA. The exception was the Roy Hill Iron Ore Mine (Roy Hill Iron Ore Holdings Pty Ltd), which was included because of its close proximity to Fortescue Marsh.

[2] Highly trafficked roads were defined as all primary roads and all paved roads, as well as secondary and other unpaved roads within 10 kilometres of a town or an operating mine (Section 3.3.5).

The spatial layer developed for future third party projects was an amalgamation of data layers provided by the EPA and data layers created by BHP Billiton based on third party environmental approvals documentation. Third party iron ore mining operations considered to be reasonably foreseeable and included in the layer (**Figure 2**) were:

- Brockman Syncline 4, Hope Downs 1, Hope Downs 4, Koodaideri, Marandoo, West Angelas, Western Turner Syncline Section 10, Western Turner Syncline Stage 2, Yandicoogina (Junction SE; Junction SW and Oxbow) (Rio Tinto Iron Ore; including Hamersley Iron, Hamersley HMS and Robe River Mining Co.);
- Cloudbreak, Christmas Creek, Mindy Mindy and Nyidinghu (Fortescue Metals Group);
- Davidsonõs Creek (Atlas Iron);
- Hardey (API Management);
- Iron Valley (Iron Ore Holdings);
- Marillana (Brockman Resources);
- Roy Hill Stage 1 and Roy Hill Stage 2 (Hancock Prospecting).

Haul roads and accommodation camps were excluded from the future third party disturbance footprint as these were considered to be of minor disturbance at a regional scale and not required for the CIA. Rail was excluded due to a large number of potential options.

2.5.7 Ecohydrological change potential

BHP Billiton Iron Ore (2015) conducted a hydrological study to assess the potential of existing and proposed mining operations to change groundwater and surface water regimes and, in turn, affect key ecohydrological receptors where connectivity exists between hydrological and ecological systems. The hydrological study used the current understanding of the hydrological systems in the vicinity of the Proposal, and an estimation of the likely ecohydrological change due to existing BHP Billiton Iron Ore mining operations, existing and reasonably foreseeable future third party iron ore operations, and the Full Development Scenario.

The BHP Billiton Iron Ore (2015) study considered the main threatening processes with the potential to change hydrology at both the regional and ecohydrological receptor level. For groundwater and surface water hydrology respectively, the main threatening processes were considered to be watertable drawdown due to mine dewatering and loss of catchment area due to excavation of open cut pits and development of overburden storage areas. The study produced six key datasets that were applied as potential impacts to relevant MNES, namely a groundwater and a surface water change potential map for each of the development scenarios considered in the CIA. The BHP Billiton Iron Ore (2015) methods and key outputs are described further in **Appendix A**. The ecohydrological change potential maps produced by the study and considered in the CIA are provided in **Figure A3** to **Figure A8** in **Appendix A**.

2.5.8 Base layer data for modelled MNES habitat suitability

The key study undertaken to support the assessment of potential cumulative impacts to MNES was species habitat suitability modelling conducted by ELA (2015). The study utilised considerable datasets from multiple sources and produced models that were used as base layers in a Geographic Information

System (GIS) to which datasets representing potential impacts were applied to quantify cumulative impacts.

The base layers produced were relative habitat suitability models by ELA (2015) for the Greater Bilby, Hamersley Lepidium, Northern Quoll, Pilbara Leaf-nosed Bat and Pilbara Olive Python, utilising over 2,700 species records from BHP Billiton Iron Ore and Parks and Wildlife, along with data for a range of topographic (elevation), terrain (ruggedness, position), climatic, hydrological, landscape, substrate and vegetation variables.

Base case habitat suitability models for MNES incorporated the best available data on species locations and environmental variables from a range of sources, including BHP Billiton Iron Ore and publicly available records and databases. Species locations included records from several targeted surveys commissioned by BHP Billiton Iron Ore, as well as additional public records obtained through Parks and Wildlife. Species records were filtered by date, accuracy and spatial independence (**Appendix A**) to ensure compatibility with the scale of modelling and of environmental background data. Data pertaining to environmental variables were obtained through BHP Billiton Iron Ore, Landgate, Geoscience Australia and the Bureau of Meteorology.

The ELA (2015) study is summarised in **Table 5** and described further in **Appendix A**. Figures and a description of the base layers produced by the study are provided in Section 3.3.1 (Greater Bilby), Section 4.3.1 (Hamersley Lepidium), Section 5.3.1 (Northern Quoll), Section 6.3.1 (Pilbara Leaf-nosed Bat and Section 7.3.1 (Pilbara Olive Python).

2.6 ANALYSIS APPROACH AND PRESENTATION OF RESULTS

Potential cumulative impacts were determined through application of relevant impacts (as GIS spatial layers) to the base case spatial layer for each MNES. A conservative approach was taken for the assessment without the inclusion of management and mitigation measures. The amount of the cumulative impact attributable to each individual component impact was determined through analysis of the change from one scenario to another scenario, or to the base case, as follows:

- The effect of existing impacts was determined from the change from the base case to Scenario 1.
- The effect of future third party iron ore mining projects was determined from the change from Scenario 1 to Scenario 2.
- The effect of the Full Development Scenario was determined from the change from Scenario 2 to Scenario 3.

Key results of the CIA are provided in Section 3.5 (Greater Bilby), Section 4.5 (Hamersley Lepidium), Section 5.5 (Northern Quoll), Section 6.5 (Pilbara Leaf-nosed Bat) and Section 7.5 (Pilbara Olive Python). These sections present the key outcomes of the CIA, rather than exhaustive results, for each MNES and include discussion in relation to indicators of significant effects (Section 2.6.1) where relevant.

2.6.1 Indicators of potentially significant impacts

Indicators of potentially significant impacts (reduction in the extent of categories of habitat suitability) were set at 70 and 90 per cent, using an approach consistent with regulatory authorities and conservation organisations internationally, nationally, within Western Australia and other states in Australia, which are summarised below. Exceedance of one or more of these values does not necessarily indicate a significant impact (equally, non-exceedance of the values does not guarantee an insignificant impact); rather, the values provide an indicator of potentially significant impacts that should be considered in light of the methods and limitations of the CIA (including limitations associated with base layer modelling) and with regard to potential mitigation and management options.

These levels of potential impact were considered appropriate for use in the CIA to provide an indication of the potential significance of impacts and to ensure consistency across the broad range of MNES. The values used to indicate potentially significant impacts have been discussed in guidance material for species and communities; examples of regulatory documents are discussed in the following sections.

It is acknowledged that historical impacts have already occurred, so these indicator values are to be used as a guide only. Percentages were determined using the Pilbara bioregion; however, it is noted that the distributions of some of the MNES considered extend beyond the bioregion and this assessment therefore may overstate the potential impacts to these species if considered across the speciesô entire range.

THE NATIONAL OBJECTIVES AND TARGETS FOR BIODIVERSITY CONSERVATION 2001-2005

The National Objectives and Targets for Biodiversity conservation 2001-2005 report (Department of Environment and Heritage [DEH] 2001) states that all jurisdictions should have mechanisms or clearing controls in place to ñprevent clearance of ecological communities with an extent below 10 per cent of that present pre-1750ò by 2001 and to ñprevent clearance of ecological communities with an extent below 30 per cent of that present pre-1750ò by 2003.

EPA POSITION STATEMENT NO. 2

EPA Position Statement No. 2 (EPA 2000) states ñthe óthreshold levelô below which species loss appears to accelerate exponentially at an ecosystem level is regarded as being at a level of 30% of the pre-clearing extent of the vegetation typeò and ña level of 10% of the original extent is regarded as being a level representing óendangeredôò.

A GUIDE TO THE ASSESSMENT OF APPLICATIONS TO CLEAR NATIVE VEGETATION

The guide to the assessment of applications to clear native vegetation by the Department of Environment Regulation (DER) references DEH (2001), in recognition of a retention level of 30 per cent for pre-clearing extent of each ecological community to protect biodiversity (DER 2014). The DER (2014) suggests that 30 per cent retention is a threshold level below which species loss appears to accelerate exponentially, and therefore loss below this level should not be allowed. In regards to clearing principle (e) Native vegetation should not be cleared if it is significant as a remnant of native vegetation in an area that has been extensively cleared, the DER (2014) states: ñUnder this principle, clearing in areas with greater than 30 per cent native vegetation is not likely to be at variance if there is greater than 30 per cent of the total vegetation in the local area and within the bioregion in ógoodô condition.ò

However, the DER (2014) warns that this 30 per cent level within a bioregion does not consider the effect of habitat fragmentation and isolation, or naturally rare or restricted ecological communities.

These areas may require substantially more than 30 per cent of their pre-European extent to sustain biodiversity (DER 2014).

ECOLOGICAL COMMUNITIES IN WESTERN AUSTRALIA

Ecological communities in Western Australia may be listed as Critically Endangered Threatened Ecological Communities if ñthe estimated geographic range, and/or total area occupied, and/or number of discrete occurrences since European settlement have been reduced by at least 90%ò (and if certain criteria apply) and as Endangered Threatened Ecological Communities if ñthe geographic range, and/or total area occupied, and/or number of discrete occurrences have been reduced by at least 70% since European settlementò (and if certain criteria apply) (Department of Environment and Conservation [DEC] 2010).

EPA GUIDANCE STATEMENT NO. 10

EPA Guidance Statement No. 10 (EPA 2006) sets levels for native vegetation retention of at least 30 per cent of the pre-clearing extent of the ecological communities, and references DEH (2001) and EPA (2000) as the rationale behind this approach. The object is to ñretain at least 30% of the pre-clearing extent of the ecological communities, where >30% of an ecological community remainsò and ñpreferentially locate developments in cleared areas, particularly where 30% or <30% of the pre-clearing extent of the ecological community remainsò. It is noted that EPA Guidance Statement No. 10 relates to proposals affecting natural areas within the System 6 Region and Swan Coastal Plain portion of the System 1 Region in Western Australia.

The EPA (2006) also discusses a lower limit of 10 per cent for constrained urban areas as most of the area has already been cleared (i.e. retention of 30 per cent is no longer possible). The objective for these óconstrained areasô is to ñretain at least 10% of the pre-clearing extent of the ecological community where >10% of the ecological community remainsò and ñretain all remaining areas of each ecological community where <10% of this ecological community remainsò.

INTERNATIONAL UNION FOR CONSERVATION OF NATURE (IUCN) RED LIST CATEGORIES AND CRITERIA

Taxa may be listed under the International Union for Conservation of Nature (IUCN) Red List Categories and Criteria (IUCN 2012) as Critically Endangered if the best available evidence indicates a ñé population size reduction of Ó90%...ò (and if certain criteria apply; or a reduction of 80 per cent or more if other criteria apply) or as Endangered if the best available evidence indicates a ñé population size reduction of Ó70%...ò (and if certain criteria apply; or a reduction of 50 per cent or more if other criteria apply).

VEGETATION MANAGEMENT ACT 1999 (QLD)

Regional ecosystems may be listed under the *Vegetation Management Act 1999* (QLD) (VM Act) as óendangeredô if:

- ñremnant vegetation is less than 10% of its pre-clearing extent across the bioregionò, or
- ñ10-30% of its pre-clearing extent remains and the remnant vegetation is less than 10,000 haò, or
- ñless than 10% of its pre-clearing extent remains unaffected by severe degradation and/or biodiversity lossò, or

- ñ10-30% of its pre-clearing extent remains unaffected by severe degradation and/or biodiversity loss and the remnant vegetation is less than 10,000 haò

Regional ecosystems may be listed under the VM Act as óof concernô if:

- ñremnant vegetation is 10-30% of its pre-clearing extent across the bioregionò or
- ñmore than 30% of its pre-clearing extent remains and the remnant extent is less than 10,000 haò or
- ñ10-30% of its pre-clearing extent remains unaffected by moderate degradation and/or biodiversity lossò

Regional ecosystems may be listed under the VM Act as óleast concernô if ñremnant vegetation is over 30% of its pre-clearing extent across the bioregion, and the remnant area is greater than 10,000 haò

LIMITATIONS OF INDICATORS

While the potential impact levels of 70 or 90 per cent (10 or 30 per cent retention levels) are discussed in guidance material, caution should be exercised if these values are used as indicators of significant environmental impacts or as minimum retention limits applied during project implementation. Scientific literature (Huggett 2005; Lindenmayer and Luck 2005) indicates these levels may have limited accuracy or value for some species and communities. This is due to the complex nature of ecological thresholds; or the point below that which the loss of an environmental value might be expected to accelerate exponentially. These 70 or 90 per cent potential impact levels may be overly conservative or risky, depending on the specific resilience or sensitivity of individual environmental receptors. However, these values were considered appropriate for use in the CIA as a general first pass indicator of potentially significant effects on environmental receptors, and were used to ensure consistency across the MNES considered. They should be considered in light of the methodology and limitations of the CIA.

2.7 PEER REVIEW PROCESS

BHP Billiton Iron Ore used a peer review strategy to address areas of potential risk in this CIA as it is a key technical component of the IAR. The peer review panel included a subject matter expert for each of the five MNES included in the CIA and strategic reviewers for the overall approach to the CIA. The peer reviewers engaged as part of the review strategy were:

- Mr Warren Tacey: Strategic reviewer, whose area of expertise includes State and Commonwealth approvals, including strategic assessments under Part 10 of the EPBC Act.
- Professor Chris Moran: Strategic reviewer, whose area of expertise includes digital data representation, strategic planning and environmental modelling.
- Dr. Rick Southgate: Subject matter expert for the Greater Bilby.
- Dr. Eddie van Etten: Subject matter expert for Hamersley Lepidium.
- Dr. Mike Bamford: Subject matter expert for the Northern Quoll.
- Dr. Kyle Armstrong: Subject matter expert for the Pilbara Leaf-nosed Bat.
- Dr. Mark Fitzgerald: Subject matter expert for the Pilbara Olive Python.

Table 4: Spatial data used to apply potential impacts to MNES in the CIA

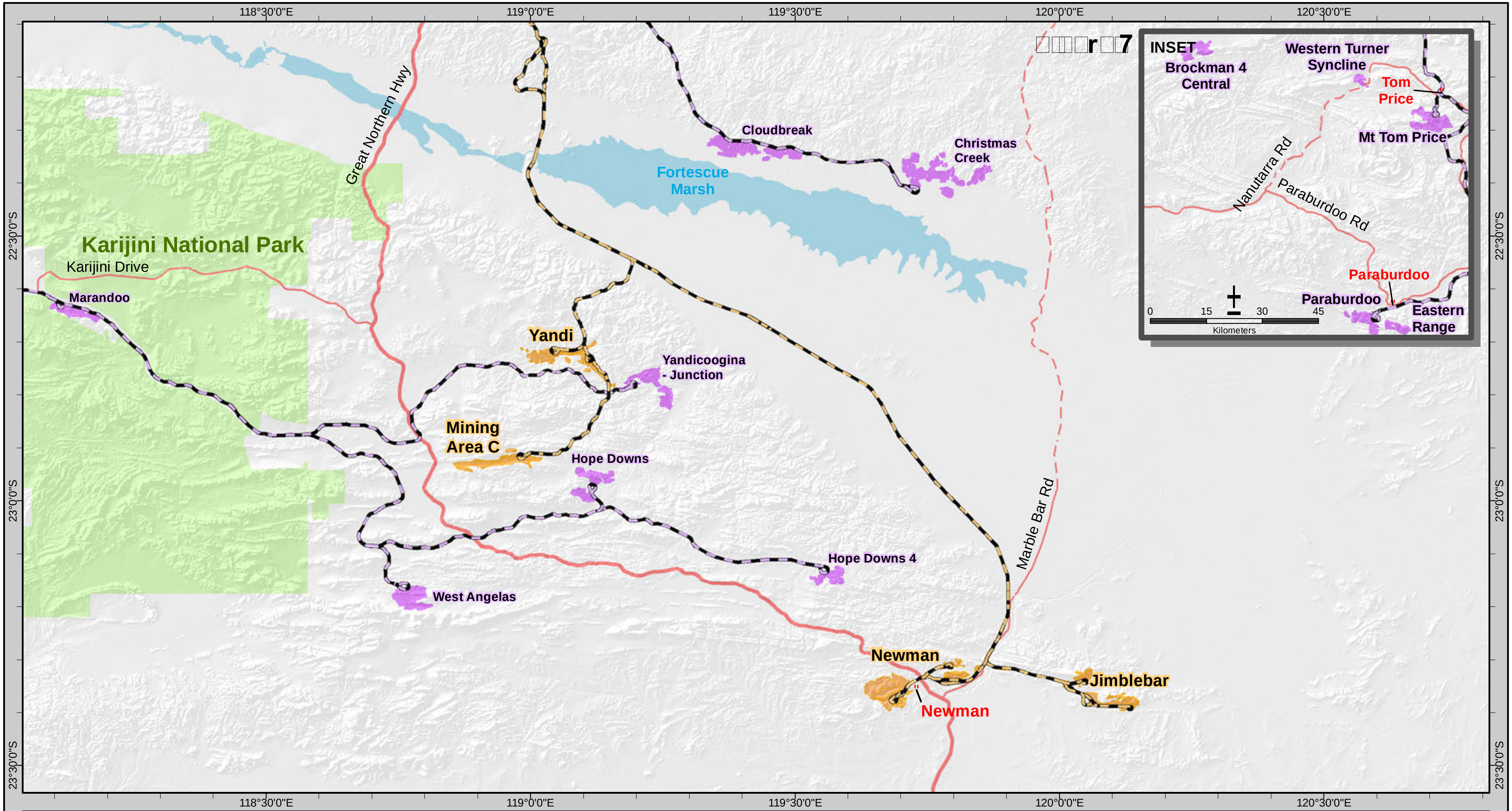
<table>
<tr><th rowspan="2">Potential impact</th><th colspan="3">Spatial layers</th></tr>
<tr><th>Existing impacts</th><th>Reasonably foreseeable future third party iron ore mines</th><th>Full Development Scenario</th></tr>
<tr><td rowspan="2">Removal of habitat</td><td colspan="3">The extent of impact of habitat removal was based on publicly available spatial data from Geoscience Australia and spatial data provided by BHP Billiton Iron Ore, comprising:</td></tr>
<tr><td>• disturbance footprint data for existing BHP Billiton Iron Ore operations and rail infrastructure and existing third party iron ore mines;
• disturbance footprint, point and line data for roads, power lines, airfields, railway yards, human settlements and built-up areas (Geoscience Australia[1]);
• disturbance footprint data for Aboriginal communities, homesteads and roadhouses (publicly available data provided by BHP Billiton Iron Ore).</td><td>• disturbance footprint data for future third party iron ore operations.</td><td>• disturbance footprint data for the Full Development Scenario.</td></tr>
<tr><td>Fragmentation of habitat</td><td colspan="3">The extent of impact of habitat fragmentation was based on the spatial layers used for habitat removal; however, for roads, only highly trafficked roads[2] were included and, for existing impacts, power lines were excluded. The impact of habitat fragmentation was applied based on the size of remaining habitat patches.</td></tr>
<tr><td>Predation</td><td colspan="3">The extent of impact of predation was based on the spatial layers used for habitat removal (excluding closed mines and rail); however, for existing impacts, railway yards were excluded.</td></tr>
<tr><td rowspan="2">Mortality from collision with vehicles</td><td colspan="3">The extent of impact of collisions with vehicles was based on:</td></tr>
<tr><td>• existing BHP Billiton Iron Ore rail infrastructure;
• Scenario 1 highly trafficked roads.</td><td>• Scenario 2 highly trafficked roads.</td><td>• Scenario 3 highly trafficked roads (rail infrastructure associated with the Proposal was considered closed in this scenario and therefore excluded).</td></tr>
<tr><td>Grazing</td><td>The existing impact of grazing was based on a spatial</td><td colspan="2">NA</td></tr>
</table>

Potential impact	Spatial layers		
	Existing impacts	Reasonably foreseeable future third party iron ore mines	Full Development Scenario
	layer for grazing pressure developed by ELA (**Appendix A**).		
Introduction or spread of weeds	The extent of impact of weeds was based on the spatial layers used for habitat removal (excluding closed mines and rail).		
Change in groundwater hydrogeology	The extent of impact of change in groundwater hydrogeology was based on spatial data for groundwater change potential developed by BHP Billiton Iron Ore (2015).		
Change in surface water hydrology	The extent of impact of change in surface water hydrology was based on spatial data for surface water change potential developed by BHP Billiton Iron Ore (2015).		

[1] Data for roads, power lines, airfields, railway yards, human settlements, and built-up areas were obtained from Geoscience Australia and were based on the Global Map 2001 (1:1 million) dataset. Roads and power lines were line data and were buffered 12.5 metres either side of the line to generate a disturbance area 25 metres wide. Airfields, railway yards and human settlements were point data and were buffered 100 metres to create a circular disturbance area with a 100 metre radius. [2] Highly trafficked roads were defined as all primary roads and all paved roads, as well as secondary and other unpaved roads within 10 kilometres of a town or an operating mine (Section 3.3.5).

Table 5: Spatial data for MNES considered in the CIA

Base layer	Description and source of base layer	Limitations of the use of base layer data
Species habitat models for the Greater Bilby (Section 3.3.1), Hamersley Lepidium (Section 4.3.1), Northern Quoll (Section 5.3.1), Pilbara Leaf-nosed Bat (Section 6.3.1) and Pilbara Olive Python (Section 7.3.1)	Predictive models of potential species habitat were developed by ELA (2015) using statistical analysis software (S-Plus), a GIS program (ArcGIS), and purpose-built software (Generalised Regression Analysis and Spatial Prediction; ôGRASPö, Lehman et al 2002). Predictive models are based upon statistical relationships of species locations to variation in environmental variables. This informed construction of a predictive model surface across the Pilbara bioregion for the relative probability of potential habitat (ôhabitat suitabilityö) for each species. Several authors have evaluated and compared the common approaches used within the field (Austin 2007, Elith et al. 2006 and Liu et al. 2013). The method used in the CIA is a common technique in contemporary scientific literature.	Key limitations relevant to the use of the species habitat models in the CIA include: • survey effort and bias of records of species observations to particular areas; • limited attribute information for species data; • lack of species absence data; • lack of scientific design of surveys that collected the species data; • lack, incomplete coverage, or coarse scale of available environmental datasets; and lack of information on other variables that may influence species distribution; • lack of consideration of temporal or seasonal variation; • lack of field validation of the model. Overall, the species habitat models should be treated as indicative, highlighting those parts of the landscape where there is potentially a higher probability of species habitat being present. Further, it is noted that the models do not indicate the potential utilisation of these habitats by the species, nor the relative abundance of species. While there are some limitations with the models, they are considered valid for use in a range of applications. They are considered suitable for use in this Commonwealth CIA given the aims of the study, the analysis approach adopted and the regional focus. All the models generated were evaluated by ELA (2015) as being ôgoodö, ôgood-moderateö or ômoderateö predictions of potential habitat, where designations of ôgoodö indicate that the results were of the highest standard and designations of ôgood-moderateö and ômoderateö indicate lower performance or increasing departure from expected results, but still considered suitable results. Designations of ôlowö would reflect results unsuitable for further modelling; however, no species received this designation for any evaluation criteria (ELA 2015).



