5 Northern Quoll

5.1 OVERVIEW

This section provides background information relevant to the assessment of potential cumulative impacts to the Northern Quoll from the Proposal. It provides an overview of key ecological characteristics of the Northern Quoll, 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 including the outcomes of a workshop facilitated by Parks and Wildlife in July 2013. The workshop sought specifically to identify key threats to the Northern Quoll and identify knowledge gaps and research priorities (Cook 2013; Cremona 2013; Dixon 2013; Hamilton 2013; Heidrich 2013a; Klvac 2013; Oats and Johnson 2013; Ritchie and McGrath 2013; Samaraweera and Luccitti 2013; Spencer 2013; Sustainable Consulting 2013c, 2013d; van Leeuwen 2013b; Whitehead 2013).

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 Northern Quoll is provided in Section 5.3 and was based on a review of the best available literature on the likely susceptibility of the Northern Quoll to each impact, along with an understanding of the speciesôkey ecological characteristics as outlined in Section 5.2. Some of the identified threats and potential impacts were excluded from the CIA, the rationale for which is provided in Section 5.3.2.

5.2 SPECIES SYNOPSIS

5.2.1 Description

The Northern Quoll is the smallest, most arboreal and reportedly one of the most aggressive of the four Australian quoll species (DoE 2013b). It is a medium-sized omnivorous marsupial in the family Dasyuridae. The species has a short life span, with males living to approximately one year, or, at most, not beyond their second breeding season. The oldest record of the species in the wild was a female which was three years of age (TSSC 2005).

5.2.2 Conservation status

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

5.2.3 Distribution

The Northern Quoll was widespread across northern Australia, occurring from the north-west cape of Western Australia to south-east Queensland (Biota 2009; **Figure 33**); however, its range has contracted severely in the past 20 years and is now restricted to six main areas (Biota 2009; DoE 2013b):

- the Pilbara bioregion of Western Australia;
- the north-west Kimberley in Western Australia;
- the north and western Top End of the Northern Territory;
- north of Cape York in Queensland;
- the Atherton-Cairns area in Queensland;
- the Carnarvon Range-Bowen area of Queensland.

In Western Australia, the species occurs predominantly in the Pilbara and Northern Kimberley bioregions, but records have also been obtained in surrounding bioregions, including Central Kimberley, Victoria Bonaparte, Dampierland, Little Sandy Desert and Carnarvon (**Figure 34**). The Northern Quoll also occurs on a number of Western Australian islands, including Adolphus, Augustus, Berthier, Bigge, Boongaree, Caffarelli, Capstan, Carlia, Dolphin, Hidden, Koolan, Purrungku, Sir Fredrick, Uwins and Wollaston islands (DoE 2013b).

Despite recent declines in the distribution and abundance of the Northern Quoll across much of Australia, the species remains widespread in the Pilbara bioregion and is generally abundant in the wetter areas of the bioregion. Recorded sightings have been made across the Hamersley, Fortescue Plains, Chichester and Roebourne Plains subregions of the Pilbara bioregion (**Figure 35**). The species is distributed across a range of land systems in the Pilbara, but is thought to prefer the Rocklea, Macroy and Robe land systems (DoE 2013b). Rocky areas are considered to be prime habitat for the Northern Quoll (Begg 1981).

5.2.4 Habitat requirements

The Northern Quoll occupies a diverse range of habitats including rocky areas, eucalypt forests and woodlands, rainforests, sandy lowlands and beaches, shrublands, grasslands and desert (DoE 2013b). Within the Pilbara, the Northern Quoll shows a close association with rocky habitats such as ironstone ridges, basalt mesas, granite outcrops and gorges (Begg 1981).

Rocky areas are identified in the National Recovery Plan for the Northern Quoll (Hill and Ward 2010) as habitat critical to the survival of the species as they are often used as denning and refuge sites. Northern Quoll dens are often made in rock crevices, with surrounding vegetated habitats used for foraging and dispersal (TSSC 2005). Den sites may also include tree holes, logs, termite mounds, and goanna burrows, but these are used less often than rocky habitats (Cook 2013) and are usually only occupied by a single individual (Oakwood 2002).