LEGEND

BHPBIO Existing Disturbance

- BHPBIO Existing Disturbance
- BHPBIO Operated Existing Rail Corridor

Third Party Existing Disturbance

- Third Party Existing Direct Disturbance
- Third Party Operated Rail Corridor

- Town
- Highways
- Sealed Road
- Unsealed Road

The content of this map is conceptual only, of a general nature and does not purport to contain all information relevant to future project development associated with the Project. This map has been prepared solely for the purposes of informing environmental impact assessment pursuant to the *Environmental Protection Act 1986 (WA) and Environment Protection and Biodiversity Conservation Act 1999 (Cth)* and is not intended for use for any other purpose. No representation or warranty is given that project development associated with any or all of the disturbance indicated on this map will actually proceed. As project development is dependent upon future events, the outcome of which is uncertain and cannot be assured, actual development may vary materially from this conceptual map.

Data Sources:
National Parks (DPaW 2015).

Hillshade (Derived from Geoscience Australia 1 Sec DEM).

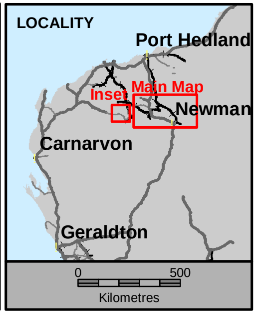
Third Party Disturbamce digitised from Aerial Imagery (Aug - Sept 2013) & Approval Documentations.

Fortescue Marsh (DOE 2001).

Towns (Geoscience Australia 250K v3)

All other data supplied by BHPBIO (2012)

LOCALITY



Corporate Affairs
BHP BILLITON IRON ORE

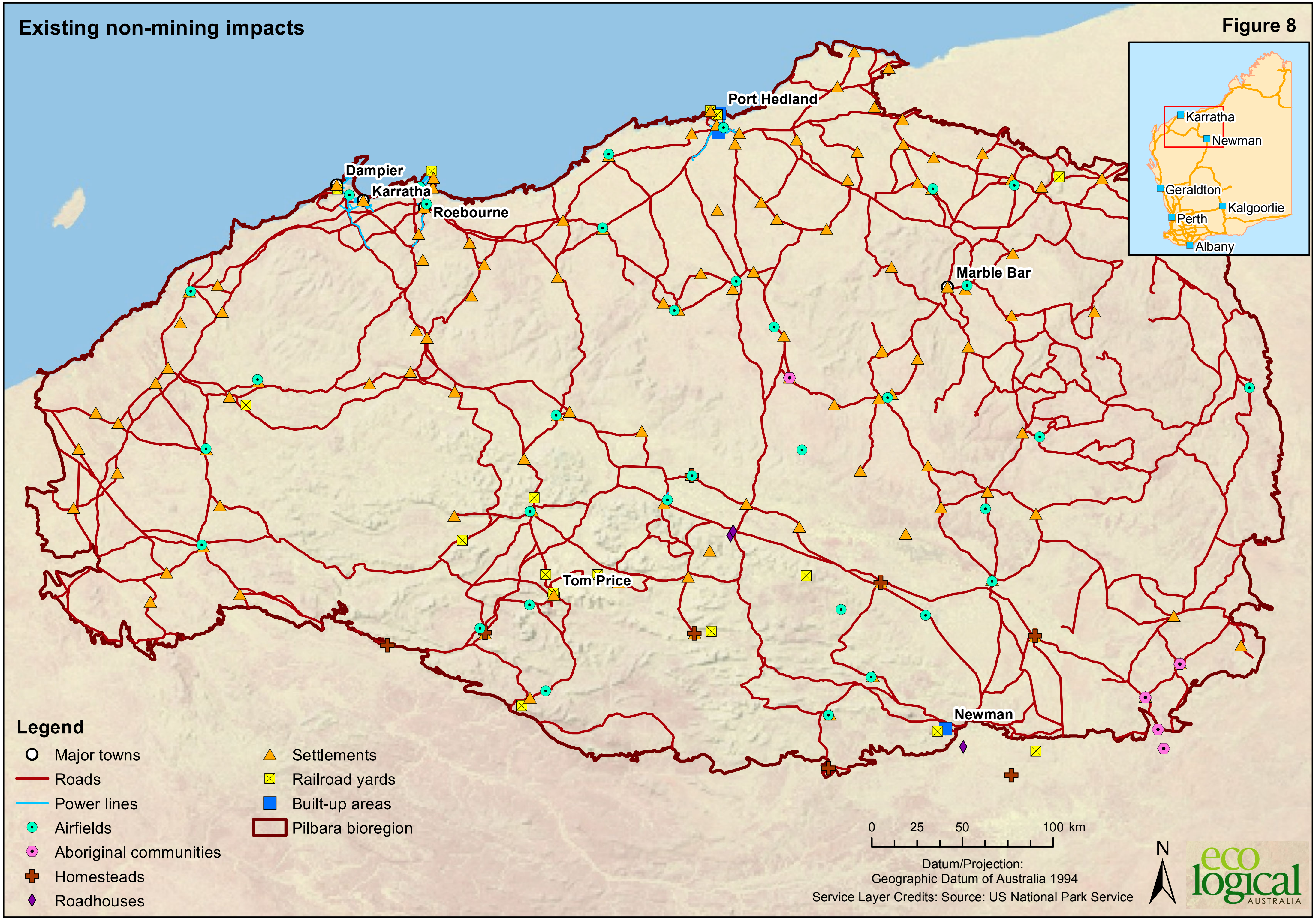
CENTRAL PILBARA
STRATEGIC ENVIRONMENTAL ASSESSMENT
BHP Billiton Iron Ore and Third Party Existing Disturbance

0 10 20 40 60
Kilometres

Coordinate System: GCS GDA 1994, Datum: GDA 1994, Units: Degree

Scale @ A4: 1:1,100,000	Prepared: M. LYTTLE	Project No: A650/15 R Rev A
Date: 8/05/2015	Checked: J. ROBERTS	
	Reviewed: L. REILLY	

Document Path: Y:\Jobs\A501_A1000\A650\3Project\A650_015_R_A4_CurrentBHPThirdParty_RevA.mxd


Existing non-mining impacts
Figure 8
Port Hedland
Dampier
Karratha
Roebourne
Marble Bar
Tom Price
Newman
Karratha
Newman
Geraldton
Kalgoorlie
Perth
Albany
Legend
Major towns
Roads
Power lines
Airfields
Aboriginal communities
Homesteads
Roadhouses
Settlements
Railroad yards
Built-up areas
Pilbara bioregion
0 25 50 100 km
N
Datum/Projection:
Geographic Datum of Australia 1994
Service Layer Credits: Source: US National Park Service
eco logical AUSTRALIA

3 Greater Bilby

3.1 OVERVIEW

This section provides background information relevant to the assessment of potential cumulative impacts to the Greater Bilby from the Proposal. It provides an overview of key ecological characteristics of the Greater Bilby, with particular attention paid to those applicable in the area that may be affected by the Proposal, being the Pilbara bioregion of Western Australia. This section also outlines the potential impacts to the species from implementation of the Proposal, along with key threats to the species as determined through review of the best available literature, data and specialist expertise and knowledge, including the outcomes of a workshop facilitated by Parks and Wildlife in October 2013. The workshop sought specifically to identify key threats to the Greater Bilby and identify knowledge gaps and research priorities (Burrows 2013; Dziminski 2013; Greatwich 2013; Ogburn 2013; Page 2013; Parsons 2013; Ritchie 2013a; Southgate 2013; Southgate and Paltridge 2013; Sustainable Consulting 2013a, 2013b; van Leeuwen 2013a).

The potential impacts identified were considered for their application in the CIA. For those applied in the CIA, the estimated relative magnitude of the impact to the Greater Bilby is provided in Section 3.3 and was based on a review of the best available literature on the likely susceptibility of the Greater Bilby to each impact, along with an understanding of the speciesôkey ecological characteristics as outlined in Section 3.2. Some of the identified potential impacts were excluded from the CIA, the rationale for which is provided in Section 3.3.2.

3.2 SPECIES SYNOPSIS

3.2.1 Description

The Greater Bilby is a small, generally nocturnal, burrowing marsupial that is restricted to the arid regions of central Australia. The species is characterised by its large ears, pointed snout and long, soft, blue grey fur over most of its body, with white to cream fur on the underside (DoE 2013b). It has three stoutly clawed toes, and two un-clawed toes, that enable the Greater Bilby to burrow effectively. The species shows sexual dimorphism with males (up to 2.5 kilograms) growing approximately twice as large as females (up to 1.2 kilograms). This species grows to around 55 centimetres long with a tail up to 29 centimetres long (DoE 2013b).

3.2.2 Conservation status

The Greater Bilby is listed as Vulnerable under the EPBC Act and as Rare or Likely to Become Extinct under Schedule 1 of the *Wildlife Conservation Act 1950* (WA).

3.2.3 Distribution and abundance

The Greater Bilby once occurred across 70 per cent of the Australian mainland, but now occurs in less than 20 per cent of its former range, with (non-introduced) Greater Bilby populations restricted predominantly to the Tanami Desert in the Northern Territory, and the Great Sandy and Gibson Deserts in Western Australia (DoE 2013b). The extent of occurrence for the Greater Bilby (**Figure 9**) is thought to have remained relatively stable over the last 20 years (DoE 2013b).

There are disjunct populations of the Greater Bilby throughout Western Australia, including in the Gibson Desert, south-western Kimberley, inland areas of the Pilbara and northern Great Sandy Desert (**Figure 10**). Within the Pilbara bioregion of Western Australia, most records are from the eastern half of the bioregion, although there are a small number of records in the western and northern parts (**Figure 11**). The density of Greater Bilby populations is currently unknown, but the total population size is estimated to be around 5,000 to 10,000 in Western Australia (Friend et al. 2008).

3.2.4 Habitat requirements

The Greater Bilby occurs in a variety of habitats, usually on landforms with level to low slopes and light to medium soils (DoE 2013b). The species utilises a wide range of habitat types including open tussock grasslands, hummock grassland plains, hills, lowlands, *Acacia* woodlands such as *A. stellaticeps*; Greatwich 2013) and shrublands on red sand ridges and slopes. Within these habitats, the presence of the Greater Bilby is strongly associated with substrate type; the species is generally restricted to areas that contain suitable burrowing habitat, e.g. sandy and alluvial areas. Swale habitat and interdune areas are less suitable as they are often too hard for burrow construction (Moseby and O'Donnell 2003).

Laterite/rock features or drainage/calcrete substrates are also important for the Greater Bilby as they can support shrubs with root-dwelling larvae, which is an important food source for the Greater Bilby (DoE 2013b). Thompson and Thompson (2008) suggested that burrowing habitat was the main factor restricting Greater Bilby distribution; however, in the Tanami Desert, the Greater Bilby is less abundant on dune and sand substrate than on laterite/rock features, probably due to the increased food availability (Southgate 2006). Laterite and rock substrates also support spinifex hummocks, which tend to be fairly uniform and discrete, and provide corridors or runways for easier movement and foraging (Southgate et al. 2007).

Habitat analysis undertaken by Dunwoody et al. (2009) showed that individuals within an enclosure at Currawinya National Park in south-west Queensland preferred to dig burrows in acidic rudosol soils within shrubland with dead wood land cover. Their feeding sites occurred fairly evenly on acidic, basic and salic rudosol soils, which are also common in the Pilbara bioregion (van Vreeswyk et al. 2004), but they showed a preference for shrubland land cover in which to feed.

The habitat analysis revealed the following:

- The Greater Bilby's micro-habitat for feeding and resting could be accurately predicted within the confines of the enclosure.
- The Greater Bilby depended upon only a small part of the larger area available to them with suitable micro-habitats representing only a small percentage of the enclosure.
- The Greater Bilby exhibited distinct preferences for specific soil and land cover types for constructing burrows and feeding.
- The Greater Bilby also shows a stronger association with areas of higher rainfall and temperature than with areas of lower rainfall and temperature. These areas may provide increased food resources and are less well-tolerated by feral predators such as the European Red Fox (fox; *Vulpes vulpes*) (DoE 2013b).

3.2.5 Burrows

The Greater Bilby digs burrows that descend in a gentle spiral two to three metres deep. Most burrows are isolated; however, complex systems consisting of inter-connecting burrows are sometimes excavated (Pavey 2006a). Some burrows have multiple entrances, such as those on Thistle Island (off the coast of South Australia), which had more than 20 entrances (Pavey 2006b).

Burrows are mainly used for shelter during daylight hours (to escape extreme temperatures), but are also used intermittently throughout the night for rest and refuge (Moseby and O'Donnell 2003). An individual may have over a dozen regularly used burrows within its home range. Females tend to exhibit long-term site fidelity, but up to 30 per cent of burrows may be reused by both males and females (Moseby and O'Donnell 2003). Burrows are often shared, although males appear to be intolerant of other males occupying the same burrow (Fortescue Metals Group 2005).

The number and condition of burrows is expected to relate directly to the time an area has been occupied; however, the local abundance and distribution of burrows is not likely to provide an accurate assessment of the number of individuals in an area (Sinclair Knight Mertz [SKM] 2012).

3.2.6 Home range, migration and movement

The Greater Bilby is a mostly solitary animal (Sustainable Consulting 2013a). It is highly mobile and has a large foraging range, with a home range of around 18 hectares for females and 320 hectares for males. Females typically have non-overlapping home ranges and show long-term burrow fidelity (Moseby and O'Donnell 2003). Home ranges can shift by approximately 15 kilometres over three months (Southgate 2013).

The Greater Bilby will utilise several active burrows within its home and will utilise the same burrows infrequently (Southgate 2013). Males can move approximately two to three kilometres (up to five kilometres) between burrows compared with 1.5 kilometres for females (Moseby and O'Donnell 2003). Females tend to remain close (less than 240 metres) to diurnal burrows. The Greater Bilby moves generally less than four kilometres overnight (Southgate et al. 2007), but can move over larger distances if required; in a study at Lorna Glen in Western Australia, individuals moved between sites separated by more than 20 kilometres (Pertuisel 2010).

The density of Greater Bilby populations is typically low, potentially as low as one to two individuals per 100 hectares (Pavey 2006b). Population density can reach up to 12 to 16 individuals per 100 hectares in optimal habitat, but rarely exceeds 20 individuals per 100 hectares (Southgate and Possingham 1995).

A study undertaken by Moseby and O'Donnell (2003) indicated that a habitat patch of 1,400 hectares was too small an area to allow for the natural dispersal of a population containing nine individuals. The Parks and Wildlife workshop held in October 2013 suggested that an area of 50,000 hectares is required to support a viable Greater Bilby population (Dziminksi 2013).

3.2.7 Breeding

Breeding habitat is restricted to areas with soil properties that can support suitable burrow construction; the main factor in reproduction success appears to relate to the availability of a light to medium soil capable of sustaining stable burrows (DoE 2013b). Females become sexually mature at six months and have a short gestation (14 days) and lactation period (Southgate and Possingham 1995). Pouch-life takes between 71 and 80 days and young remain dependent on the mother for a further 10 to 14 days until weaned. Mortality around weaning is often low (Southgate and Possingham 1995). Breeding can occur throughout the year and females can produce up to four litters per year.

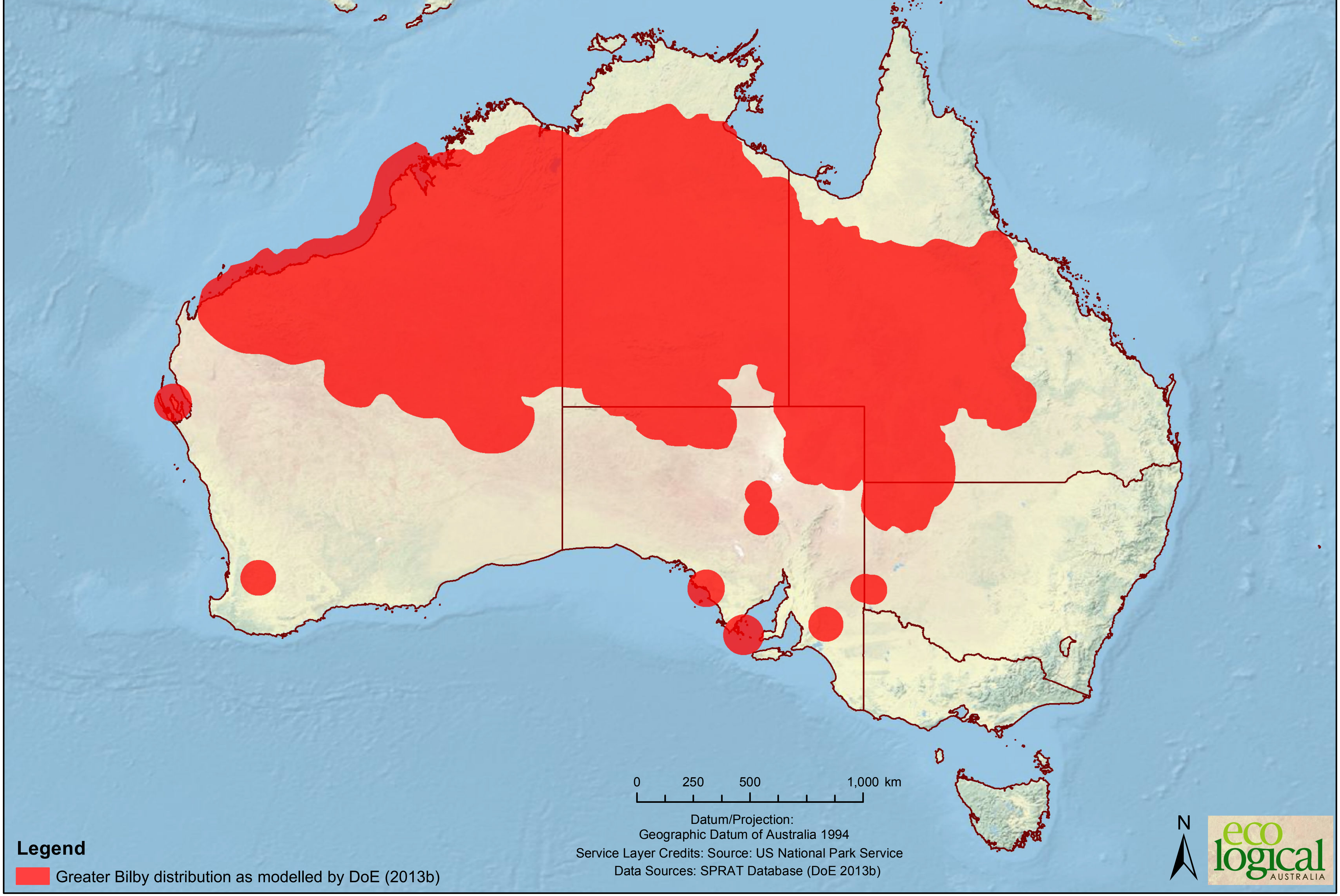
3.2.8 Feeding

The Greater Bilby is a dietary generalist that is able to take advantage of a diverse range of seasonably-available food resources. The Greater Bilby forages after twilight for food such as seeds, bulbs and invertebrates (Moseby and O'Donnell 2003). The species also feeds on root-dwelling larvae and will dig up roots of *Acacia* species to extract the larvae (DoE 2013b). The Greater Bilby is often associated with specific *Acacia* species (Sustainable Consulting 2013b), and in particular, shows a strong feeding association with *Acacia bivenosa* with foraging activity recorded in proximity and often at the base of this plant (Greatwich 2013).

The Greater Bilby is primarily insectivorous in the warmer months and granivorous in the cooler months, and will exploit ant seed stores after seeding has finished (Bice and Moseby 2008). Invertebrates such as ants and termites form a frequent component of the Greater Bilby's diet (Gibson 2001). Fire plays a role in the feeding habitats of the Greater Bilby, with the post-fire ephemeral grass, *Yakirra* (*Panicum*) *australiense*, suggested to be an important part of the Greater Bilby's diet in spinifex habitats (DoE 2013b). Fire-promoted seed is also consumed by the Greater Bilby (Southgate and Carthew 2006).

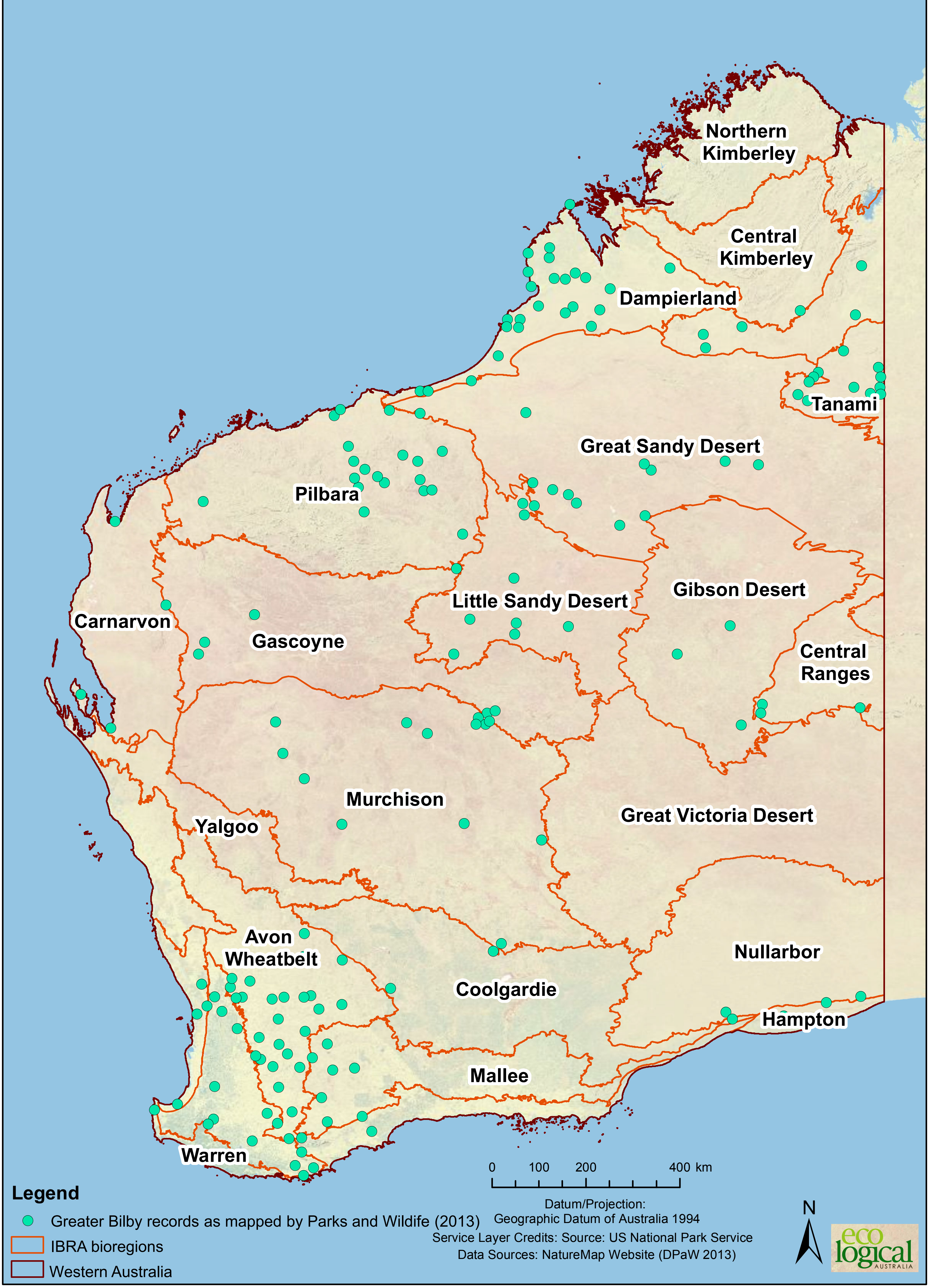
Distribution of the Greater Bilby as modelled by DoE (2013b)

Figure 9



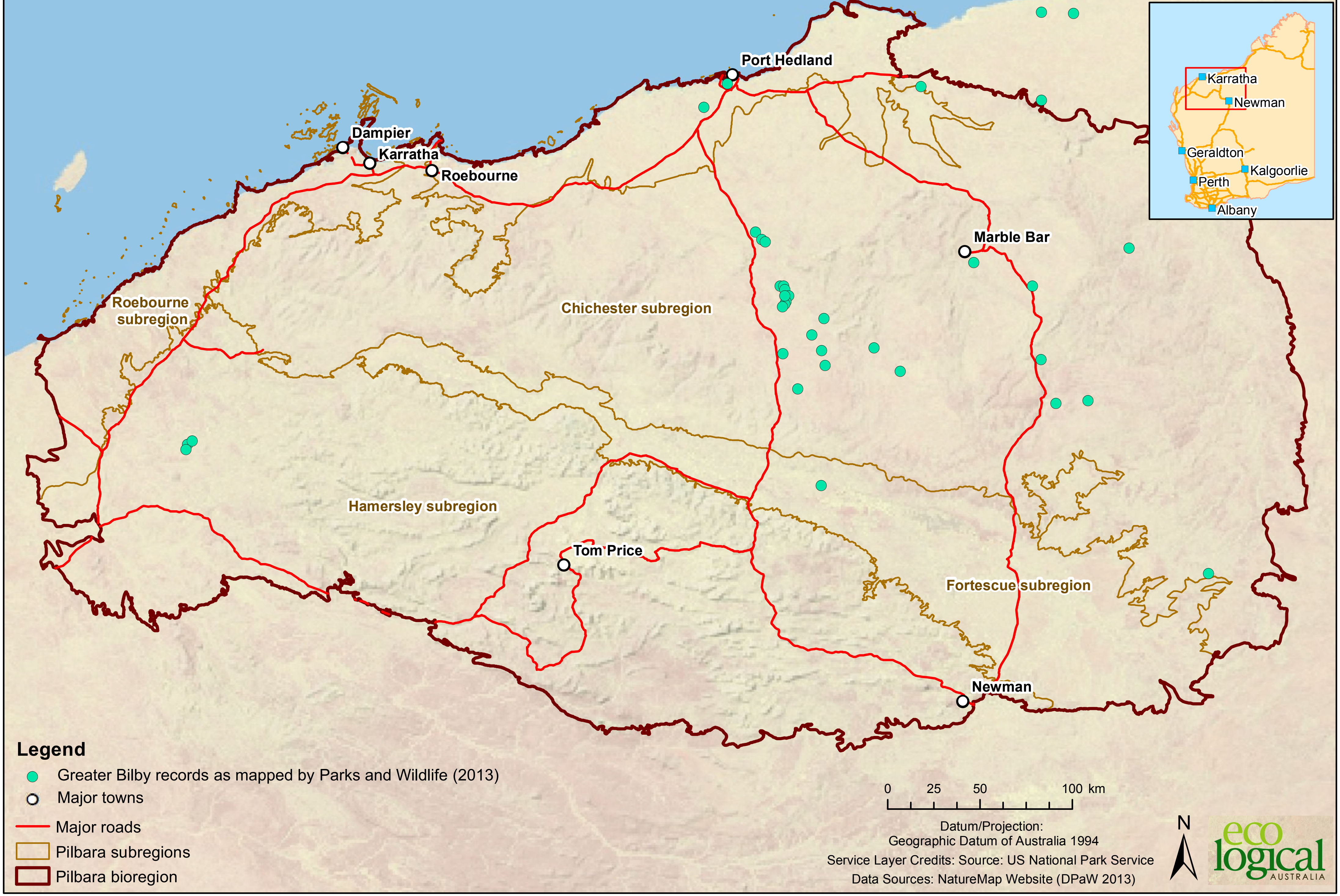
Records of the Greater Bilby in Western Australia (Parks and Wildlife 2013)

Figure 10



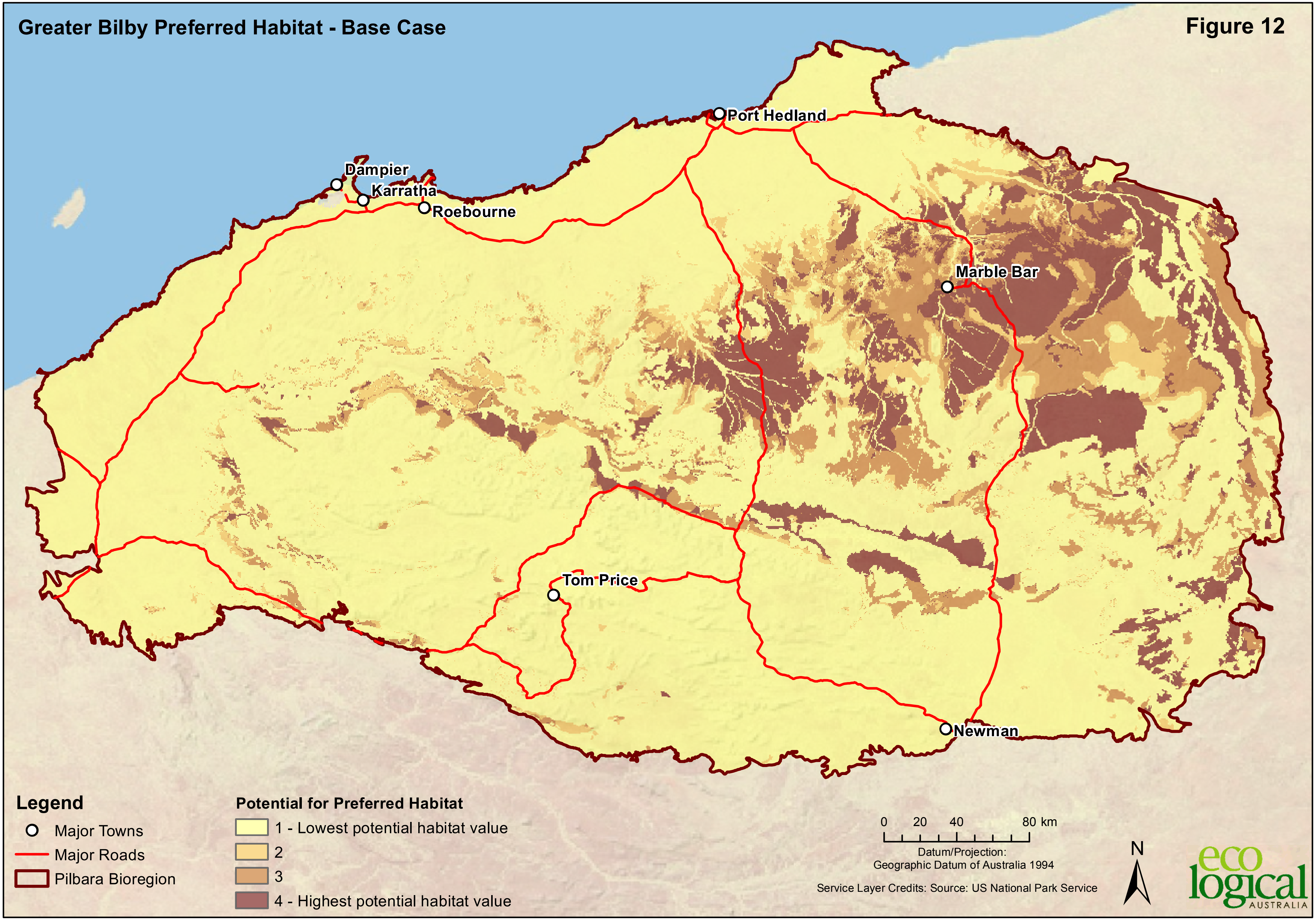
Records of the Greater Bilby in the Pilbara bioregion of Western Australia (Parks and Wildlife 2013)

Figure 11



Greater Bilby Preferred Habitat - Base Case

Figure 12



3.3 METHODS

3.3.1 Base layer considered

The Greater Bilby CIA considered relative probability of potential habitat (habitat suitability) modelled by ELA (2015), as summarised in **Table 5** and described in detail in **Appendix A**. The ELA (2015) model allocated habitat suitability values from zero to 100 per cent across the Pilbara bioregion, which were categorised into four Habitat Ranks (**Table 6**; **Figure 12**). The majority (77 per cent) of the Pilbara bioregion was modelled as lowest potential habitat suitability for the Greater Bilby, with areas of higher habitat suitability occurring mainly in the central part of the eastern Pilbara, roughly centred on Marble Bar (**Table 6**; **Figure 12**).

Table 6: Classification and ranking applied to the Greater Bilby habitat model

Model value	Habitat Rank	Habitat suitability	Area (ha) in Greater Bilby habitat model
70-100%	4	Highest probability of potential habitat	1,751,623 (10%)
30-70%	3	↓	1,513,018 (9%)
10-30%	2		877,696 (5%)
0-10%	1	Lowest probability of potential habitat	13,650,278 (77%)

3.3.2 Identification of key threats

Known and perceived threats to the Greater Bilby are identified in the Commonwealth Species Profile and Threats (SPRAT) database (DoE 2013b) and the National Recovery Plan for the species (Pavey 2006b) (**Table 7**). A Greater Bilby workshop facilitated by Parks and Wildlife in October 2013 also identified threats to the species (Sustainable Consulting 2013a) (**Table 7**).

Table 7: Key threats to the Greater Bilby

Threat	Source		
	DoE (2013b)	Pavey (2006b)	Sustainable Consulting (2013a)
Predation	✓	✓	✓
Removal of habitat	-	✓	✓
Fragmentation of habitat	-	✓	✓
Degradation of habitat	-	✓	✓
Inappropriate fire regimes	✓	✓	✓
Grazing pressure (including competition with other grazers, e.g. rabbits and cattle)	✓	✓	✓
Prolonged drought or high rainfall	✓	✓	✓

Threat	Source		
	DoE (2013b)	Pavey (2006b)	Sustainable Consulting (2013a)
Climate change	✓	-	✓
Mortality from collision with vehicles	✓	✓	✓
Barriers to movement from infrastructure	-	✓	✓
Mining/development	-	✓	✓

Of the aforementioned threats, inappropriate fire regimes were excluded from the CIA. While it is recognised that fire scar mapping is available for the Pilbara, such fire scar mapping provides only the approximate date and area of fires and does not necessarily inform the fire regime (which is a complex of many interacting factors) or about changes in regime (which may require decades of data to detect) (van Etten, E., pers. comm., 2015). In addition, the response of species to different elements of the fire regime and to changes in regime is largely unknown and difficult to predict (van Etten, E., pers. comm., 2015). Consequently, the impact of fire was not applied in the CIA due to lack of data for season, frequency and extent of fires across the Pilbara, all of which may play a key role in influencing Greater Bilby habitat suitability in the Pilbara bioregion (DoE 2013b).

With regard to reasonably foreseeable future impacts of fire, the effect of mining and non-mining activities on alteration of fire impacts is rather equivocal and likely to be influenced primarily by assumptions of fire management and fire response. In addition, the response of species to different elements of the fire regime and to changes in regime is largely unknown and difficult to predict (van Etten, E., pers. comm., 2015). The effect of fire on each species is complex and can be positive or negative in different situations. Limitations associated with fire are discussed in Section 8.1.2.

The potential effect of weeds was considered for inclusion in the CIA, as weeds contribute to habitat degradation and alteration of fire regimes (Adair and Groves 1998). Some introduced grasses have high fuel loads, which increase the intensity and frequency of fires (Hill and Ward 2010). Weeds can suppress or out-compete native flora species, which form part of the diet of the Greater Bilby (Section 3.2.8). *Cyperus bulbosus* (Yalka, Bush Onion) is an important food plant for the Greater Bilby and is currently threatened by the introduced *Cynodon dactylon* (Couch Grass) in some parts of its range (Parks and Wildlife Commission of the Northern Territory 1998). By altering the vegetation community composition through competitive recruitment or modified fire regimes, weeds have the ability to alter habitat suitability for the Greater Bilby. However, as weeds have not been listed as a key threatening process to the Greater Bilby by the DoE (2013b), nor in the National Recovery Plan for the species (Pavey 2006b), they have been excluded from the CIA for the Greater Bilby.

The Cane Toad is not listed as a known or potential threat to the Greater Bilby and the Pilbara bioregion is currently beyond the range of the Cane Toad; however, the Cane Toad is predicted to become extensive throughout the Pilbara in the future (Kearney et al. 2008; Tingley et al. 2012). The Greater Bilbyǿs diet includes a wide range of plants, including grass and sedge seeds, bulbs and fungi, along with a range of invertebrates such as termites and spiders (Section 3.2.8); however, it has not been recorded, nor is it believed to prey on vertebrate fauna, such as native frogs. Therefore, future exposure of the Greater Bilby to Cane Toad toxin through direct ingestion can be considered as a low risk, and not a significant threat.

The potential effects of noise and light on the Greater Bilby were also considered for inclusion in the CIA as, while not listed as key threats to the species, they are associated with the Proposal and have been documented to affect some fauna (e.g. Larkin et al. 1996). With specific reference to the Greater Bilby, the extent to which the species may be affected by noise or light is not well understood and there is a lack of available data to enable assessment of the potential effects of these impacts on the species. Therefore, noise and light were not applied to the Greater Bilby in the CIA. Limitations associated with noise and light are discussed in Section 8.1.2.

Preliminary analysis and modelling of potential effects as a result of recognised predicted climate change estimates was undertaken; however, the level of uncertainty associated with the modelling outcomes was considered to limit its interpretation in relation to cumulative impacts in the Pilbara. Climate change is discussed further in Section 8.1.2.

3.3.3 Potential impacts applied

In consideration of the key threats identified and the available data (Section 3.3.2), the potential impacts applied in the Greater Bilby CIA were:

- removal of habitat;
- fragmentation of habitat;
- predation;
- mortality from collision with vehicles;
- degradation of habitat as a result of grazing pressure.

These potential impacts are considered appropriate for a regional-scale impact assessment. The significance of each impact was rated as Low, Medium, or High (Sections 3.3.4 to 3.3.8). Impacts were applied as spatial layers that changed the habitat model base case. Technical detail on the rating system and the spatial application of impacts in the CIA is provided in Section 2.4.

3.3.4 Removal of habitat

The removal of habitat may result in the loss of active burrows and habitat suitable for burrowing, as well as habitat suitable for foraging and dispersal. This may reduce the speciesôdistribution, which may be compounded by other threats (Pavey 2006a, 2006b). Removal of habitat may also displace individuals, which can jeopardise reproduction potential and therefore local population viability, and increase predation by, or competition with feral animals (Pavey 2006a, 2006b). Removal of habitat was rated as High impact: areas where habitat was removed were assigned a High (100 per cent) level of potential impact as habitat would become unsuitable in these areas (assuming clearing is permanent); areas where habitat was not removed were unchanged (**Table 8**).

Table 8: Potential impacts of removal of potential Greater Bilby habitat

Vegetation clearing/ removal of habitat	Level of potential impact	Confidence in level of potential impact	Assumptions
Habitat removed	High (100%)	High. Habitat would be unsuitable in	Clearing is permanent. Edge

Vegetation clearing/ removal of habitat	Level of potential impact	Confidence in level of potential impact	Assumptions
		cleared areas.	effects are not considered for this impact.

3.3.5 Fragmentation of habitat

Greater Bilby habitat fragmentation could reduce genetic connectivity and the potential for physical dispersal across affected areas and increase the risk of local extinctions. A patch is considered a discrete area used by individuals of a species to breed or obtain other resources. Mining and linear infrastructure have the potential to fragment Greater Bilby habitat if clearing reduces habitat connectivity, or infrastructure presents an obstacle to movement or dispersal.

Habitat fragmentation was considered in terms of minimum patch size: the area required for the species to maintain a viable population. The minimum patch size was determined based on reported Greater Bilby mobility and assumptions of viable population density. The Parks and Wildlife workshop held in October 2013 noted that one piece of research suggested that an area of 50,000 hectares is required to maintain a viable population (Sustainable Consulting 2013a). In contrast, based on a minimum estimate of 40 individuals for a viable population (from studies completed for re-introduced populations; Assessment of Australiaꞌs Terrestrial Biodiversity [AATB] 2008, Pertuisel 2010) and an a population density of one to three individuals per 100 hectares (from a predator-free fenced environment [Moseby and OꞌDonnell 2003] and AATB 2008), an area of approximately 1,300 to 4,000 hectares would be required. The midpoint of these estimates is 25,650 to 27,000 hectares; a rounded value of 30,000 hectares was used in this assessment. Habitat fragmentation was considered to have occurred when patch size was reduced below 30,000 hectares; impacts were assumed to increase with decreasing patch size below this threshold (**Table 10**).

Fragmentation was applied according to the ꞌequivalent sizeꞌ of remaining ꞌpatchesꞌ of habitat after the habitat removal potential impact spatial layer had been applied to the species habitat model (Section 3.3.4). Initial habitat patches (i.e. prior to the application of habitat removal) were considered to be contiguous areas (defined by adjacent pixels within the species habitat models) of Habitat Ranks 2, 3 and 4.

Patches were identified and tagged within the GIS and the area of each patch calculated. Impacts were applied by removing habitat within the applicable disturbance footprints. Patch area was recalculated post-impact and those patches in which the area had changed were deemed ꞌaffectedꞌ and subsequently subjected to the fragmentation analysis. An equivalent area was calculated for affected patches by weighting the area of different habitat ranks, with the rationale for this being that more suitable habitat would have more value to a species (per unit area) than less suitable habitat.

Different habitat ranks were weighted as follows:

- The area of Class 4 habitat was multiplied by 1.
- The area of Class 3 habitat was multiplied by 0.5.
- The area of Class 2 habitat was multiplied by 0.25.

The individual areas were then summed to determine the equivalent size of the patch. For example, a habitat patch containing 300 hectares of Class 3 habitat and 180 hectares of Class 2 habitat would have an equivalent size of 195 hectares ([300 x 0.5] + [180 x 0.25]).

In the application of the potential impact of habitat fragmentation, the use of the spatial layer for roads was limited to a subset defined as ôhighly trafficked roadsö The publicly available road layer used in the CIA categorised roads as either primary, secondary or other, and then for each of these categories as either paved or unpaved. Highly trafficked roads were defined as all primary roads and all paved roads, as well as secondary and other unpaved roads within 10 kilometres of a town or an operating mine (**Table 9**). A separate highly trafficked road layer was developed for each scenario of the CIA.

Table 9: Highly trafficked roads

Road type	≤ 10 km of a town or operating mine	> 10 km from a town or operating mine
Primary	✓	✓
Secondary (paved)	✓	✓
Secondary (unpaved)	✓	✗
Other (paved)	✓	✓
Other (unpaved)	✓	✗

Table 10: Potential impacts of fragmentation of potential Greater Bilby habitat

Patch size	Level of potential impact	Confidence in level of potential impact	Assumptions
10,000-30,000 ha	Low (20%)	Low: The patch size required for breeding is unknown.	Greater Bilby habitat is completely isolated by mine infrastructure (including rail and ôhighly trafficked roadsö). Forty individuals will sustain a population (based on AATB 2008, Pertuisel 2010). The density of Greater Bilby populations is two individuals per 100 ha (based on Moseby and OÕDonnell 2003, AATB 2008). Habitat suitability is considered to decrease as patch size decreases.
2,000-10,000 ha	Medium (50%)		
<2,000 ha	High (100%)		

3.3.6 Predation

The occurrence of feral predators, in particular the fox, was previously considered the main threatening process to the Greater Bilby as it caused a significant decline in Greater Bilby populations across south-western Australia (DoE 2013b). The historic decline and the current areas of occurrence of the Greater Bilby correlate well with the spread and current distribution of the fox (DoE 2013b). The extent to which the fox affects Pilbara populations of the Greater Bilby is currently not well understood. The fox is present within coastal parts of the bioregion, but absent from the arid Pilbara (Pearson, D., Parks and Wildlife, pers. comm., Parks and Wildlife workshop, 2013). Other feral predators, such as the feral cat (*Felis catus*), are also known to prey on the Greater Bilby and have caused some populations to decline (e.g. at Lorna Glen, close to the geographic centre of Western Australia and straddling the boundary between the Murchison and Gascoyne IBRA bioregions, Pertuisel 2010). Dingoes may also prey on the Greater Bilby, but are more likely to improve habitat suitability for the species by preying on cats and rabbits, and displacing foxes (Southgate et al. 2007).

While there is likely to be some level or predation throughout the Pilbara generally, feral predators are considered likely to occur in greater numbers near areas of human settlement (such as towns and mine camps) as a result of increased opportunities for food and near roads as a result of facilitated movement (e.g. Andrews 1990; Brown et al. 2006; Lach and Thomas 2008; Mahon et al. 1998; May and Norton 1996). The increased spatial and temporal availability of free water from mining activities (for example, due to increased surface water discharge into water bodies, dust suppression, or creation of pit lakes upon mine closure) can also result in feral predator populations that are more resilient and persistent, with greater home ranges (Department of Environment and Heritage Protection 2012). As such, impacts of predation were related to proximity to human settlements and roads/tracks (and to power lines under the assumption that power lines have an associated access track), with distances relating to the home ranges of feral predators.

The home range of feral cats was estimated by Johnston et al. (2013) as approximately 1,000 hectares, which equates to a radius of approximately 1.8 kilometres, assuming a circular area. The home range of foxes was estimated by Coman et al. (1991) as approximately 500 to 700 hectares, which equates to a radius of approximately 1.4 kilometres, assuming a circular area. Based on these studies, a conservative proximity of two kilometres to human settlements or roads was used as the basis for predation impacts (**Table 11**).

Table 11: Potential impacts to the Greater Bilby from predation

Proximity to human settlement/ road/ power line	Level of potential impact	Confidence in level of potential impact	Assumptions
<2 km	Low (20%)	Medium. Feral predators are considered likely to occur in greater numbers near areas of human settlement and roads.	There is an increased risk of predation around human settlements and roads/tracks (and power lines under the assumption that power lines have an associated access track). The spatial extent of the impact relates to the estimated maximum home range of cats and foxes of 1,000 ha, which equates to a radius of approximately 1.8 km, assuming a circular area (Johnston et al. 2013).