Both sexes have longer life spans in rocky habitats, and also grow to a larger size than animals in savanna habitats (DoE 2013b). This is likely due to better protection from predators, better nutrition and less exposure to agricultural activities (DoE 2013b). Rocky habitats are also reported to support higher densities of Northern Quoll dens, and breeding success is reportedly increased for animals that secure a den close to a creek line (Oakwood 2000; DoE 2013b).

The Northern Quoll also occurs around mine sites, human dwellings and campgrounds where they may find increased food resources (e.g. human refuse, higher concentrations of insects around lights, or roadkill; Oakwood 2008), or enhanced shelter among mining infrastructure (such as buildings, waste rock dumps, laydown areas, vehicles, machinery and scrap metal piles; Oats and Johnson 2013).

5.2.5 Home range, migration and movement

Home range is defined by Menkhorst and Knight (2011) as the area normally utilised by an individual animal (usually not the total range of an individual). This includes the area in which an animal lives, forages and travels through, but does not generally encompass movement during dispersal. The size of the Northern Quoll's home range varies between the sexes and with habitat type and season, as well as food abundance and denning suitability (King 1989, Oakwood 2002, Rankmore et al 2008, Schmitt et al. 1989).

Home range data for the Northern Quoll are variable between studies and biogeographic regions. King (1989) recorded a large variation in home ranges for the Northern Quoll in the Pilbara; female home ranges between 75 and 443 hectares, and males between five and 1,109 hectares. Oakwood (2002) recorded Northern Quoll home ranges in lowland forest habitats in the Northern Territory that averaged 35 hectares and reached up to 66 hectares for females, and that were around 35 hectares during the non-breeding season and 100 to 150 hectares during the breeding season for males. Schmitt et al. (1989) recorded much smaller home ranges of 2.3 hectares (females) and 1.8 hectares (males) within rugged habitat in the Northern Kimberley bioregion. The rugged habitat was presumably higher quality (Rankmore et al. 2008) and therefore home ranges in this habitat would likely be smaller due to increased food availability.

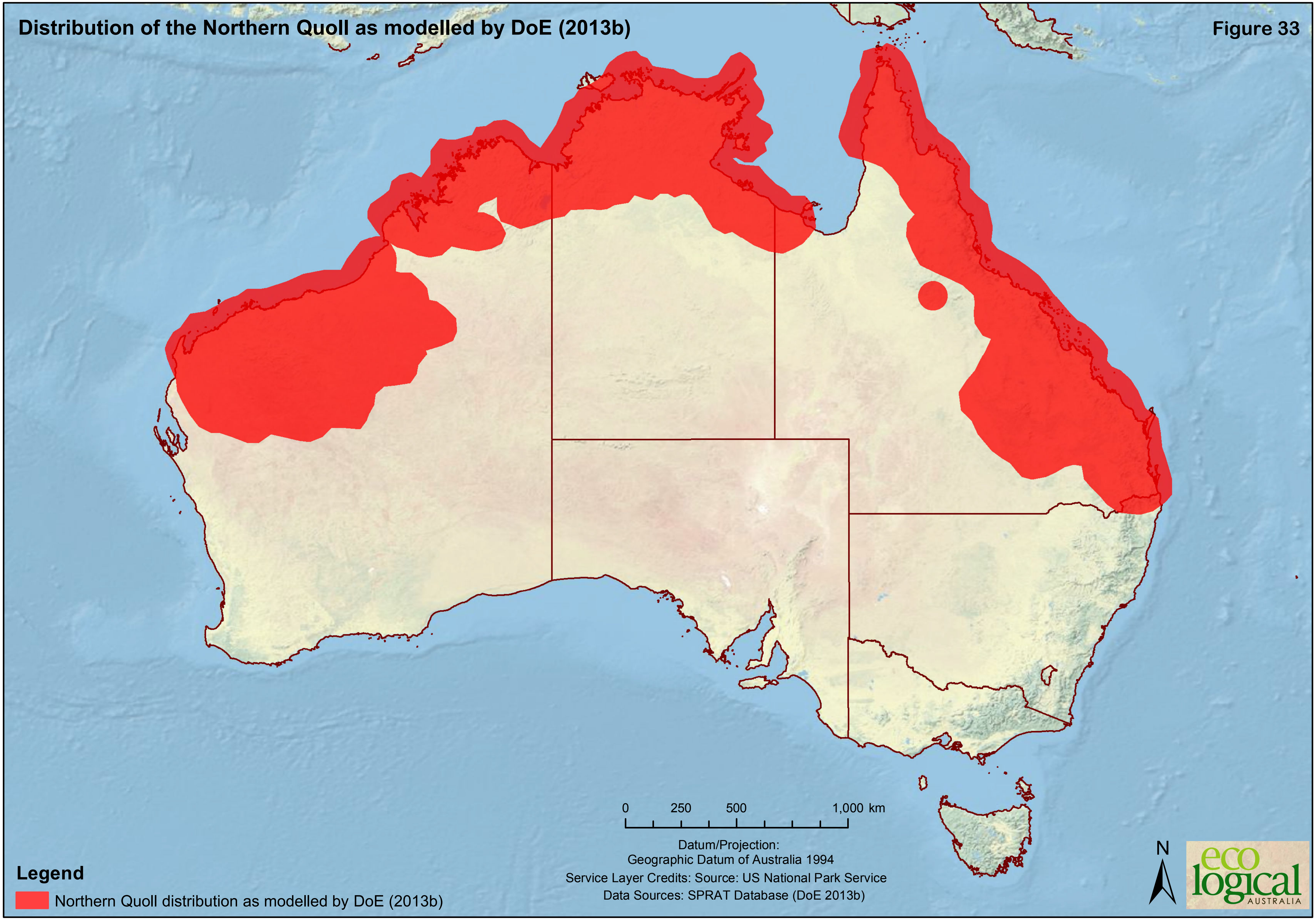
5.2.6 Breeding

The Northern Quoll reaches sexual maturity around 11 months of age and females breed during their first year, producing a mean litter size of seven young (O'Donnell et al. 2010). The species has one breeding season per year and mates generally over a three to four week period during June and July (DoE 2013b), although in the Pilbara mating is spread over a longer period between June and September (Cook 2013). The females carry pouch young for about two months during August to December when they are presumably more bound to breeding den sites as they suckle the young. At eight to nine weeks, juveniles are left in a succession of nursery dens for the next three months for periods at night while the mother forages (Oakwood 2002). During this period, juveniles are likely to suffer high mortality (DoE 2013b). The young start eating invertebrates around four months of age, and begin to forage outside the den at five months. They are fully weaned by six months, after which time they become free ranging and disperse to other areas (Begg 1981), although they may continue to spend additional time (up to two months) with their mothers (Cremona 2013).