3.3.7 Mortality from collision with vehicles

Mortality from collision with vehicles is not listed as a key threat to the Greater Bilby, but has been noted to occur at a local scale (Pavey 2006b, SKM 2012). There are limited data for roadkill rates for the Greater Bilby, although data exist for mortality on haul roads and public roads in the Northern Territory. Haul roads and railways may be a significant cause of Greater Bilby mortality at a local scale due to the combination of vehicles operating throughout the night (when the Greater Bilby is most active) and in locations where roads or rail lines are adjacent to suitable Greater Bilby habitat.

Mortality from collision with vehicles was considered in the CIA as, where road and rail infrastructure occurs in proximity to Greater Bilby habitat, Greater Bilby deaths can be attributed to associated vehicle movements (Pavey 2006b). Impacts of road and rail mortality were estimated based on the proximity of roads/rail to potential Greater Bilby habitat; collisions were considered to potentially affect Greater Bilby habitat suitability at a distance of up to 500 metres, with the greatest effect being within 50 metres (**Table 12**). In the application of the potential impact of mortality from collision with vehicles, the use of the spatial layer for roads was limited to ôhighly trafficked roadsô(Section 3.3.5).

Table 12: Potential impacts to the Greater Bilby from collision with vehicles

Proximity to roads/rail	Level of potential impact	Confidence in level of potential impact	Assumptions
50-500 m	Low (20%)	Low. Mortality from collision with vehicles is not listed as a key threat to the Greater Bilby, but has been noted to occur at a local scale (Pavey 2006b, SKM 2012).	Habitat suitability is assumed to decrease as the distance to roads/rail decreases.
<50 m	Medium (50%)		

3.3.8 Grazing pressure

There is strong evidence that competition with rabbits for food resources (and potentially burrow resources) is a major threatening process to the Greater Bilby, with Greater Bilby distribution correlating to areas where rabbits are now absent, or in low abundance (SKM 2012). Other introduced herbivores such as cattle and camels also present a threat to the Greater Bilby through physical damage to soil structure, competition for preferred grass/food species, and reduction in termite/ant abundance due to reduced grass seed biomass from grazing (SKM 2012). The distribution of the Greater Bilby is negatively correlated with pastoral land, although it appears the species is able to survive in low densities within grazed areas (Southgate et al. 2007; SKM 2012). Further, cattle grazing and presence (ground disturbance) is likely to change the nature of fire (e.g. intensity and extent) based on the effect cattle can have on low strata vegetation, including the potential for introduction or spread of weeds with high fuel loads. The interaction of grazing pressure and fire may act to compound negative effects on the Greater Bilby; however, this was not directly considered in the application of the potential impacts of grazing.

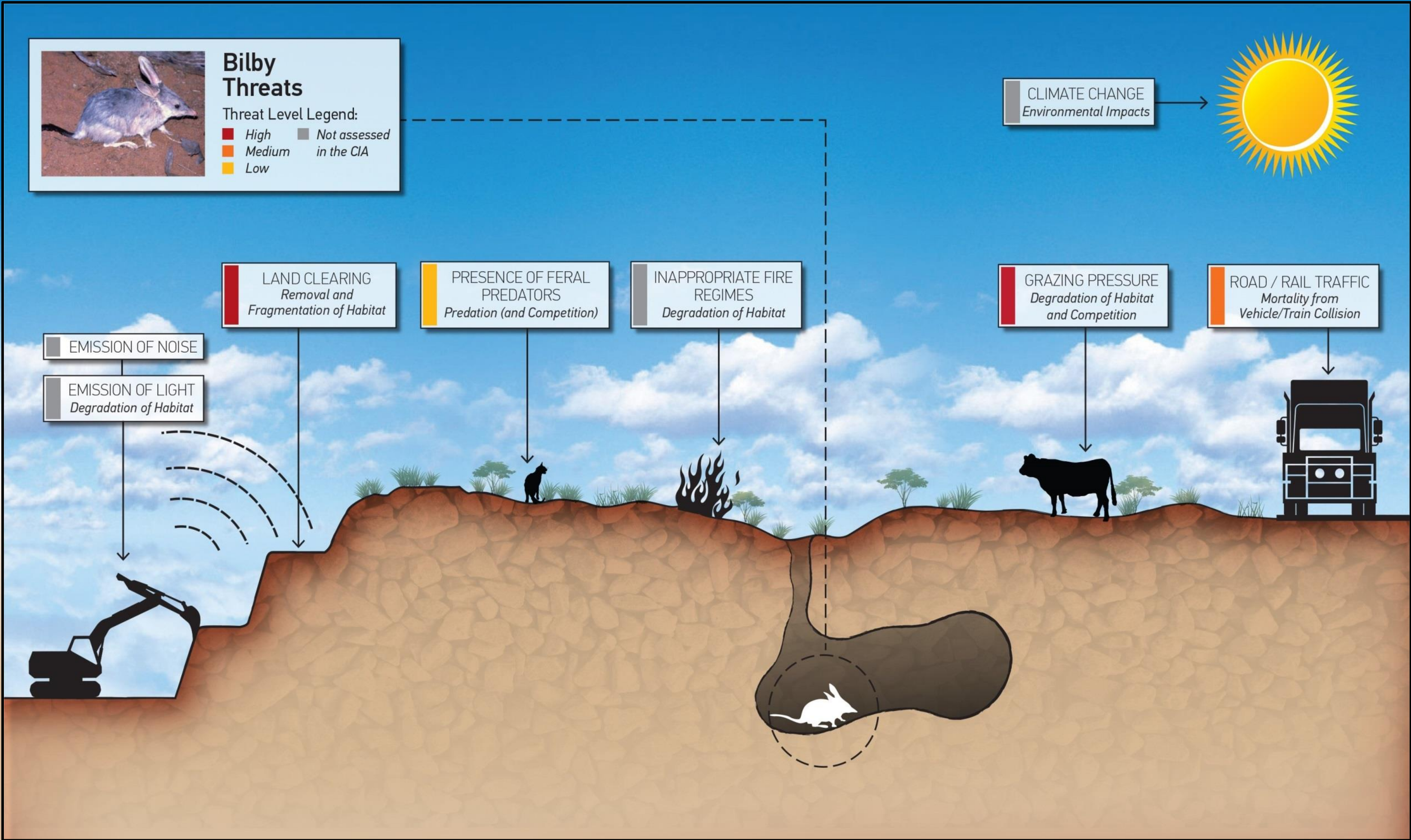
Habitat suitability is expected to reduce as habitat condition is degraded and prey becomes less abundant as grazing pressure increases (**Table 13**). The impact of grazing was applied to the Greater Bilby from a spatial layer for grazing pressure developed for the Pilbara bioregion by ELA. The grazing pressure layer categorised areas as either zero, low, medium or high grazing pressure based on land system data (which contain a ôPastoral Potentialô spatial attribute; land systems are characterised according to vegetation types, substrate and landscape characteristics; van Vreeswyk et al. 2004) and distance to water. Development of the grazing layer is described in **Appendix A**.

Table 13: Potential impacts to the Greater Bilby from grazing

Grazing pressure	Level of potential impact	Confidence in level of potential impact	Assumptions
Low (infrequently grazed)	Low (20%)	Medium. The Greater Bilby is likely to be able to withstand some pressure from introduced herbivores, but the specific level of tolerance is not well understood.	Habitat suitability is expected to reduce as habitat condition is degraded and competition with other grazers increases as grazing pressure increases.
Medium (moderately grazed)	Medium (50%)		
High (heavily grazed)	High (100%)		

3.4 GREATER BILBY CONCEPTUAL DIAGRAM

A conceptual diagram was prepared to depict the Greater Bilby in its natural habitat in the Pilbara and the key threatening processes and potential impacts to the species and its habitat that were considered in the CIA (**Figure 13**). The conceptual diagram shows the potential impacts applied in the CIA and their level of potential impact (High, Medium or Low; Section 3.3). For potential impacts with multiple levels, the conceptual diagram shows the highest level applied in the CIA and in this respect is relatively conservative. For example, mortality from collision with vehicles was rated as Medium impact within 50 metres of roads/rail and Low impact from 50 to 500 metres (**Table 12**); the conceptual diagram shows only the Medium level impact. The conceptual diagram also shows some of the potential impacts considered, but not applied in the CIA, such as noise and light.



Greater Bilby conceptual diagram | **Figure 13**

3.5 RESULTS

Results of the CIA for Greater Bilby habitat suitability are provided in **Table 14** and **Table 15**. **Table 14** provides the area affected by potential impacts associated with existing impacts, future third party mines, and the Full Development Scenario. **Table 15** provides the area that increased or decreased by zero, one, two or three Habitat Ranks as a result of potential impacts associated with existing impacts, future third party mines, and the Full Development Scenario.

The modelled extent of Greater Bilby habitat suitability in Scenario 1 to Scenario 3 is provided in **Figure 14** to **Figure 16**. The area of each Habitat Rank affected by potential impacts associated with existing impacts, future third party mines, and the Full Development Scenario is provided in **Figure 17**. The marginal change from one scenario to another, and from the base case to Scenario 1, is provided in **Figure 18** to **Figure 20**.

For all potential impacts to MNES, a reduction in the extent of any particular Habitat Rank usually means that class of habitat has been lost (cleared), or downgraded (affected by potential impacts other than habitat removal), or a combination of these. Habitat Rank 1 includes all cleared habitat (zero per cent habitat suitability) and intact habitat of low suitability (from greater than zero per cent to 10 per cent habitat suitability); all other habitat ranks include only intact habitat.

In some cases, reduction in the extent of a Habitat Rank from one scenario to another may mean that habitat class has been óupgradedô This is generally associated with mine closure in Scenario 3, whereby some of the potential impacts to MNES were not applied to closed mines and infrastructure, resulting in an apparent increase in habitat suitability from Scenario 2 to Scenario 3. Apparent increases in habitat suitability may also be as a result of a reduction in the extent of impacts associated with ecohydrological change potential mapped by BHP Billiton Iron Ore (2015).

It is noted that the distribution of the Greater Bilby extends beyond the Pilbara bioregion and this assessment therefore may overstate the potential impacts to the species if considered across the speciesô entire range.

3.5.1 Existing impacts

The potential effect of existing impacts was a substantial decrease in Greater Bilby habitat suitability relative to the base case (**Figure 12**, **Figure 14**, **Figure 17** and **Figure 18**). Approximately 1.6 million hectares (94 per cent) of the most suitable habitat (Habitat Rank 4) in the base case habitat model was affected and downgraded to less suitable habitat (Habitat Ranks 1, 2 and 3) (**Table 14**). Overall, a total of approximately 3.2 million hectares decreased in habitat suitability as a result of existing impacts, the majority of which (approximately 2.9 million hectares) decreased by one Habitat Rank (**Table 15**).

The substantial decrease in habitat suitability from existing impacts is likely due to a combination of:

- Grazing pressure, due to Greater Bilby habitat of greater modelled habitat suitability generally coinciding with areas of medium grazing pressure, within which a Medium level of potential impact was applied in the CIA (**Figure 12** and **Figure A9**, **Appendix A**). Introduced herbivores such as cattle and camels present a threat to the Greater Bilby through physical damage to soil structure, competition for preferred grass/food species, and reduction in termite/ant abundance due to reduced grass seed biomass from grazing (SKM 2012). The distribution of the Greater Bilby is negatively correlated with pastoral land, although it appears the species is able to survive in low densities within grazed areas (Southgate et al. 2007; SKM 2012).

- Extensive development of roads and human settlements around and to the east and south-east of Marble Bar, and in the area around 170 kilometres south of Port Hedland, coinciding with areas of high Greater Bilby habitat suitability (**Figure 8** and **Figure 12**). This development likely contributed to:
  - Habitat fragmentation ï Low to High potential impact applied in the CIA for habitat patches smaller than 30,000 hectares. Based on typical population density for the Greater Bilby of one to three individuals per 100 hectares (Moseby and ODonnell 2003; AATB 2008), a viable population of 40 individuals (based on studies completed for re-introduced populations; AATB 2008, Pertuisel 2010) would require up to 4,000 hectares. The Parks and Wildlife workshop held in October 2013 suggested that an area of 50,000 hectares is required. An intermediate value of 30,000 hectares was used in the CIA.
  - Predation ï Low impact applied in the CIA within two kilometres of human settlements, roads/tracks and power lines. The occurrence of feral predators, in particular the fox, was previously considered the main threatening process to the Greater Bilby in other parts of its historic range (outside the Pilbara; however, the extent to which the fox affects Pilbara populations of the Greater Bilby is currently not well understood. The fox is present within coastal parts of the bioregion, but absent from the arid Pilbara (Pearson, D., Parks and Wildlife, pers. comm., Parks and Wildlife workshop, 2013). Other feral predators, such as the cat, are also known to prey on the Greater Bilby and have been shown to cause populations outside the Pilbara to decline (Pertuisel 2010).
  - Mortality from collision with vehicles ï Low to Medium impact applied in the CIA within 500 metres of roads and rail lines. Mortality from collision with vehicles is not listed as a key threat to the Greater Bilby and there is a lack of data for roadkill rates for the Greater Bilby; however, data for road mortality in the Northern Territory suggest roads may be a significant cause of Greater Bilby mortality at a local scale (Pavey 2006b, SKM 2012).

3.5.2 Future third party mines

The potential effect of future third party mines on Greater Bilby habitat suitability was minor as a percentage of the total area of the Pilbara bioregion (**Figure 12**, **Figure 15**, **Figure 17** and **Figure 19**). There was a slight decrease in the extent of Habitat Rank 3 (less than one per cent) and a slight increase in the extent of Habitat Ranks 1 and 2 (less than one per cent; **Table 14**). Overall, a total of approximately 11,400 hectares decreased in habitat suitability as a result of future third party mines, the majority of which (approximately 7,900 hectares) decreased by one Habitat Rank (**Table 15**).

3.5.3 Full Development Scenario

The potential effect of the Full Development Scenario was minor as a percentage of the total area of the Pilbara bioregion (**Figure 12**, **Figure 16** and **Figure 20**). There was a slight decrease in the extent of Habitat Ranks 1, 3 and 4 (less than one per cent) and a slight increase in the extent of Habitat Rank 2 (less than one per cent; **Table 14**). Overall, a total of approximately 6,000 hectares decreased in habitat suitability as a result of the Full Development Scenario, the majority of which (approximately 5,900 hectares) decreased by one Habitat Rank (**Table 15**).

There was a potential slight positive (beneficial) effect of the Full Development Scenario in some areas, with a total of approximately 5,200 hectares increasing in habitat suitability by one Habitat Rank

(**Table 15**). This potential positive effect was associated with mine closure in Scenario 3, whereby some of the potential impacts to the Greater Bilby were not applied to closed mines and infrastructure.

3.5.4 Potential cumulative impacts

The potential cumulative impact to Greater Bilby habitat suitability was a decrease in the extent of the most suitable habitat (Habitat Rank 4) of approximately 1.6 million hectares (94 per cent of the modelled extent in the base case). Existing impacts were the main contributor to this potential impact. Habitat Rank 4 was downgraded into lower ranked habitat; therefore the extent of Habitat Ranks 1, 2 and 3 increased. The contributions of future third party mines and the Full Development Scenario to the overall potential cumulative impact to Greater Bilby habitat suitability were minor as a percentage of the total area of the Pilbara bioregion and in comparison to the effect of existing impacts (**Table 14** and **Table 15**).

Table 14: Area of potential change in Greater Bilby habitat suitability

Habitat Rank	Base case	Area (ha) of potential change*			Potential cumulative impact**
		Existing impacts	Future third party mines	Full Development Scenario	
1	13,650,278	678,551 (5%)	6,396 (<1%)	-1,835 (<-1%)	683,112 (5%)
2	877,696	586,570 (67%)	2,180 (<1%)	4,659 (1%)	593,409 (68%)
3	1,513,018	374,211 (25%)	-8,576 (-1%)	-2,709 (<-1%)	362,926 (24%)
4	1,751,623	-1,639,332 (-94%)	0 (0%)	-114 (<-1%)	-1,639,446 (-94%)

*Positive values indicate the area of a Habitat Rank has increased relative to the previous scenario; negative values indicate the area has decreased. **Positive values indicate the area of a Habitat Rank has increased as a result of the combined effect of existing impacts, future third party mines and the Full Development Scenario; negative values indicate the area has decreased.

Table 15: Area of habitat that increased or decreased by one, two or three ranks, or that did not change between scenarios for the Greater Bilby CIA

Change in Habitat Rank	Area (ha) of potential change		
	Existing impacts (Base Case to Scenario 1)	Future third party mines (Scenario 1 to Scenario 2)	Full Development Scenario (Scenario 2 to Scenario 3)
+3	0 (0%)	0 (0%)	0 (0%)
+2	0 (0%)	0 (0%)	0 (0%)

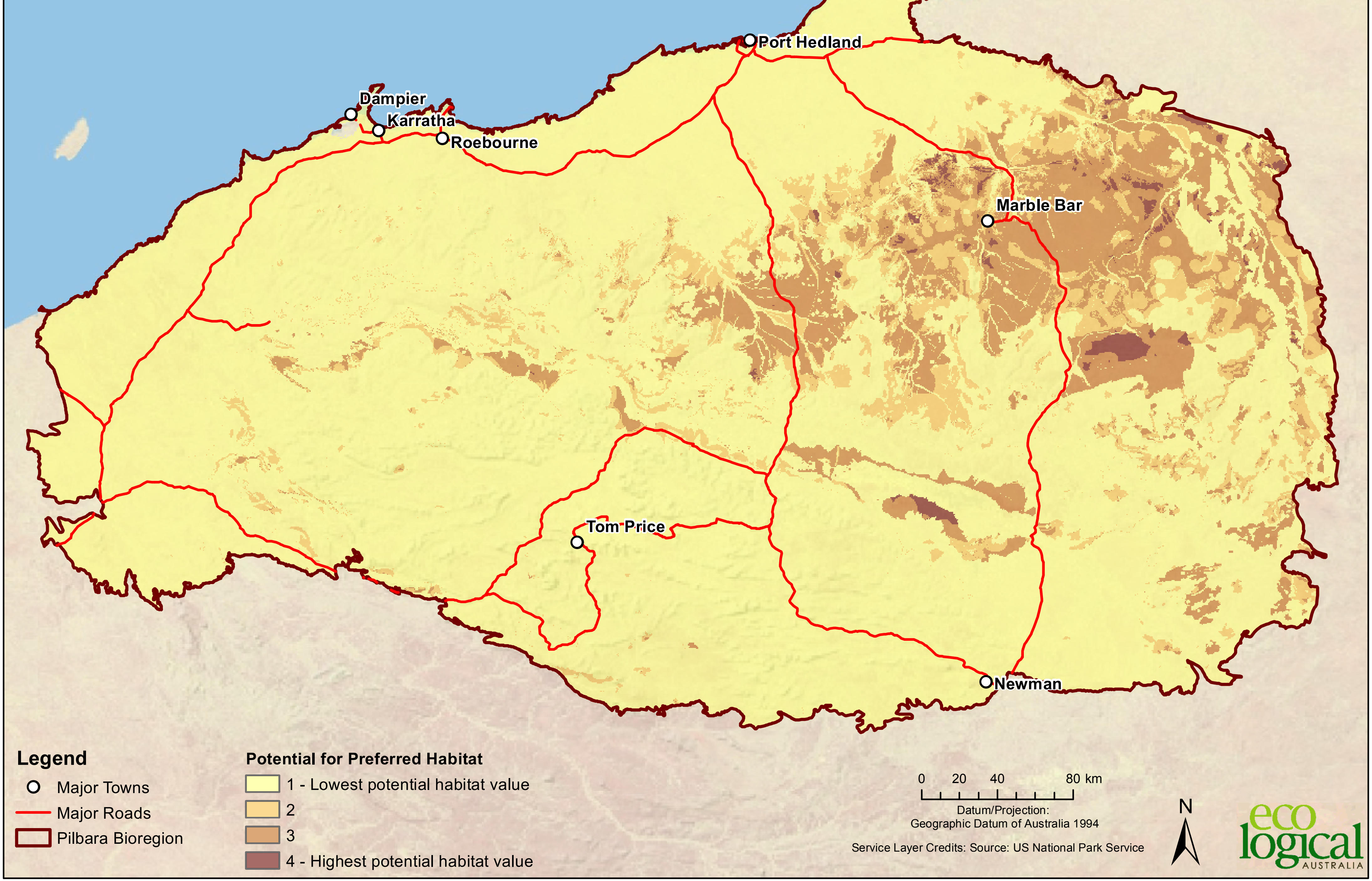
Change in Habitat Rank	Area (ha) of potential change		
	Existing impacts (Base Case to Scenario 1)	Future third party mines (Scenario 1 to Scenario 2)	Full Development Scenario (Scenario 2 to Scenario 3)
+1	0 (0%)	0 (0%)	5,153 (<1%)
0	14,583,610 (82%)	17,781,176 (100%)	17,781,362 (100%)
-1	2,901,431 (16%)	7,903 (<1%)	5,946 (<1%)
-2	241,145 (1%)	3,535 (<1%)	154 (0%)
-3	66,428 (<1%)	0 (0%)	0 (0%)

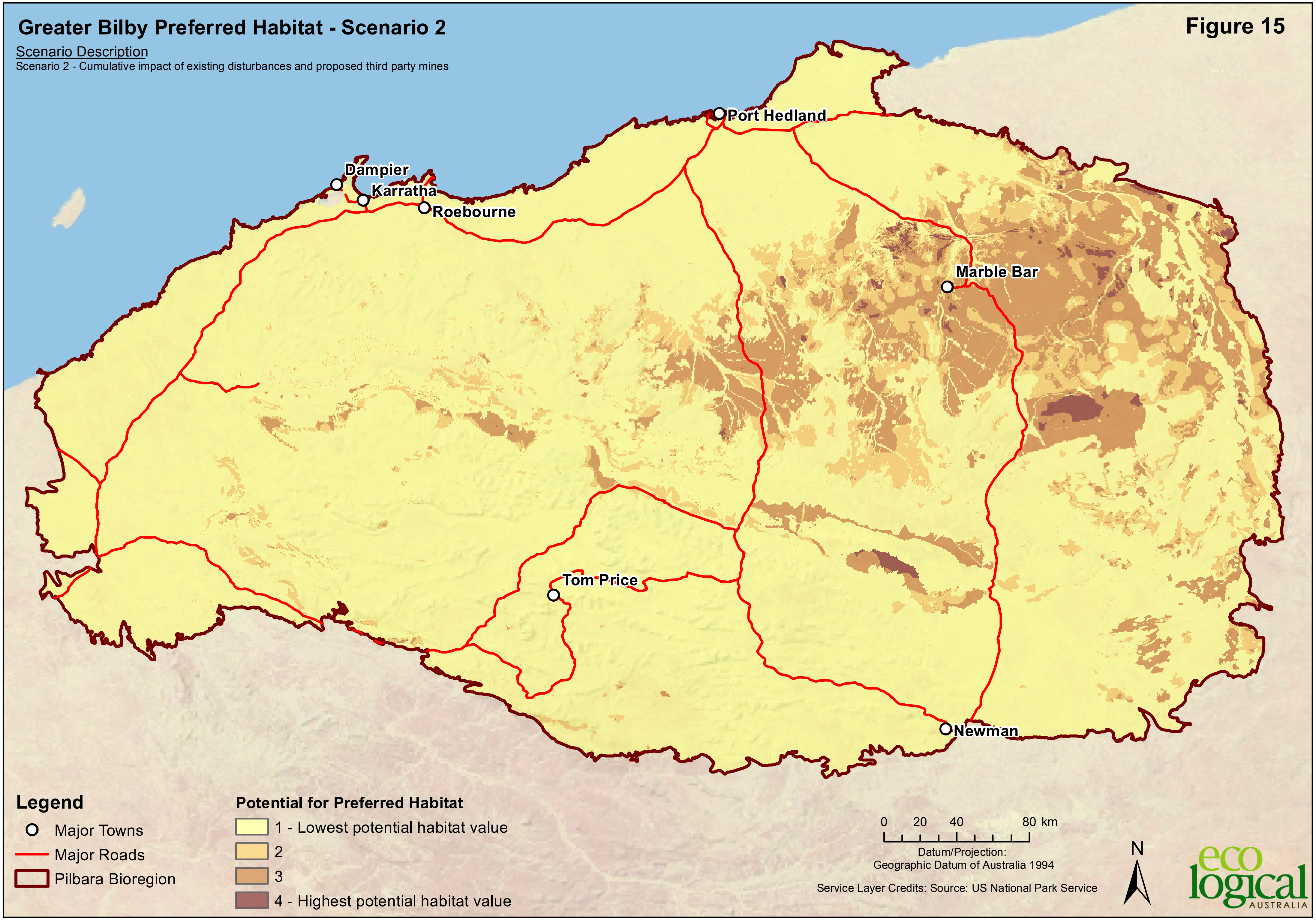
Greater Bilby Preferred Habitat - Scenario 1