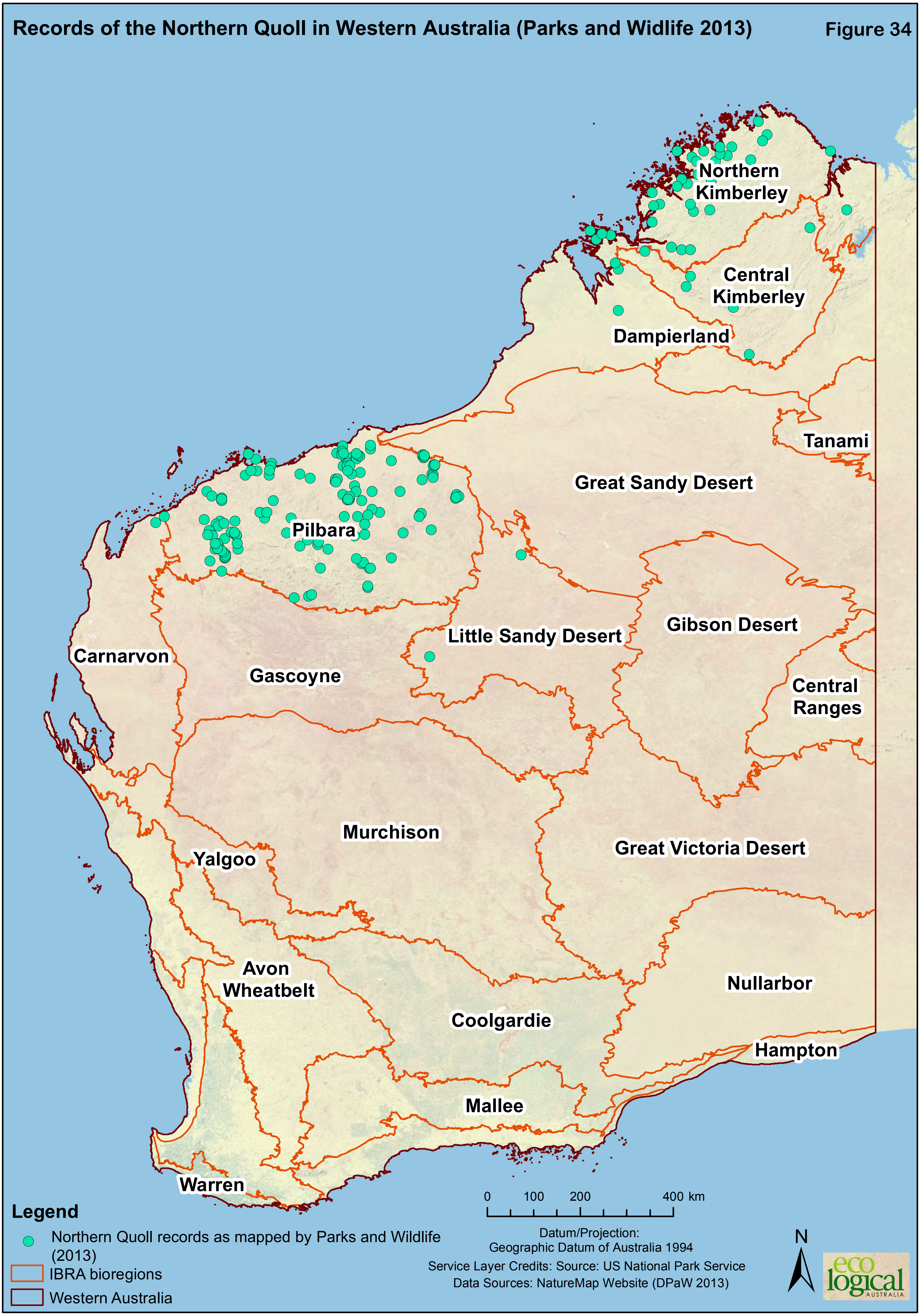
Females usually produce male-dominated litters in their first year and female-dominated litters thereafter; however, they rarely survive to reproduce for a third year (DoE 2013b). In some regions, following mating, males show significant physiological decline and widespread die-off similar to a number of other dasyurid species, which is attributed to the stress and physiological exertion of travelling in search of females during the mating season (Oakwood 2002). In other areas, male die-off appears to be incomplete in the Northern Quoll. This may be related to environment; Braithwaite and Begg (1995) suggest both males and females are effectively annual in savanna environments but that both sexes may survive for two years in rocky environments.