Figure 14

Scenario Description

Scenario 1 - All pre-existing disturbances (including existing mining infrastructure)





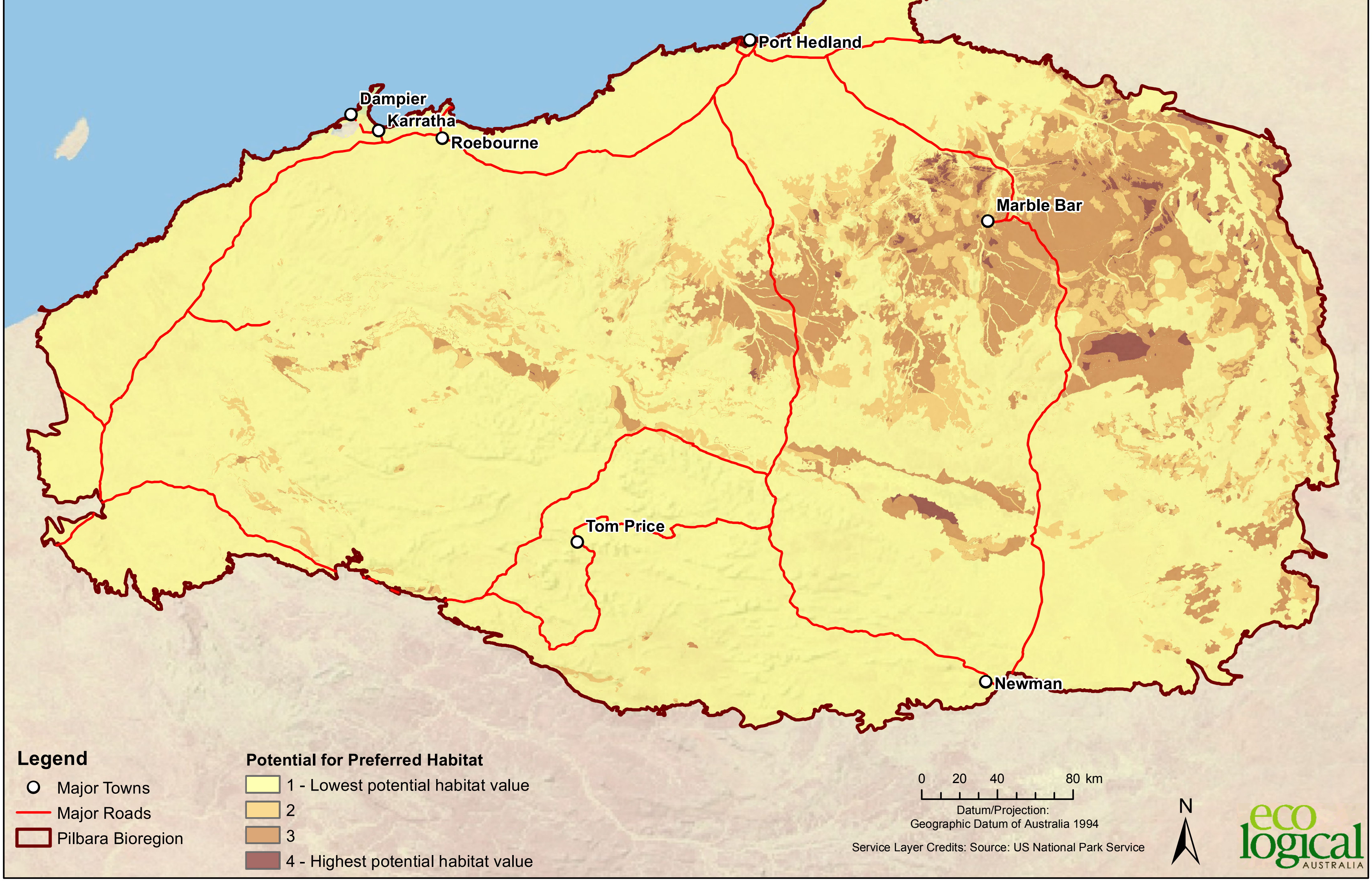
Greater Bilby Preferred Habitat - Scenario 2
Figure 15
Scenario Description
Scenario 2 - Cumulative impact of existing disturbances and proposed third party mines
Port Hedland
Dampier
Karratha
Roebourne
Marble Bar
Tom Price
Newman
Legend
Major Towns
Major Roads
Pilbara Bioregion
Potential for Preferred Habitat
1 - Lowest potential habitat value
2
3
4 - Highest potential habitat value
0 20 40 80 km
Datum/Projection:
Geographic Datum of Australia 1994
Service Layer Credits: Source: US National Park Service
N
eco logical AUSTRALIA

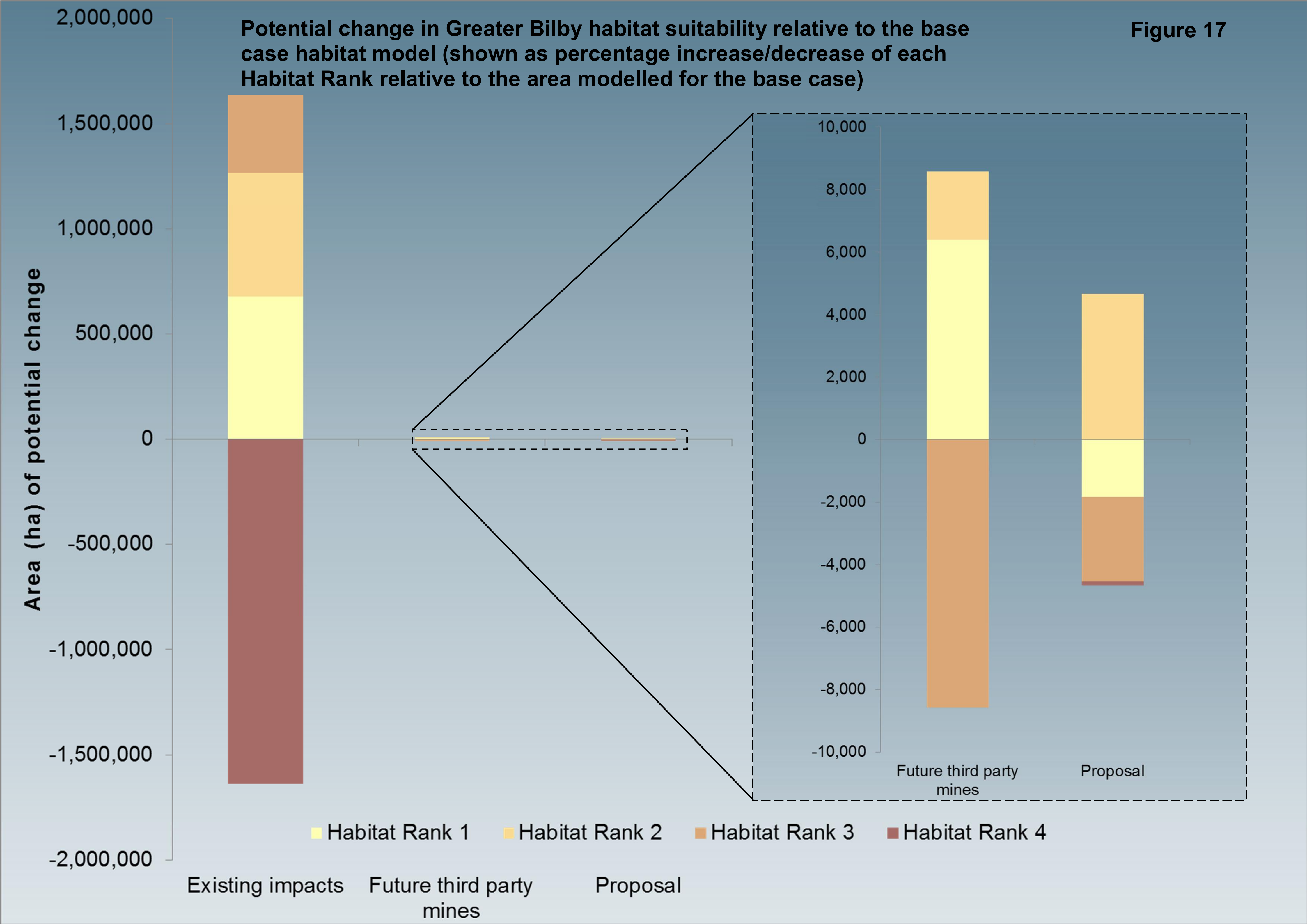
Figure 16

Greater Bilby Preferred Habitat - Scenario 3

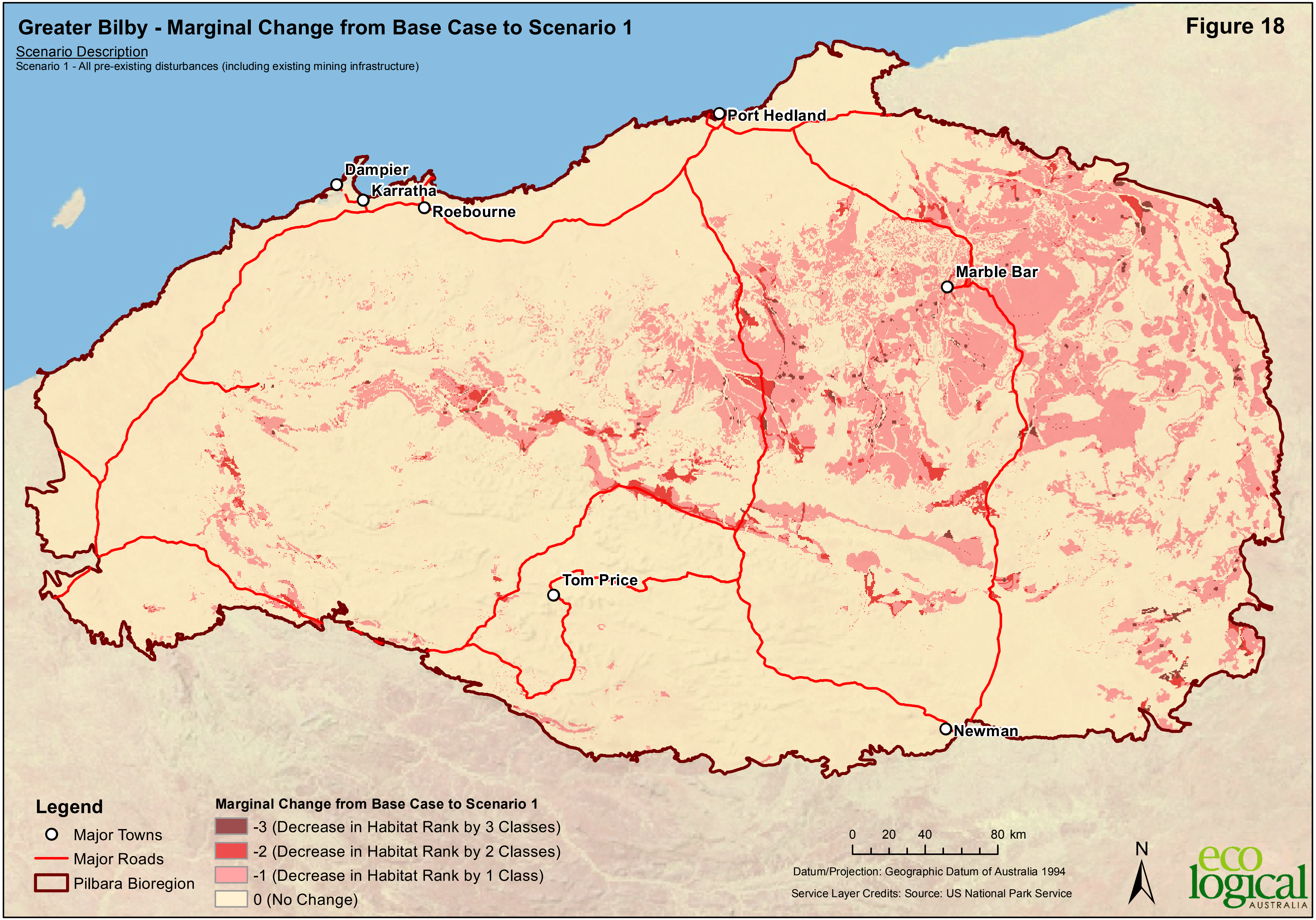
Scenario Description

Scenario 3 -Cumulative impact of existing disturbances, proposed third party mines and the Full Development Scenario





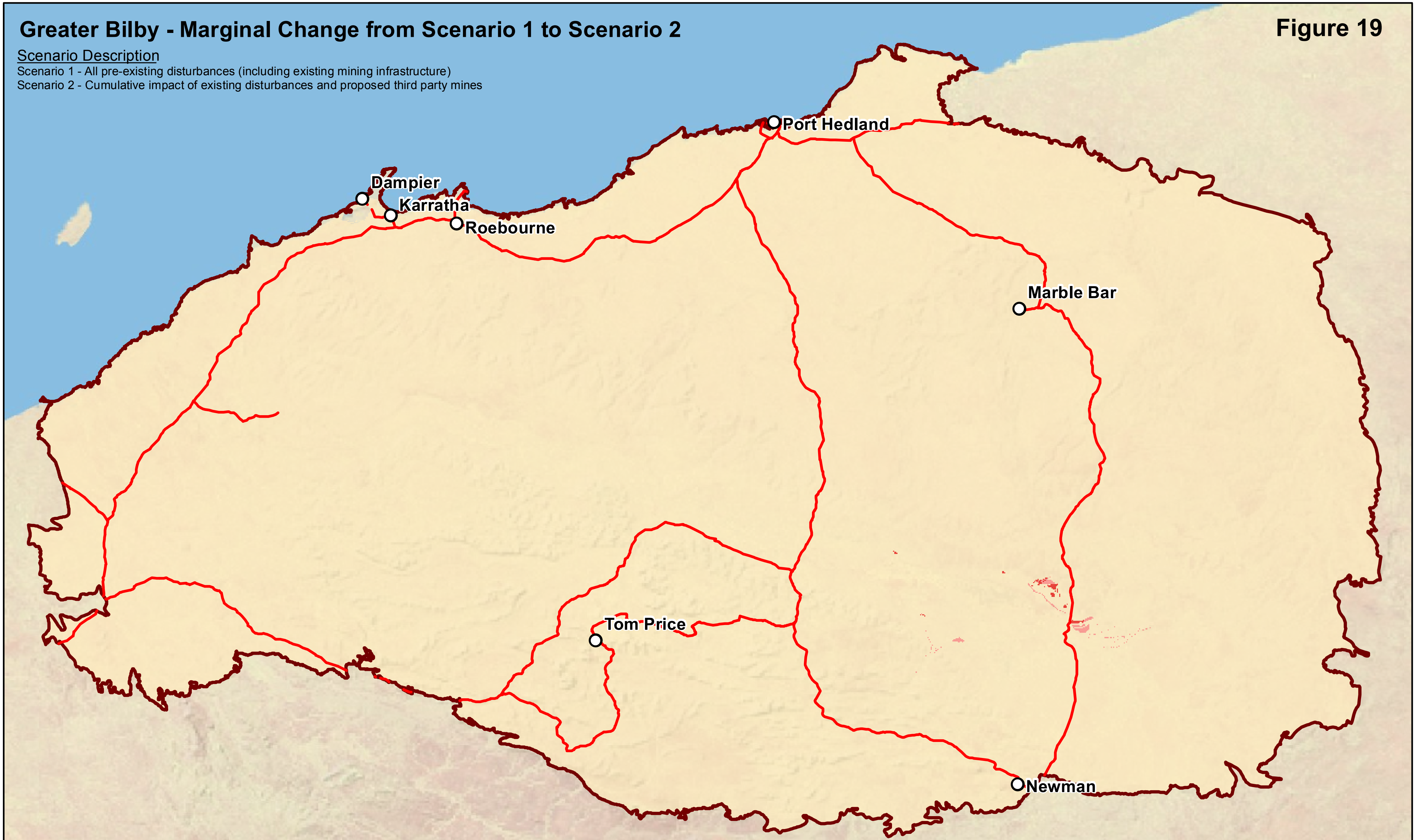
Potential change in Greater Bilby habitat suitability relative to the base case habitat model (shown as percentage increase/decrease of each Habitat Rank relative to the area modelled for the base case)
Figure 17
Area (ha) of potential change
2,000,000
1,500,000
1,000,000
500,000
0
-500,000
-1,000,000
-1,500,000
-2,000,000
Existing impacts
Future third party mines
Proposal
10,000
8,000
6,000
4,000
2,000
0
-2,000
-4,000
-6,000
-8,000
-10,000
Future third party mines
Proposal
Habitat Rank 1
Habitat Rank 2
Habitat Rank 3
Habitat Rank 4


Greater Bilby - Marginal Change from Base Case to Scenario 1
Figure 18
Scenario Description
Scenario 1 - All pre-existing disturbances (including existing mining infrastructure)
Port Hedland
Dampier
Karratha
Roebourne
Marble Bar
Tom Price
Newman
Legend
Major Towns
Major Roads
Pilbara Bioregion
Marginal Change from Base Case to Scenario 1
-3 (Decrease in Habitat Rank by 3 Classes)
-2 (Decrease in Habitat Rank by 2 Classes)
-1 (Decrease in Habitat Rank by 1 Class)
0 (No Change)
0 20 40 80 km
Datum/Projection: Geographic Datum of Australia 1994
Service Layer Credits: Source: US National Park Service
N
eco logical AUSTRALIA

Greater Bilby - Marginal Change from Scenario 1 to Scenario 2

Figure 19

Scenario Description
Scenario 1 - All pre-existing disturbances (including existing mining infrastructure)
Scenario 2 - Cumulative impact of existing disturbances and proposed third party mines



Legend

- Major Towns
- Major Roads
- Pilbara Bioregion

Marginal Change from Scenario 1 to Scenario 2

- -2 (Decrease in Habitat Rank by 2 Classes)
- -1 (Decrease in Habitat Rank by 1 Class)
- 0 (No Change)

0 20 40 80 km

N

Datum/Projection: Geographic Datum of Australia 1994

Service Layer Credits: Source: US National Park Service

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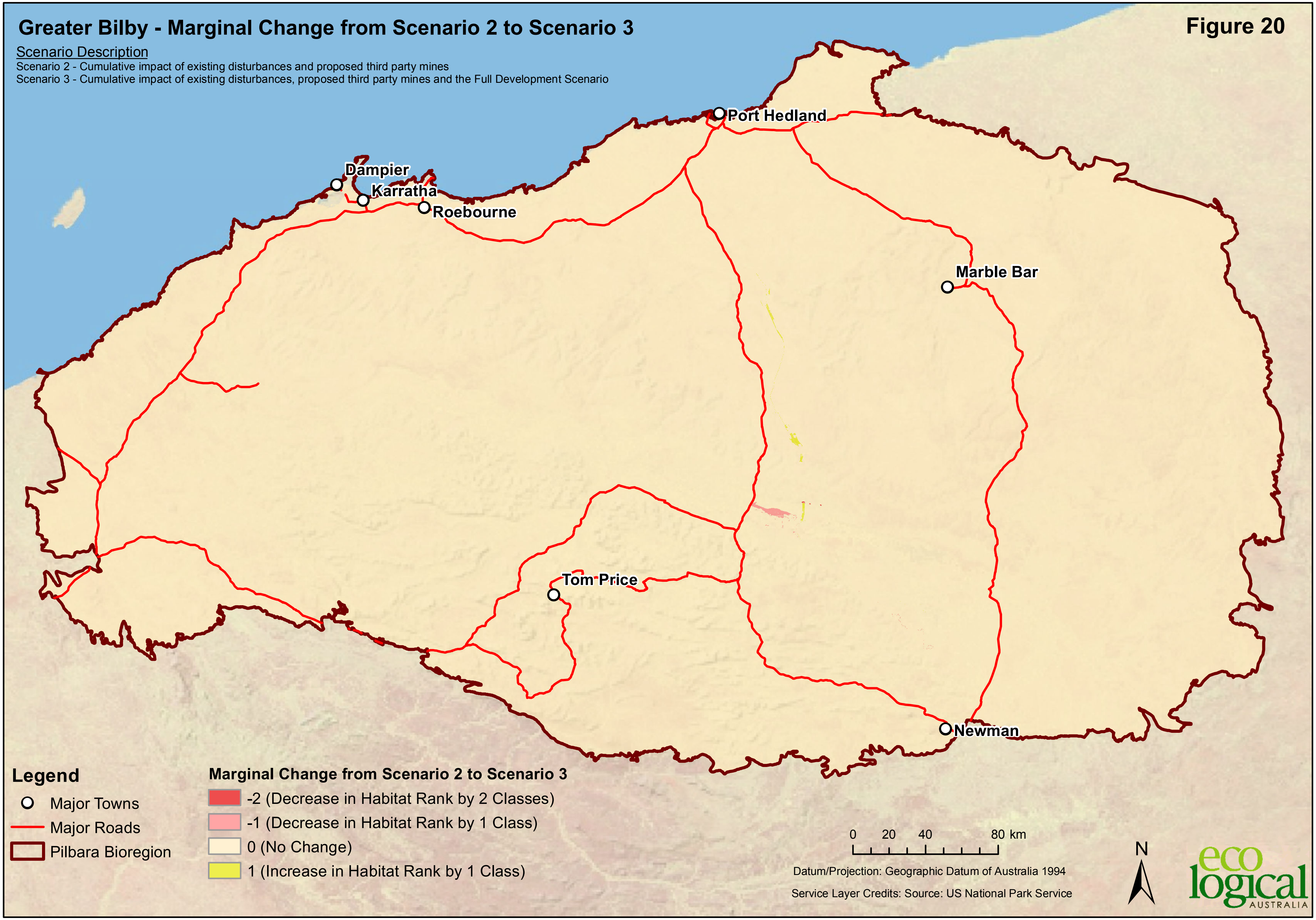
Greater Bilby - Marginal Change from Scenario 2 to Scenario 3
Figure 20
Scenario Description
Scenario 2 - Cumulative impact of existing disturbances and proposed third party mines
Scenario 3 - Cumulative impact of existing disturbances, proposed third party mines and the Full Development Scenario
Port Hedland
Dampier
Karratha
Roebourne
Marble Bar
Tom Price
Newman
Legend
Major Towns
Major Roads
Pilbara Bioregion
Marginal Change from Scenario 2 to Scenario 3
-2 (Decrease in Habitat Rank by 2 Classes)
-1 (Decrease in Habitat Rank by 1 Class)
0 (No Change)
1 (Increase in Habitat Rank by 1 Class)
0 20 40 80 km
Datum/Projection: Geographic Datum of Australia 1994
Service Layer Credits: Source: US National Park Service
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4 Hamersley Lepidium

4.1 OVERVIEW

This section provides background information relevant to the assessment of potential cumulative impacts to Hamersley Lepidium from the Proposal. It provides an overview of key ecological characteristics of Hamersley Lepidium with particular attention paid to those applicable in the area that will be affected by the Proposal, being the Pilbara bioregion of Western Australia. This section also outlines the potential impacts to the species from implementation of the Proposal, along with key threats to the species as determined through review of the best available literature, data and specialist expertise and knowledge.

The potential impacts identified were considered for their application in the CIA. For those applied in the CIA, the estimated relative magnitude of the impact to Hamersley Lepidium is provided in Section 4.3 and was based on a review of the best available literature on the likely susceptibility of Hamersley Lepidium to each impact, along with an understanding of the species' key ecological characteristics as outlined in Section 4.2.

4.2 SPECIES SYNOPSIS

4.2.1 Description

Hamersley Lepidium is a short-lived perennial herb or shrub growing up to 0.4 metres high with stems bent at the nodes in a prominent zigzag form (Brown et al. 1998; Hewson 1981). The leaves are small, linear, terete, succulent-like and papillose (having minute projections on the surface) (Hewson 1981). Flowers grow up to six millimetres long and form a dense terminal raceme (Hewson 1981, 1982). The fruit is winged and papillose (Brown et al. 1998; Hewson 1981).

4.2.2 Conservation status

Hamersley Lepidium is listed as Vulnerable under the EPBC Act and as Threatened Flora (Declared Rare Flora – Extant) under the *Wildlife Conservation Act 1950* (WA).

4.2.3 Distribution

Hamersley Lepidium's known extent of occurrence (**Figure 21**) has been estimated to be approximately 2,173,600 hectares (Onshore Environmental 2012); however, the area of occupancy, that is the area in which the species actually occurs, is unknown (Threatened Species Scientific Committee [TSSC] 2008; DoE 2013b). The species is endemic to the Pilbara bioregion of Western Australia and has a scattered distribution in populations ranging from a few to several hundred individuals. The majority of populations occur in the Hamersley subregion, extending into the southernmost edge of the Fortescue subregion of the Pilbara bioregion. There is also a disjunct population approximately 125 kilometres north-east of the other populations in the Chichester subregion (**Figure 22** and **Figure 23**; Parks and Wildlife 2013).

4.2.4 Habitat

Hamersley Lepidium prefers skeletal soils on steep rocky hill slopes of ranges and hills and is often located along breakaway slopes and the steepest sections of ridges among exposed rocks (Onshore Environmental 2012). It also occurs in gullies, gorges, drainage lines, footslopes, low undulating hills and alluvial plains, usually located downslope of populations on higher hill slopes (Onshore Environmental 2012).

The species is more frequently found on south-facing slopes and is commonly associated with species such as *Eucalyptus leucophloia* (Snappy Gum), *E. xerothermica*, *E. gamophylla* (Blue Mallee), *Triodia wiseana* (Limestone Spinifex), *T. basedowii* (Hard Spinifex), *Acacia bivenosa* (Two-veined Wattle), *A. hilliana* (Hill's Tabletop Wattle), and *A. pruinocarpa* (Black Gidgee) (Rio Tinto 2011; Brown et al. 1998). Hamersley Lepidium has been recorded near Tom Price on the lower slopes of Mount Nameless on steep south-facing shaly hill slopes supporting *Eucalyptus repullulans* low open mallee woodland over *Triodia angusta* scattered hummock grasses (Biota 2007).

Hamersley Lepidium has also been associated with disturbance, being recorded on road verges and cuttings (Hewson 1981).

4.2.5 Ecology

Hamersley Lepidium flowers mainly in August to January (Brown et al. 1998; Hewson 1981), although flowering and fruiting has also been recorded in March (Mattiske and Associates 1994). Seed maturation time may vary depending on the flowering periods and conditions; mature seed used for a germination trial by Cochrane (2000) was collected in November. Time to reproductive maturity has not been documented for the species, although it is likely to vary according to conditions. A similar arid-zone *Lepidium* species, *L. sisymbrioides* subsp. *matau*, was found to flower in its first year under favourable greenhouse conditions, but authors suggested that few seedlings in the wild would establish in their first and second years (Allen 1998).

Hamersley Lepidium is generally considered a short-lived disturbance opportunist that requires disturbance events, such as fire, to recruit from soil-stored seed (Brown et al. 1998). It has been identified as a pioneer species that responds rapidly to disturbance, in particular fire, but has also been recorded growing in undisturbed hummock grasslands at some sites (Onshore Environmental 2012). Despite this, it is likely the species is killed by fire or becomes displaced by spinifex (*Triodia* spp.) over time (Rio Tinto 2011), and recruits from soil-stored seed. The preferred fire frequency regime is currently unknown for Hamersley Lepidium. Biota (2007) recorded a population of over 1,000 individuals, many of which were seedlings, in an area that had been burnt approximately three years previous.

Hamersley Lepidium, like many other *Lepidium* species, is likely to produce large numbers of viable seeds. For example, *Lepidium hyssopifolium* (Basalt Peppercress), a small perennial herb that occurs in New South Wales, Victoria and Tasmania, is a prolific seed producer (Tumino 2010), and abundant seed production has been noted in many populations of *Lepidium aschersonii* (Spiny Peppercress), a small perennial herb that is widely (but patchily) distributed from New South Wales to Western Australia (Carter 2010). Outside Australia, a study of arid-zone *L. sisymbrioides* subsp. *matau* in New Zealand recorded an average of 800 seeds produced per plant (Allen 1998). In a trial investigating the germination requirements of Hamersley Lepidium (Cochrane 2000), more than 7,000 seeds, many of which were viable, were collected in a single day (although it was not stated from how many plants the seeds were collected). Despite a likely high level of seed production, the numbers of seeds that remain in the soil may be relatively low, as studies of other plant species in semi-arid environments have indicated that post-dispersal seed predation occurs and may significantly limit recruitment (Allen 1998).

Requirements for breaking seed dormancy may be complex, with germination not recorded for Hamersley Lepidium by Cochrane (2000) after a five week period under basic light, temperature and moisture conditions. Cochrane's (2000) germination trial found that heat treatment using near-boiling water damaged seeds, with no germination following this treatment, but that gibberellic acid (a plant hormone that can increase seed germination rate) overcame seed dormancy with up to 89 per cent germination rates achieved. Hamersley Lepidium's seed may require time within the soil for germination success (Cochrane 2000). This has implications for rehabilitation of sites using the species and also land management practices that disturb soil-stored seed too frequently (DoE 2013b).

Hamersley Lepidium pollinators have not been documented; however, Hewson (1981) described the flowers of *Lepidium* as containing nectariferous glands that are variable within species. The presence of these glands suggests *Lepidium* species, including Hamersley Lepidium, are pollinated by insects. The distance that pollinators will travel between populations of Hamersley Lepidium has not been documented.

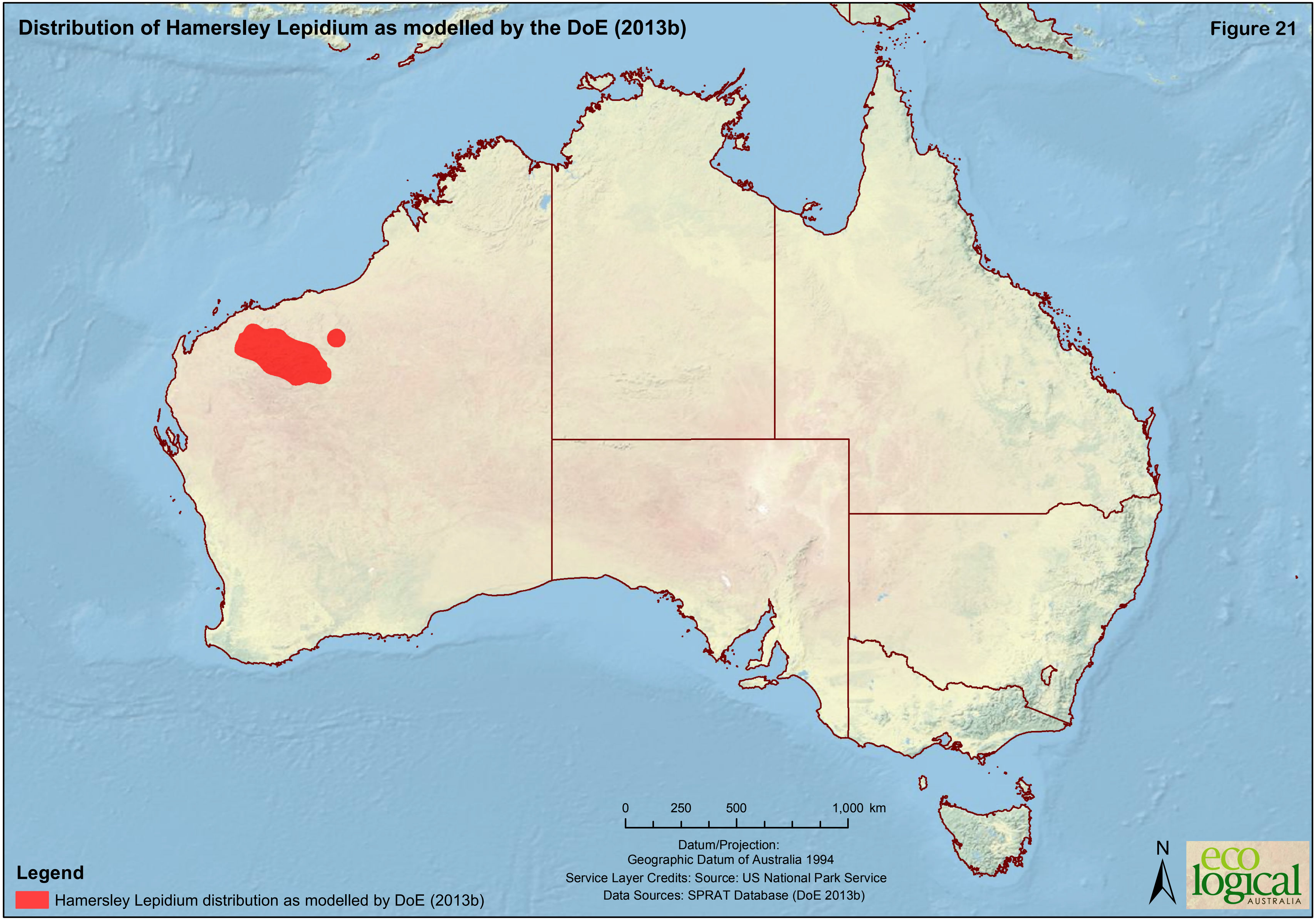
The seed dispersal mechanism for Hamersley Lepidium is unknown. Insects and water may play a role in seed dispersal given that the genus *Lepidium* generally has pendulous, round to flat seeds that are winged with a mucous texture (Hewson 1982), and the seeds of *Lepidium* species from arid regions generally have very strongly developed seed mucosity with a thick translucent testa (seed coat), which is important for water absorption and retention (Hewson 1981).

Seed dispersal rates for Hamersley Lepidium have not been documented. A reproductive study of the annual species *Lepidium sisymbrioides* subsp. *matau* in New Zealand, suggested that seed dispersal distances are usually not greater than a few metres (Allen 1998). *L. sisymbrioides* subsp. *matau* may be similar to Hamersley Lepidium since this species also occurs in a semi-arid environment, restricted to dry habitats (with annual rainfall less than 300 millimetres) in the eastern part of New Zealand's south island. Populations of this species are confined to gravelly hillslopes and terrace faces at Galloway in the lower Manuherikia valley, although part of the population grows in grassland 10 to 30 centimetres tall (Allen 1998). Tumino (2010) similarly recorded that the seeds of *L. hyssopifolium* lack any apparent long-distance seed dispersal mechanisms, mainly due to their large size, and so the seeds are likely to remain close (within a few metres) of the parent plants. *Lepidium hyssopifolium* does not share similarities to Hamersley Lepidium in terms of habitat (the former grows in temperate grasslands on fertile clay loams in south-eastern Australia) but some of its ecology appears to be similar, with the species requiring disturbance for seed germination. Also, there are many records of the species along roadsides (Tumino 2010).

Following the emergence of seedlings from the seed bank after disturbance, it is likely that successful establishment of the species is driven by the frequency, timing and volume of rainfall. This is the case for many flora species growing in semi-arid areas, and may be the case for the similar arid-zone *Lepidium* species, *L. sisymbrioides* subsp. *matau* (Allen 1998).

Distribution of Hamersley Lepidium as modelled by the DoE (2013b)

Figure 21



Legend

Hamersley Lepidium distribution as modelled by DoE (2013b)

Records of Hamersley Lepidium in Western Australia (Parks and Wildlife 2013b)

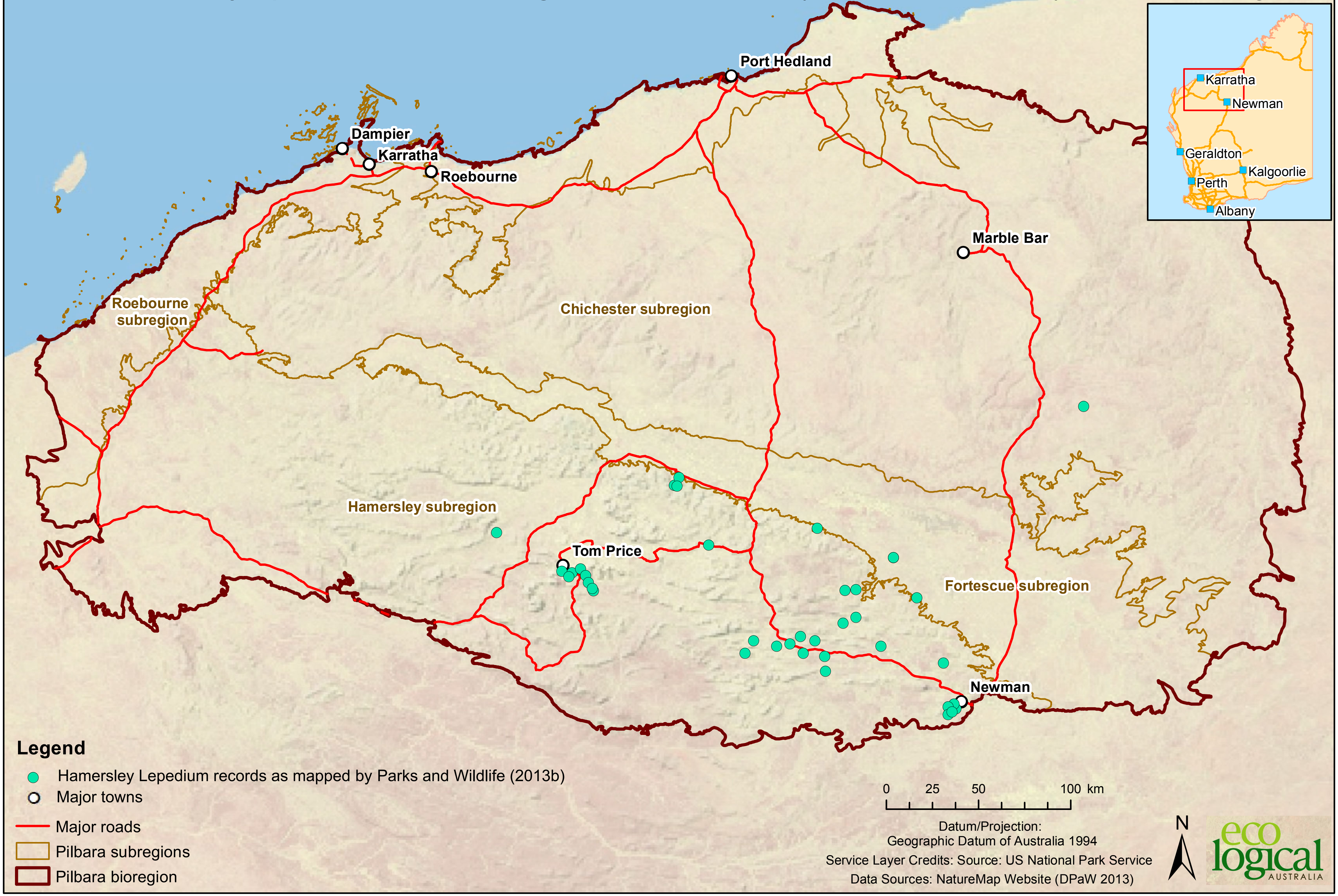
Figure 22

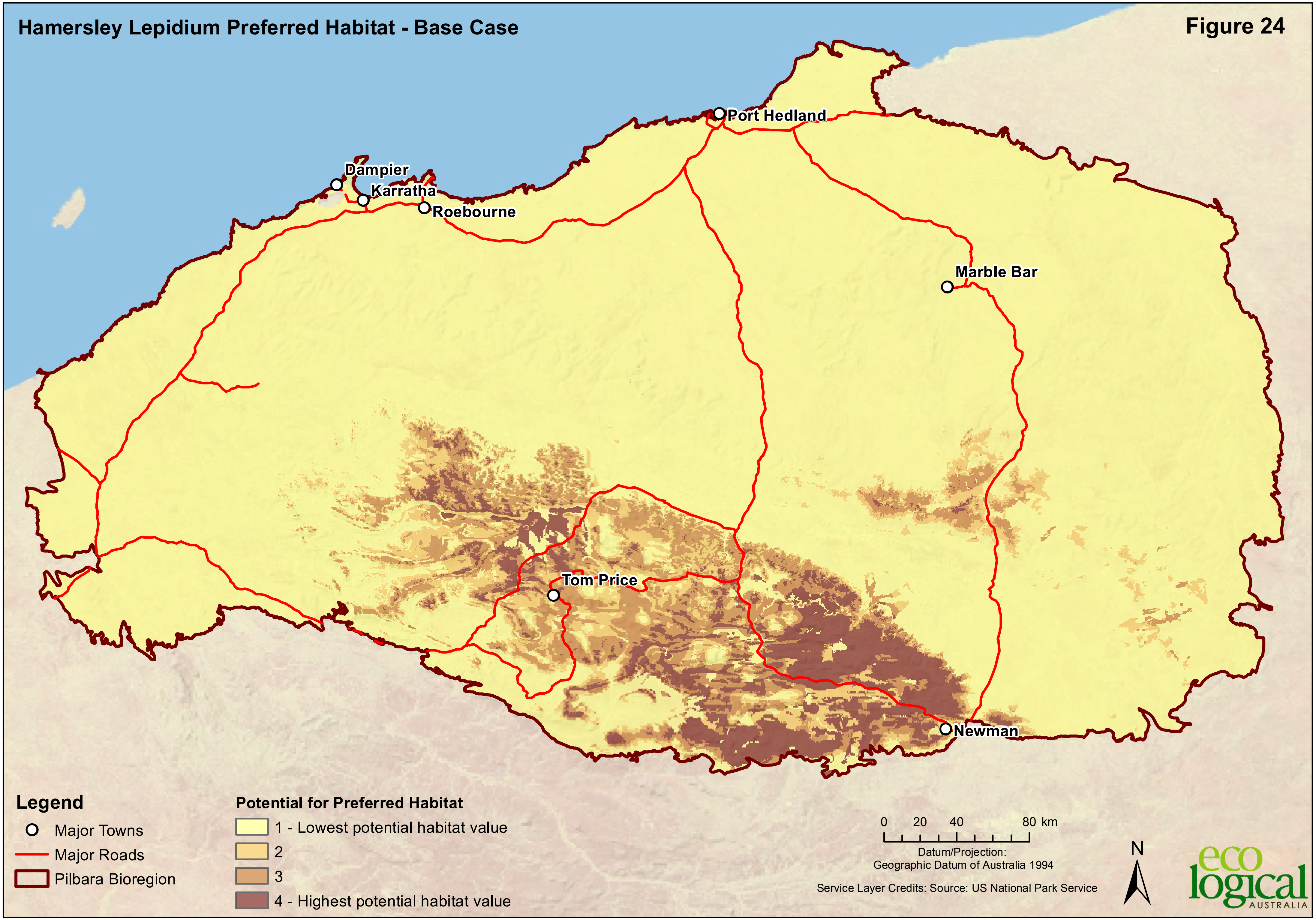
Legend

- *Lepidium catapycnon* records as mapped by Parks and Wildlife (2013b)
- IBRA bioregions
- Western Australia

Datum/Projection:
Geographic Datum of Australia 1994
Service Layer Credits: Source: US National Park Service
Data Sources: NatureMap Website (DPaW 2013)

Records of Hamersley Lepidium in the Pilbara bioregion of Western Australia (Parks and Wildlife 2013b) **Figure 23**




Hamersley Lepidium Preferred Habitat - Base Case
Figure 24
Port Hedland
Dampier
Karratha
Roebourne
Marble Bar
Tom Price
Newman
Legend
Major Towns
Major Roads
Pilbara Bioregion
Potential for Preferred Habitat
1 - Lowest potential habitat value
2
3
4 - Highest potential habitat value
0 20 40 80 km
Datum/Projection:
Geographic Datum of Australia 1994
Service Layer Credits: Source: US National Park Service
N
eco logical AUSTRALIA

4.3 METHODS

4.3.1 Base layer considered

The Hamersley Lepidium CIA considered relative probability of potential habitat (habitat suitability) modelled by ELA (2015), as summarised in **Table 5** and described in detail in **Appendix A**. The ELA (2015) model allocated habitat suitability values from zero to 100 per cent across the Pilbara bioregion, which were categorised into four Habitat Ranks (**Table 16**; **Figure 24**). The majority (83 per cent) of the Pilbara bioregion was modelled as lowest potential habitat suitability for Hamersley Lepidium, with areas of higher habitat suitability occurring mainly in the central part of the southern Pilbara, predominantly to the west and north-west of Newman (the south-east portion of the Hamersley Range) and to a lesser extent to the north and north-west of Tom Price (**Table 16**; **Figure 24**).