5.2.7 Feeding

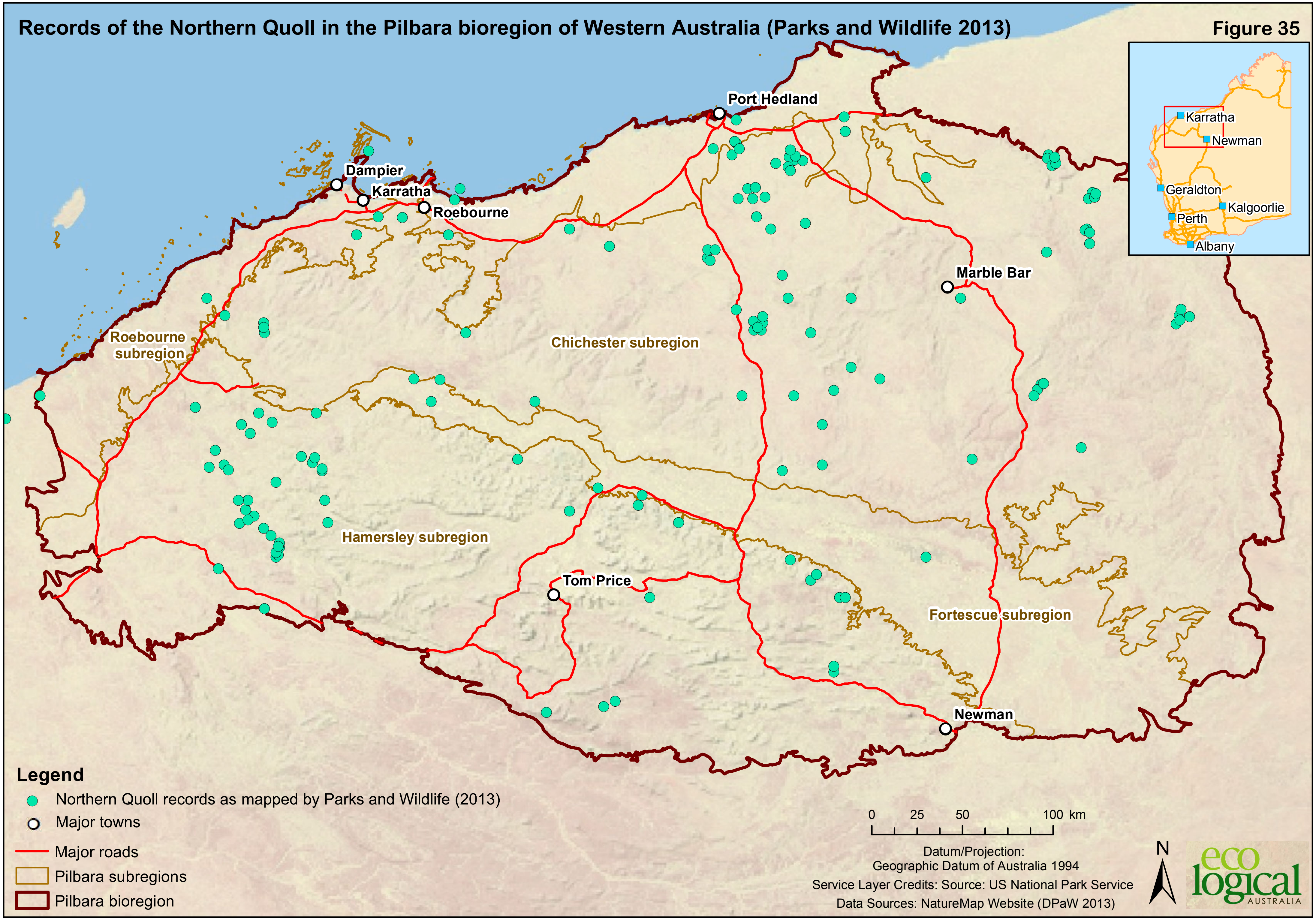
The Northern Quoll is generally a nocturnal, opportunistic forager that feeds on a wide range of items, and changes dietary preferences according to season and availability (Hill and Ward 2010). While it is predominantly insectivorous, the species has been known to take small mammals, birds, frogs, reptiles and fleshy fruits when available (Cook 2013). The Northern Quoll will also scavenge on roadkill and human refuse where available (DoE 2013b). The species is known to forage widely over several kilometres, particularly on spinifex plains adjacent to rocky refuge habitat.