Table 16: Classification and ranking applied to the Hamersley Lepidium habitat model

Model value	Habitat Rank	Habitat suitability	Area (ha) in Hamersley Lepidium habitat model
70-100%	4	Highest probability of potential habitat	871,770 (5%)
30-70%	3	↓	1,191,995 (7%)
10-30%	2		957,475 (5%)
0-10%	1	Lowest probability of potential habitat	14,771,377 (83%)

4.3.2 Identification of key threats

Known and perceived threats to Hamersley Lepidium are identified in the SPRAT database (DoE 2013b) as:

- removal of habitat (and loss of individuals) from mining, as many populations occur on mining tenements;
- removal of habitat (and loss of individuals) due to road works, as many populations occur on or adjacent to frequently graded mining/exploration tracks;
- invasion of *Acetosa vesicaria* (Ruby Dock), which may prevent establishment of Hamersley Lepidium in some areas.

The effect of fire regimes is also a key threat to the survival of Hamersley Lepidium (van Etten, E., pers. comm., 2014); however, the impact of fire was not applied in the CIA. While it is recognised that fire scar mapping is available for the Pilbara, such fire scar mapping provides only the approximate date and area of fires and does not necessarily inform the fire regime (which is a complex of many interacting factors) or about changes in regime (which may require decades of data to detect) (van Etten, E., pers. comm., 2015). In addition, the response of species to different elements of the fire regime and to changes in regime is largely unknown and difficult to predict (van Etten, E., pers. comm., 2015); however, Biota (2007) recorded a population of over 1,000 individuals, many of which were seedlings, in an area that had been burnt approximately three years previous. With regard to reasonably foreseeable future impacts of fire, the effect of mining and non-mining activities on alteration of fire impacts is rather equivocal and likely to be influenced primarily by assumptions of fire management and fire response. Limitations associated with fire are discussed in Section 8.1.2.

Although mining and road works are listed as key threats, disturbance events such as these can also result in mass germination of Hamersley Lepidium as the species is a disturbance opportunist (Onshore Environmental 2012). However, as large populations often occur on mining tenements and around graded access tracks, road works and mining pose a potential key threat to the species (Onshore Environmental 2012).

In addition to the above-listed threats, the widespread, landscape-scale potential impacts of predicted future climate change are considered potential impacts to the species. Given that the successful establishment of Hamersley Lepidium is likely to be driven by the frequency, timing and volume of rainfall, Hamersley Lepidium may be affected by changes in rainfall associated with future climate change. Preliminary analysis and modelling of potential effects as a result of recognised predicted climate change estimates was undertaken; however, the level of uncertainty associated with the modelling outcomes was considered to limit its interpretation in relation to cumulative impacts in the Pilbara. Climate change is discussed further in Section 8.1.2.

4.3.3 Potential impacts applied

In consideration of the key threats identified and the available data (Section 4.3.2), the potential impacts applied in the Hamersley Lepidium CIA were:

- removal of habitat;
- degradation of habitat as a result of the introduction or spread of weeds.

These potential impacts are considered appropriate for a regional-scale impact assessment. The significance of each impact was rated as Low, Medium, or High (Section 4.3.4 and Section 4.3.5). Impacts were applied as spatial layers that changed the habitat model base case. Technical detail on the rating system and the spatial application of impacts in the CIA is provided in Section 2.4.

4.3.4 Removal of habitat

A key documented threat to Hamersley Lepidium is mining, as many populations occur on mining tenements (DoE 2013b), although this is likely to be due at least in part to the high level of survey effort on mining tenements relative to other areas. Vegetation clearing associated with mining and mining-related activities, as well as other activities that occur in the speciesô preferred habitat, may remove Hamersley Lepidium habitat and individuals. Removal of habitat was rated as High impact: areas where habitat was removed were assigned a High (100 per cent) level of potential impact as habitat would become unsuitable in these areas (assuming clearing is permanent); areas where habitat was not removed were unchanged (**Table 17**).

Hamersley Lepidium is generally considered a short-lived disturbance opportunist that requires disturbance events to recruit from soil-stored seed (Brown et al. 1998). Localised disturbance could be of benefit to Hamersley Lepidium where soil seed banks are present, whereas more severe or extensive ground disturbance (such as the removal of topsoil from relatively large areas) has the potential to remove individuals (or seeds), or small or localised populations. There may be some potential benefit to

Hamersley Lepidium through vegetation clearing and removal of habitat; however, as a conservative approach was taken in the CIA, potential beneficial effects were not considered.

Table 17: Potential impacts of removal of potential Hamersley Lepidium habitat

Vegetation clearing/ removal of habitat	Level of potential impact	Confidence in level of potential impact	Assumptions
Habitat removed	High (100%)	High. Habitat would be unsuitable in cleared areas.	Clearing is permanent. Edge effects are not considered for this impact.

4.3.5 Introduction or spread of weeds

Invasion of Ruby Dock is listed as one of the main potential threats to Hamersley Lepidium (TSSC 2008). This is due to competition with Ruby Dock preventing establishment of Hamersley Lepidium in some areas (Mattiske and Associates 1994). Other weeds such as *Cenchrus ciliaris* (Buffel Grass) and *Aerva javanica* (Kapok Bush) may also threaten the species as they can form large infestations in the Pilbara and potentially prevent the establishment of Hamersley Lepidium.

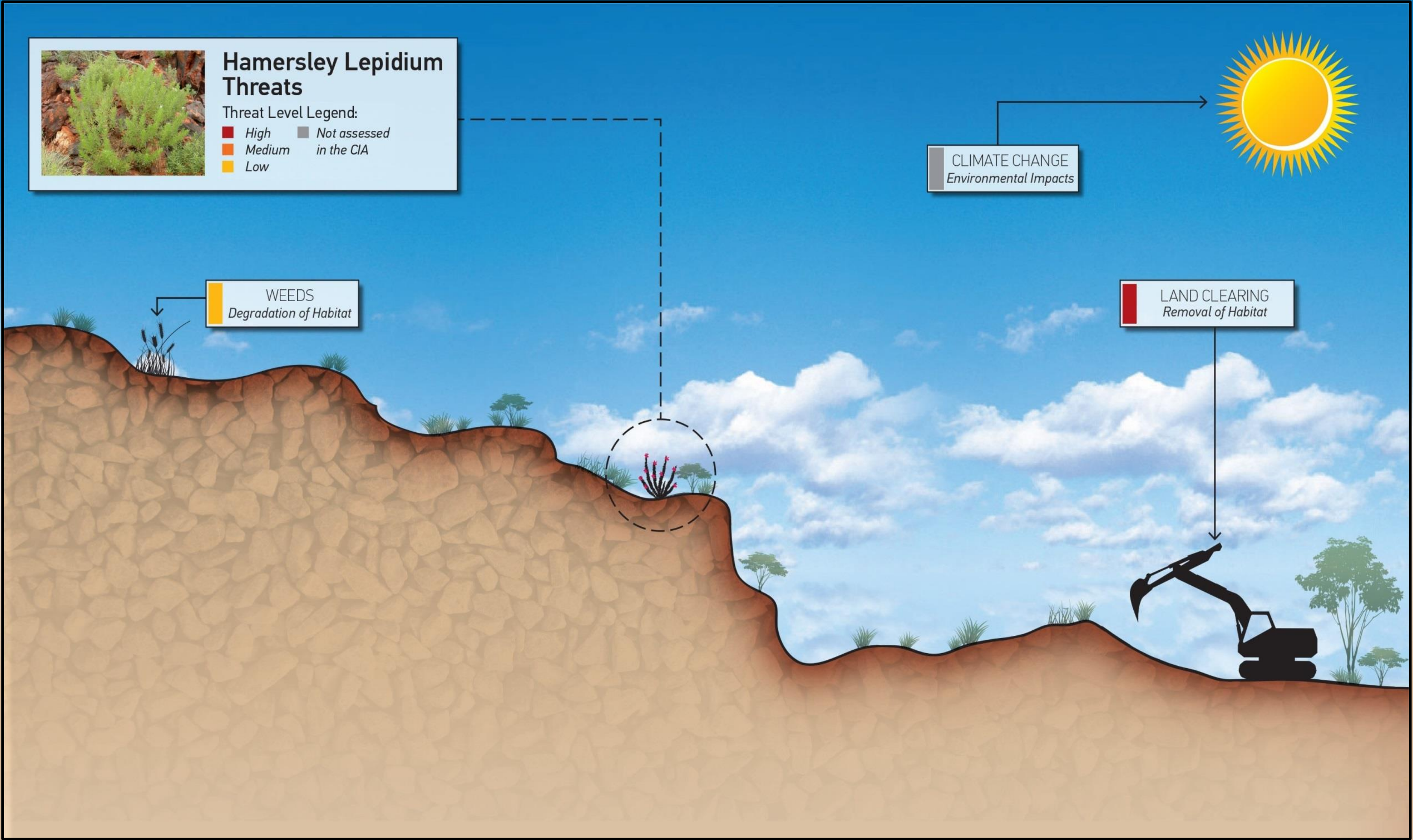
The prevalence and potential impacts of weeds were assumed to increase closer to areas of human settlements, roads and mines. The level of potential impact for the introduction or spread of weeds was developed based on proximity to human settlements, roads and mines, with the impact of weeds extending up to 500 metres from each disturbance (**Table 18**).

Table 18: Potential impacts to Hamersley Lepidium habitat from weeds

Proximity to human settlements, roads, or mines	Level of potential impact	Confidence in level of potential impact	Assumptions
<500 m	Low (20%)	Medium. Large infestations of weeds are known to prevent establishment of Hamersley Lepidium (Mattiske and Associates 1994).	Potential habitat near human settlements, roads and mines is likely to have a higher occurrence of weeds than potential habitat further away. Potential habitat subject to a higher occurrence of weeds is less suitable to Hamersley Lepidium than potential habitat subject to a lower occurrence of weeds.

4.4 HAMERSLEY LEPIDIUM CONCEPTUAL DIAGRAM

A conceptual diagram was prepared to depict Hamersley Lepidium in its natural habitat and the key threatening processes and potential impacts to the species and its habitat that were considered in the CIA (**Figure 25**). The conceptual diagram shows the potential impacts applied in the CIA and their level of potential impact (High, Medium or Low; Section 4.3). The conceptual diagram also shows climate change, which was considered, but not applied in the CIA.



Hamersley Lepidium conceptual diagram	Figure 25

4.5 RESULTS

Results of the CIA for Hamersley Lepidium habitat suitability are provided in **Table 19** and **Table 20**. **Table 19** provides the area affected by potential impacts associated with existing impacts, future third party mines, and the Full Development Scenario. **Table 20** provides the area that increased or decreased by zero, one, two or three Habitat Ranks as a result of potential impacts associated with existing impacts, future third party mines, and the Full Development Scenario.

The modelled extent of Hamersley Lepidium habitat suitability in Scenario 1 to Scenario 3 is provided in **Figure 26** to **Figure 28**. The area of each Habitat Rank affected by potential impacts associated with existing impacts, future third party mines, and the Full Development Scenario is provided in **Figure 29**. The marginal change from one scenario to another, and from the base case to Scenario 1, is provided in **Figure 30** to **Figure 32**.

For all potential impacts to MNES, a reduction in the extent of any particular Habitat Rank usually means that class of habitat has been lost (cleared), or downgraded (affected by potential impacts other than habitat removal), or a combination of these. Habitat Rank 1 includes all cleared habitat (zero per cent habitat suitability) and intact habitat of low suitability (from greater than zero per cent to 10 per cent habitat suitability); all other habitat ranks include only intact habitat.

In some cases, reduction in the extent of a Habitat Rank from one scenario to another may mean that habitat class has been óupgradedô This is generally associated with mine closure in Scenario 3, whereby some of the potential impacts to MNES were not applied to closed mines and infrastructure, resulting in an apparent increase in habitat suitability from Scenario 2 to Scenario 3. Apparent increases in habitat suitability may also be as a result of a reduction in the extent of impacts associated with ecohydrological change potential mapped by BHP Billiton Iron Ore (2015).

4.5.1 Existing impacts

The potential effect of existing impacts on Hamersley Lepidium habitat suitability relative to the base case was minor as a percentage of the total area of the Pilbara bioregion (**Figure 24**, **Figure 26**, **Figure 29** and **Figure 30**). There was a slight decrease in the extent of Habitat Rank 3 (8,700 hectares; less than one per cent) and Habitat Rank 4 (27,000 hectares; less than three per cent) and a slight increase in the extent of Habitat Ranks 1 and 2 (less than one per cent; **Table 19**). Overall, a total of approximately 68,800 hectares decreased in habitat suitability as a result of existing impacts, the majority of which (approximately 50,100 hectares) decreased by one Habitat Rank (**Table 20**).

Despite the broadly overlapping location of the most suitable Hamersley Lepidium habitat and existing mining and road disturbance in the central part of the southern Pilbara, predominantly to the west and north-west of Newman (the south-east portion of the Hamersley Range) (**Figure 7** to **Figure 8** and **Figure 24**), the small potential effect of existing impacts on Hamersley Lepidium habitat suitability (relative to some of the other MNES considered in the CIA) is likely to be at least partly due to the number of potential impacts applied to the species and their spatial extent. That is, outside the direct disturbance footprint, only the potential impact of the introduction or spread of weeds was applied to Hamersley Lepidium habitat suitability as an existing impact, with a level of potential impact of óLowôand only within 500 metres of human settlements, roads and mines (**Table 18**).

4.5.2 Future third party mines

The potential effect of future third party mines on Hamersley Lepidium habitat suitability was minor as a percentage of the total area of the Pilbara bioregion (**Figure 24**, **Figure 27**, **Figure 29** and **Figure 31**). There was a slight decrease in the extent of Habitat Ranks 2, 3 and 4 (less than one per cent) and a slight increase in the extent of Habitat Rank 1 (less than one per cent) (**Table 19**). Overall, a total of approximately 20,800 hectares decreased in habitat suitability as a result of future third party mines, the majority of which (10,500 hectares) decreased by two Habitat Ranks (**Table 20**).

4.5.3 Full Development Scenario

The potential effect of the Full Development Scenario on Hamersley Lepidium habitat suitability was minor as a percentage of the total area of the Pilbara bioregion (**Figure 24**, **Figure 28**, **Figure 29** and **Figure 32**). There was a slight decrease in the extent of Habitat Ranks 2, 3 and 4 (less than four per cent) and a slight increase in the extent of Habitat Rank 1 (less than one per cent) (**Table 19**). Overall, a total of approximately 78,000 hectares decreased in habitat suitability as a result of the Full Development Scenario, the majority of which (36,000 hectares) decreased by three Habitat Ranks (**Table 20**).

There was a potential slight positive (beneficial) effect of the Full Development Scenario in some areas, with a total of approximately 14,000 hectares increasing in habitat suitability by one Habitat Rank (**Figure 32**; **Table 20**). This potential positive effect was associated with mine closure in Scenario 3, whereby some of the potential impacts to Hamersley Lepidium were not applied to closed mines and infrastructure.

4.5.4 Potential cumulative impacts

The potential cumulative impact to Hamersley Lepidium habitat suitability was a decrease in the extent of the most suitable habitat (Habitat Rank 4) of approximately 61,000 hectares (seven per cent of the modelled extent in the base case), mostly as a result of the Full Development Scenario. There was a decrease in the extent of Habitat Rank 3 of approximately 46,000 hectares (four per cent of the modelled extent in the base case) and Habitat Rank 2 of 11,000 hectares (one per cent of the modelled extent in the base case), both of which were due mainly to the Full Development Scenario. These Habitat Ranks were downgraded into lower ranked habitat; therefore the extent of Habitat Rank 1 increased (**Table 19** and **Table 20**).

Table 19: Area of potential change in Hamersley Lepidium habitat suitability

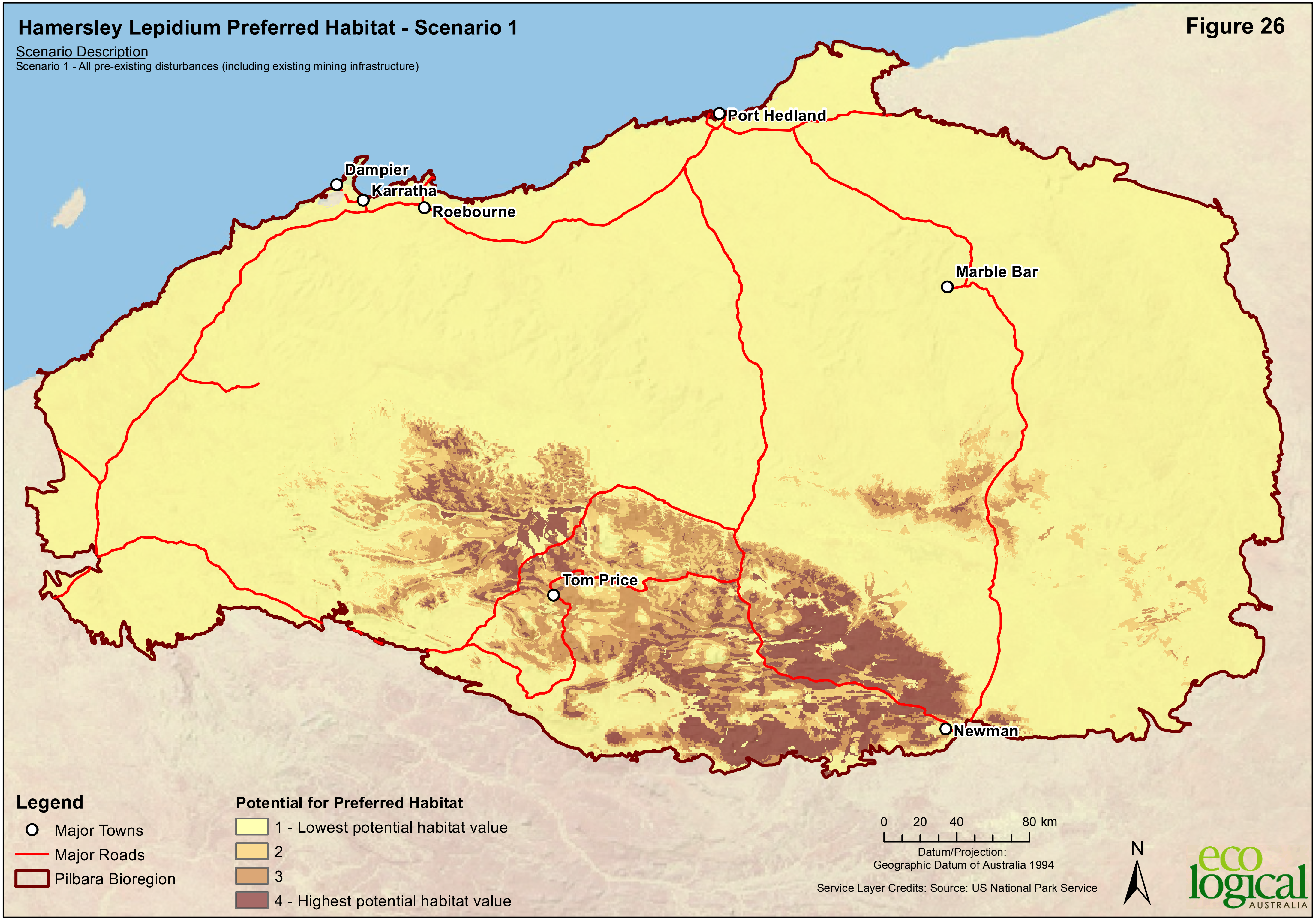
Habitat Rank	Base case	Area (ha) of potential change*			Potential cumulative impact**
		Existing impacts	Future third party mines	Full Development Scenario	
1	14,771,377	32,306 (<1%)	16,892 (<1%)	68,868 (<1%)	118,066 (<1%)
2	957,475	3,354 (<1%)	-3,445 (<-1%)	-11,084 (-1%)	-11,175 (-1%)

Habitat Rank	Base case	Area (ha) of potential change*			Potential cumulative impact**
		Existing impacts	Future third party mines	Full Development Scenario	
3	1,191,995	-8,672 (<-1%)	-10,106 (<-1%)	-26,825 (-3%)	-45,603 (-4%)
4	871,770	-26,987 (-3%)	-3,340 (<-1%)	-30,959 (-4%)	-61,286 (-7%)

*Positive values indicate the area of a Habitat Rank has increased relative to the previous scenario; negative values indicate the area has decreased. **Positive values indicate the area of a Habitat Rank has increased as a result of the combined effect of existing impacts, future third party mines, and the Full Development Scenario; negative values indicate the area has decreased.