Distribution of the Northern Quoll as modelled by DoE (2013b)
Figure 33
0
250
500
1,000 km
Datum/Projection:
Geographic Datum of Australia 1994
Service Layer Credits: Source: US National Park Service
Data Sources: SPRAT Database (DoE 2013b)
N
Legend
Northern Quoll distribution as modelled by DoE (2013b)

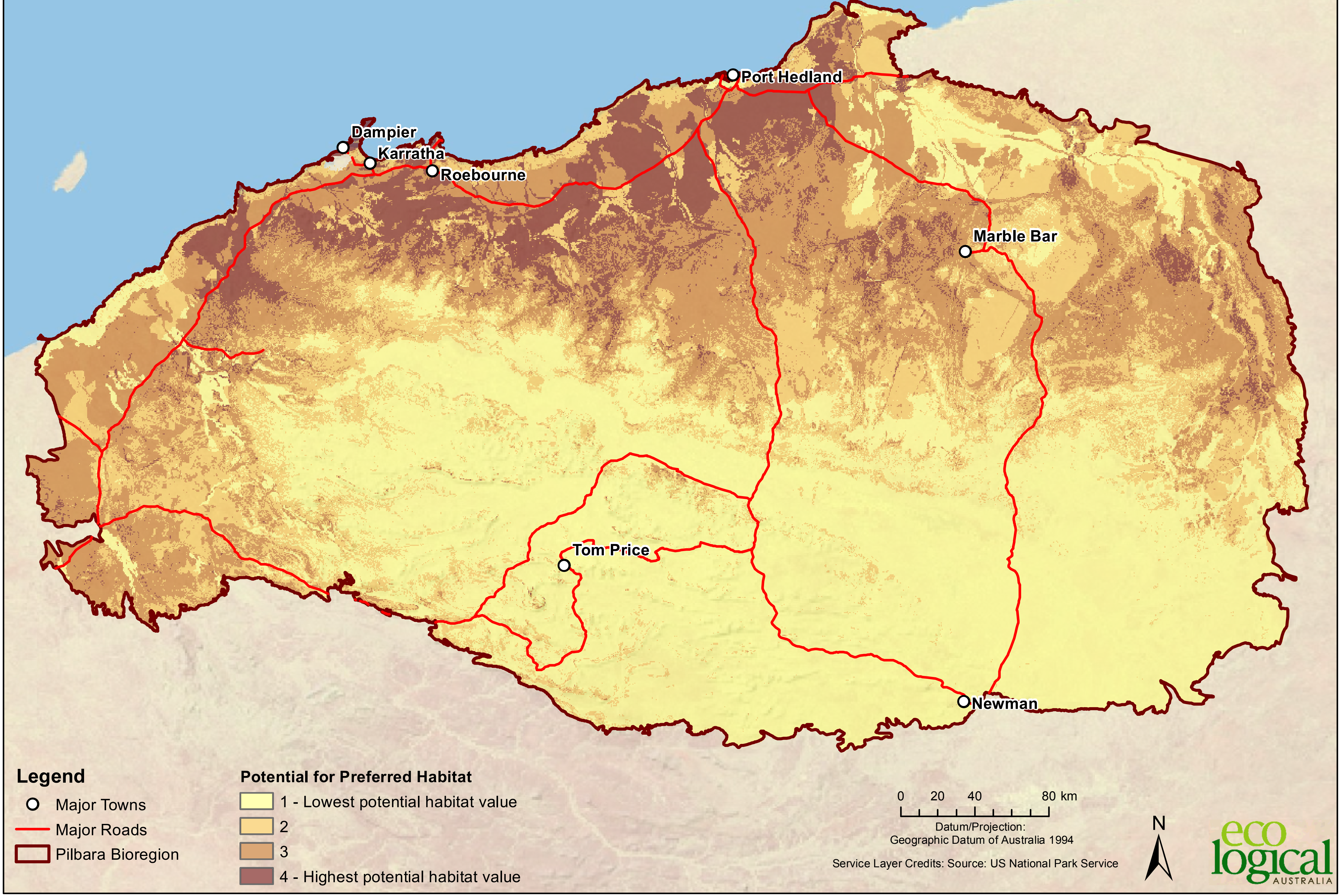

Records of the Northern Quoll in Western Australia (Parks and Widlife 2013)
Figure 34
Northern Kimberley
Central Kimberley
Dampierland
Tanami
Great Sandy Desert
Pilbara
Little Sandy Desert
Gibson Desert
Carnarvon
Gascoyne
Central Ranges
Murchison
Yalgoo
Great Victoria Desert
Avon Wheatbelt
Nullarbor
Coolgardie
Hampton
Mallee
Warren
0 100 200 400 km
Legend
Northern Quoll records as mapped by Parks and Wildlife (2013)
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)
N