Table 20: Area of habitat that increased or decreased by one, two or three ranks, or that did not change between scenarios for the Hamersley Lepidium CIA

Change in Habitat Rank	Area (ha) of potential change		
	Existing impacts (Base Case to Scenario 1)	Future third party mines (Scenario 1 to Scenario 2)	Full Development Scenario (Scenario 2 to Scenario 3)
+3	0 (0%)	0 (0%)	0 (0%)
+2	0 (0%)	0 (0%)	0 (0%)
+1	0 (0%)	0 (0%)	14,457 (<1%)
0	17,723,855 (~100%)	17,771,775 (~100%)	17,700,251 (~100%)
-1	50,103 (<1%)	9,174 (<1%)	19,401 (<1%)
-2	11,128 (<1%)	10,500 (<1%)	22,857 (<1%)
-3	7,531 (<1%)	1,168 (<1%)	35,651 (<1%)

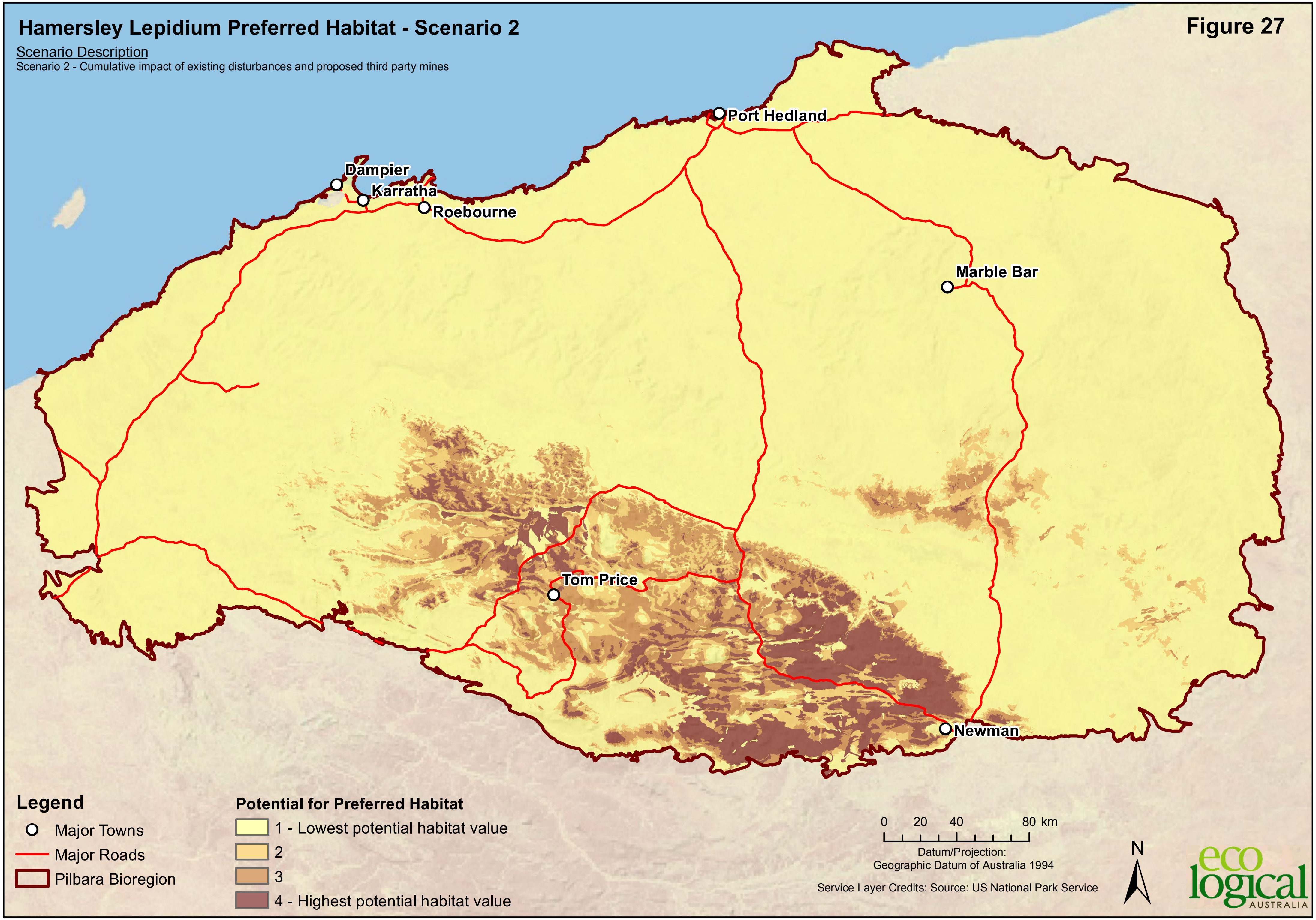


Hamersley Lepidium Preferred Habitat - Scenario 1
Figure 26
Scenario Description
Scenario 1 - All pre-existing disturbances (including existing mining infrastructure)
Port Hedland
Dampier
Karratha
Roebourne
Marble Bar
Tom Price
Newman
Legend
Major Towns
Major Roads
Pilbara Bioregion
Potential for Preferred Habitat
1 - Lowest potential habitat value
2
3
4 - Highest potential habitat value
0 20 40 80 km
Datum/Projection:
Geographic Datum of Australia 1994
Service Layer Credits: Source: US National Park Service
N
eco logical AUSTRALIA

Hamersley Lepidium Preferred Habitat - Scenario 2

Figure 27

Scenario Description
Scenario 2 - Cumulative impact of existing disturbances and proposed third party mines

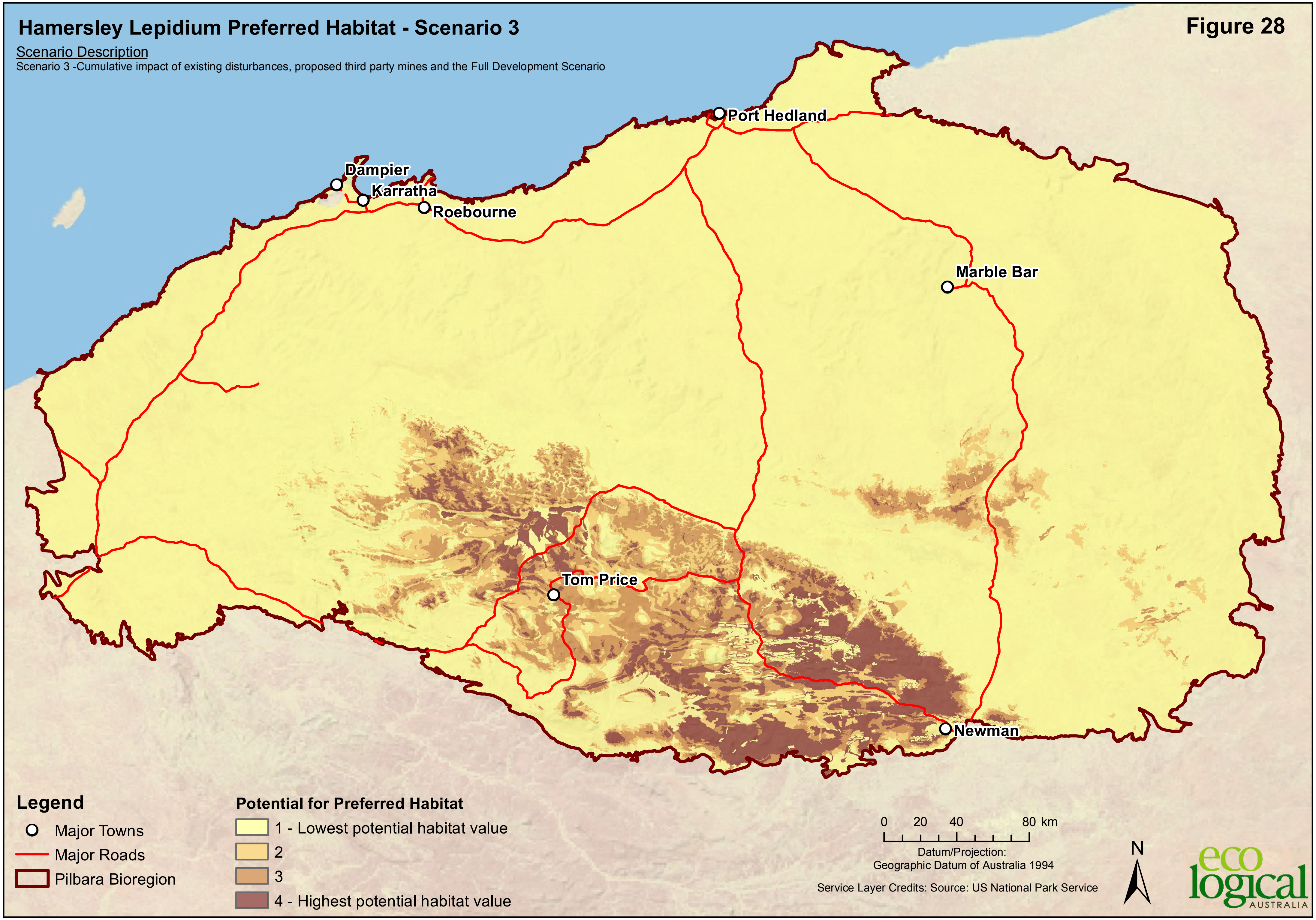


Hamersley Lepidium Preferred Habitat - Scenario 3

Figure 28

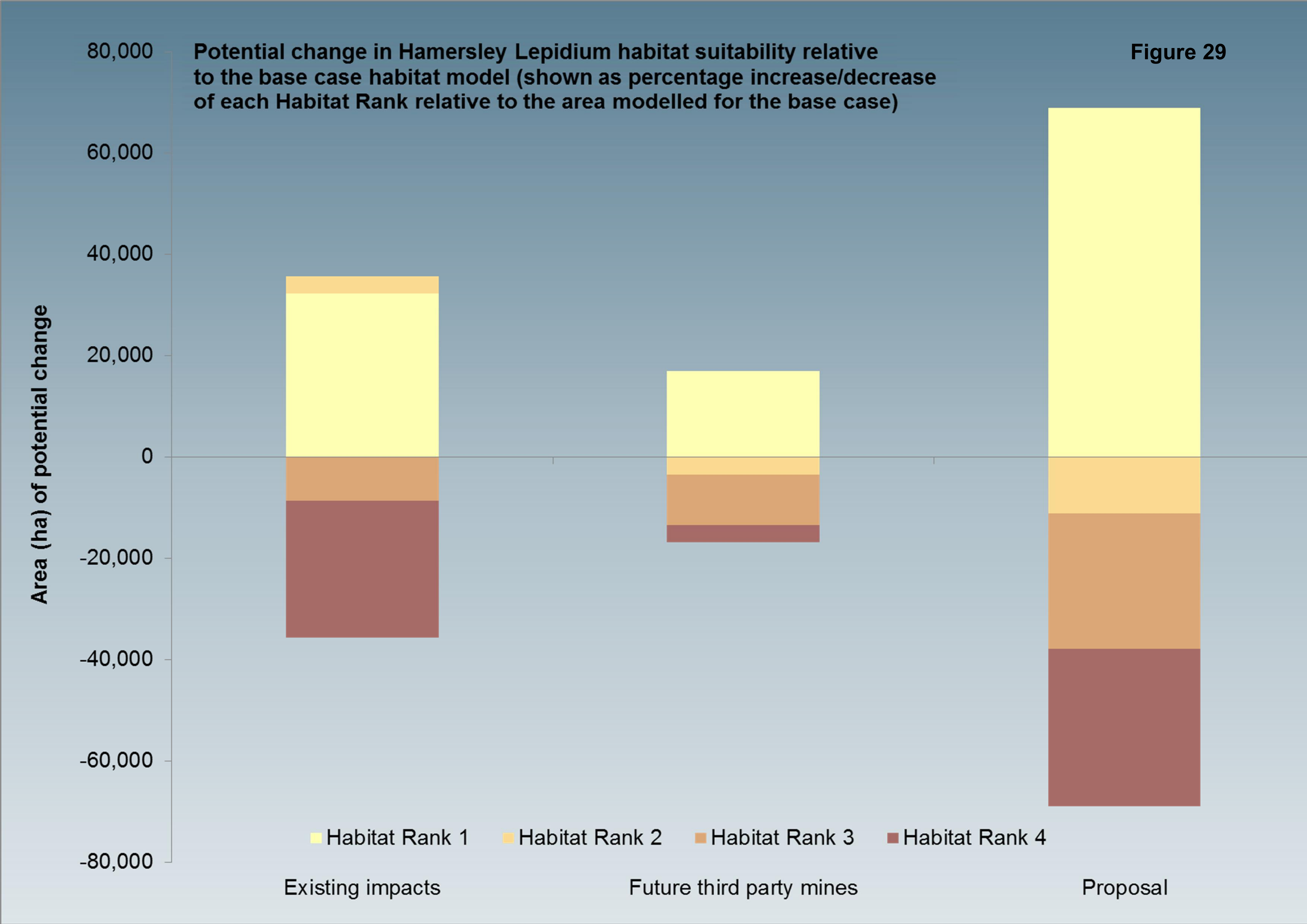
Scenario Description

Scenario 3 -Cumulative impact of existing disturbances, proposed third party mines and the Full Development Scenario



Datum/Projection:
Geographic Datum of Australia 1994

Service Layer Credits: Source: US National Park Service

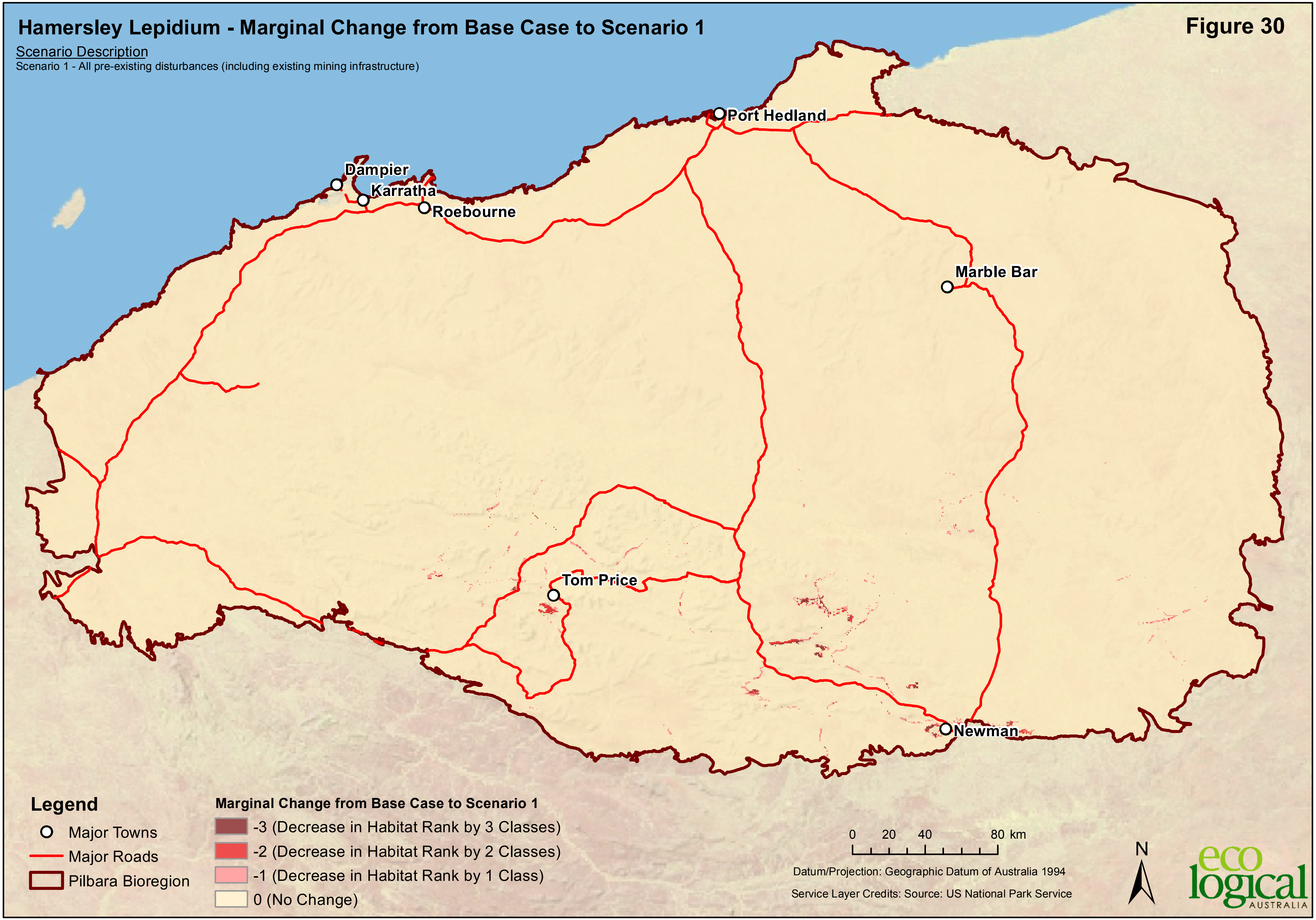

Potential change in Hamersley Lepidium habitat suitability relative to the base case habitat model (shown as percentage increase/decrease of each Habitat Rank relative to the area modelled for the base case)
Figure 29
Area (ha) of potential change
80,000
60,000
40,000
20,000
0
-20,000
-40,000
-60,000
-80,000
Habitat Rank 1
Habitat Rank 2
Habitat Rank 3
Habitat Rank 4
Existing impacts
Future third party mines
Proposal

Hamersley Lepidium - Marginal Change from Base Case to Scenario 1

Figure 30

Scenario Description

Scenario 1 - All pre-existing disturbances (including existing mining infrastructure)



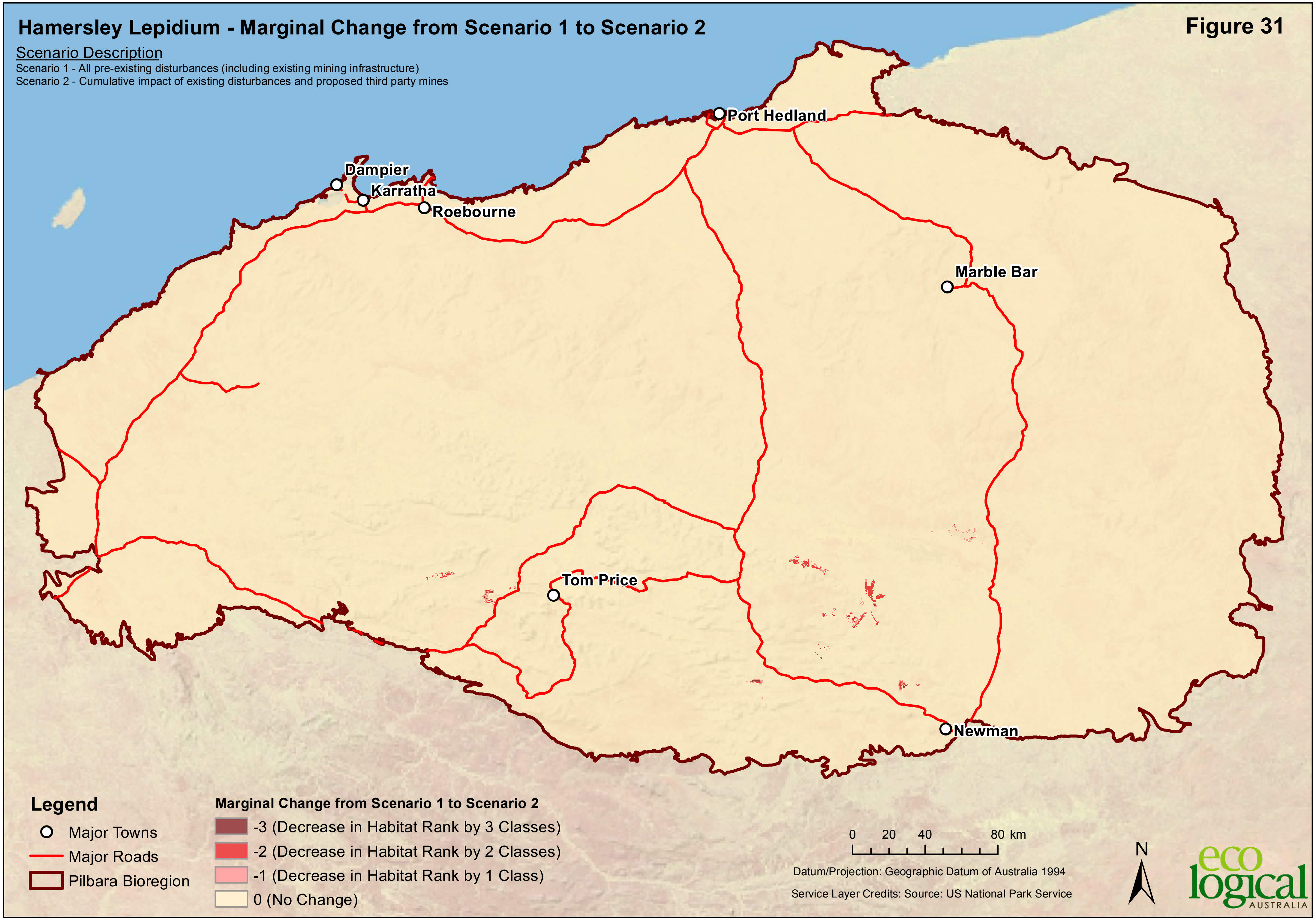
Hamersley Lepidium - Marginal Change from Scenario 1 to Scenario 2

Figure 31

Scenario Description

Scenario 1 - All pre-existing disturbances (including existing mining infrastructure)

Scenario 2 - Cumulative impact of existing disturbances and proposed third party mines



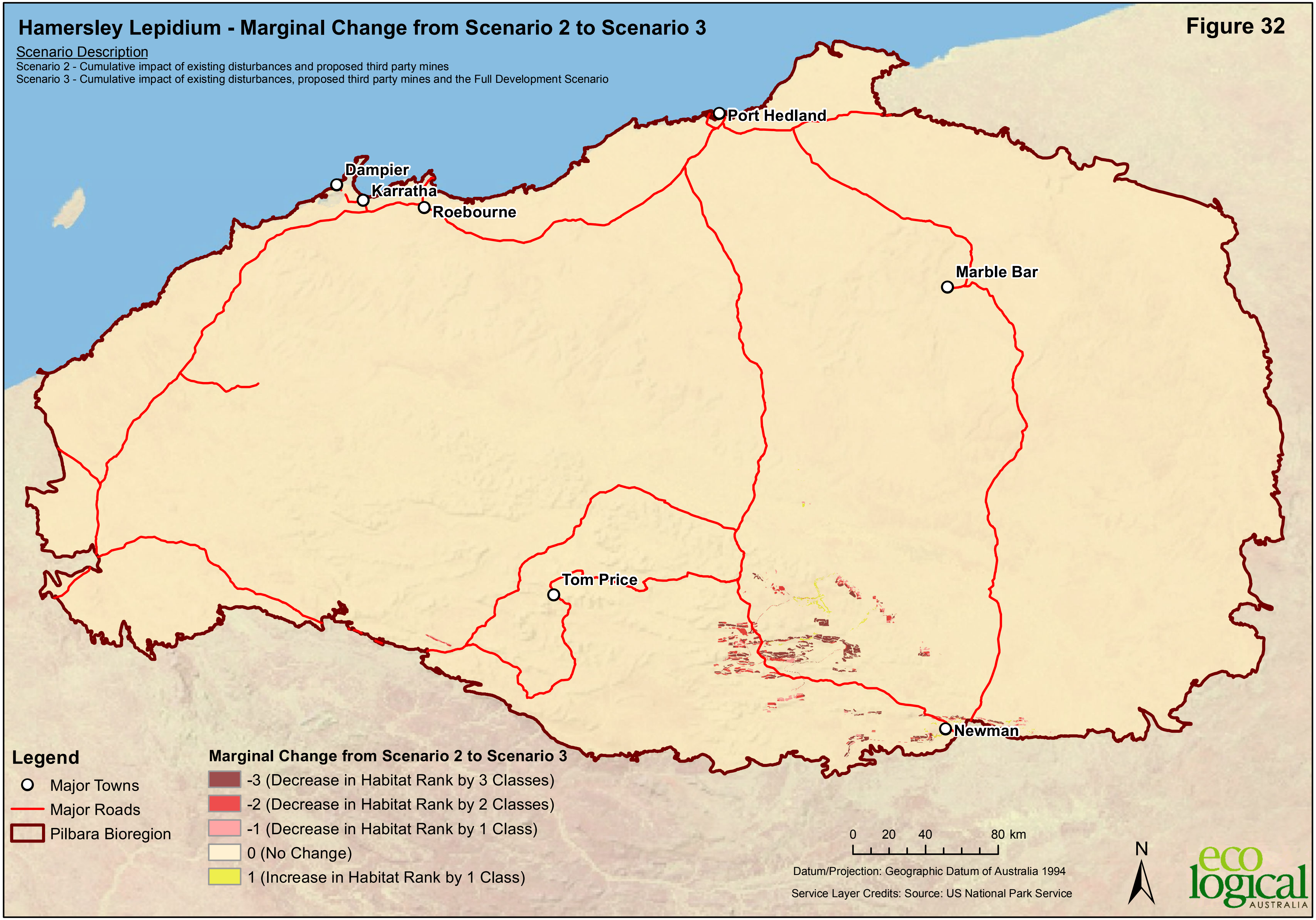


Figure 32

Hamersley Lepidium - Marginal Change from Scenario 2 to Scenario 3