Records of the Northern Quoll in the Pilbara bioregion of Western Australia (Parks and Wildlife 2013) **Figure 35**



Northern Quoll Preferred Habitat - Base Case

Figure 36



5.3 METHODS

5.3.1 Base layer considered

The Northern Quoll 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 21**; **Figure 36**). A large proportion (45 per cent) of the Pilbara bioregion was modelled as lowest potential habitat suitability for the Northern Quoll, with areas of higher habitat suitability occurring throughout the northern part, and to a lesser extent in the western and eastern parts of the bioregion (**Table 21**; **Figure 36**). The most suitable habitat was located within approximately 80 kilometres of the coast, from west of Karratha to east of Port Hedland (**Figure 36**).

Table 21: Classification and ranking applied to the Northern Quoll habitat model

Model value	Habitat Rank	Habitat suitability	Area (ha) in Northern Quoll habitat model
70-100%	4	Highest probability of potential habitat	1,552,321 (9%)
30-70%	3	↓	4,497,928 (25%)
10-30%	2		3,822,101 (21%)
0-10%	1	Lowest probability of potential habitat	7,920,267 (45%)

5.3.2 Identification of key threats

Known and perceived threats to the Northern Quoll are identified in the SPRAT database (DoE 2013b), and the speciesôNational Recovery Plan (Hill and Ward 2010) (**Table 22**). A Northern Quoll workshop facilitated by Parks and Wildlife in July 2013 also identified threats to the species (Ritchie and McGrath 2013; **Table 22**).

Table 22: Key threats to the Northern Quoll

Threat	Source		
	DoE (2013b)	Hill and Ward (2010)	Parks and Wildlife workshop
Cane Toads	✓	✓	✓
Removal of habitat	✓	✓	✓
Degradation of habitat	✓	✓	✓
Fragmentation of habitat causing population isolation	-	✓	✓
Inappropriate fire regimes	✓	✓	✓

Threat	Source		
	DoE (2013b)	Hill and Ward (2010)	Parks and Wildlife workshop
Feral predators (predation/competition)	✓	✓	✓
Weeds	✓	✓	✓
Pastoralism/grazing pressure	✓	✓	✓
Mortality from collision with vehicles	✓	-	✓
Parasitism/disease	✓	✓	✓
Other interactions with humans (e.g. hunting)	-	✓	✓
Climate change	-	-	✓

Of the aforementioned threats, the following were excluded from the CIA:

- Cane Toads ï the Pilbara bioregion is currently beyond the range of the Cane Toad; however, this species is predicted to become extensive throughout the Pilbara in the future (Kearney et al. 2008), and this view appears to be the consensus among scientists familiar with the Pilbara. Tingley et al. (2012) developed a model that predicts the Cane Toad will spread from the Kimberley to the Pilbara bioregion of Western Australia within 51 years through a coastal corridor between Broome and Port Hedland. They predict the spread of the Cane Toad will occur due to the presence of artificial water bodies, which will act as critical points for breeding, enabling the distribution of the Cane Toad to extend through the arid environment between the Kimberley and the Pilbara. While the Cane Toadôs predicted future occurrence in the Pilbara is recognised, the interactions with, and impacts to, wildlife are complex and there are limited data available to extrapolate potential future impacts of the Cane Toad within the Pilbara. Therefore, the potential future effects of the Cane Toad on the Northern Quoll were not applied in the CIA. The Northern Quoll is vulnerable to lethal toxic ingestion of Cane Toad toxin (Oakwood 2003) and the Cane Toad is considered the main threat to Northern Quoll populations in parts of their range within Australia, outside the Pilbara (Hill and Ward 2010). The future predicted spread of the Cane Toad into the Pilbara bioregion may have comparable negative impacts to the Northern Quoll as observed in other areas of northern Australia.
- Inappropriate fire regimes ï consideration of fire regime is important in the context of the CIA; 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) 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 Northern Quoll habitat suitability in the Pilbara bioregion (DoE 2013b). Further, interactions between fire, weeds, predators, prey and understorey cover are likely to be complex. For example, one study postulated decline of the Northern Quoll due to predation following fire that removed vegetative cover, which increased Northern Quoll vulnerability to predators (Hill and Ward 2010). 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.

- Weeds ï this refers mainly to *Andropogon gayanu* (Gamba Grass). Present in the Kimberley region of Western Australia, this declared weed is considered an ecosystem ótransformerô due to its ability to change eucalypt woodlands into exotic grasslands, and has a high fuel load that produces fires up to eight times more intense than native grass fires (TSSC 2009). As Gamba Grass is not present in the Pilbara, it is not considered a current threat to the Pilbara population of the Northern Quoll. Weeds have therefore not been considered in the CIA for the Northern Quoll.
- Parasitism and disease ï parasitism and disease may affect Northern Quoll populations in the Pilbara bioregion; however, relevant quantitative data were not available and therefore this threat was not included in this study.
- Hunting and persecution ï this key threat listed by Hill and Ward (2010) is considered to have been more prominent historically and to have contributed to the decline of the species, but is not considered a current threat to the Pilbara population of the species.
- Climate change ï 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.

The potential effects of noise and light on the Northern Quoll 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 Northern Quoll, 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 Northern Quoll in the CIA. Limitations associated with noise and light are discussed in Section 8.1.2.

5.3.3 Potential impacts applied

In consideration of the key threats identified and the available data (Section 5.3.2), the potential impacts applied in the Northern Quoll 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 5.3.4 to 5.3.8). 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.

5.3.4 Removal of habitat

The removal of Northern Quoll habitat may result in the loss of denning and foraging habitat, and a reduction in the speciesô distribution in the Pilbara bioregion. The Northern Quollôs distribution in this bioregion has declined since at least the early 1980s; a causal link to threatening processes has yet to be determined for this, but could be due to altered fire regimes and habitat degradation from over-grazing of stock animals (Hill and Ward 2010). Furthermore, the removal of habitat may displace individuals, which jeopardises reproduction and can result in mortality or extinction of local populations; isolation of populations and reduced gene flow; and increased predation by, or competition with, feral animals. 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 23**).

The Northern Quoll has been noted to utilise cleared and highly disturbed areas. The species occurs around mine sites, human dwellings and campgrounds where they may find increased food resources (e.g. human refuse, higher concentrations of insects around lights, or roadkill; Oakwood 2008), or enhanced shelter among mining infrastructure (such as buildings, waste rock dumps, laydown areas, vehicles, machinery and scrap metal piles; Oats and Johnson 2013). The Northern Quoll may therefore still be able to utilise cleared areas; however, as a conservative approach was taken in the CIA, potential habitat utilisation in cleared areas was not considered.

Table 23: Potential impacts of removal of potential Northern Quoll 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.

5.3.5 Fragmentation of habitat

Habitat fragmentation could isolate Northern Quoll populations, reduce genetic connectivity and the potential for physical dispersal across affected areas and increase the risk of local extinctions. Habitat fragmentation could reduce landscape permeability for this species. A reproductive strategy of male semelparity (characterised by a single reproductive episode before death) in some populations makes the Northern Quoll particularly susceptible to local extinctions following isolation of populations by habitat fragmentation (Hill and Ward 2010). A strong negative response to habitat fragmentation was observed by Rankmore and Price (2004) when habitat preferences for the Northern Quoll were modelled near Darwin. It was predicted by Rankmore and Price (2004) that landscapes with less than approximately 70 per cent woodland would no longer provide habitat for the Northern Quoll within a four kilometre radius of the trapping site.

A patch is considered a discrete area used by individuals of a species to breed or obtain other resources. Technical information on identification of habitat patches and application of fragmentation in the CIA is provided in Section 3.3.5. Mining and linear infrastructure have the potential to fragment Northern Quoll 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 Northern Quoll mobility and the assumption of viable population density, incorporating overlaps in foraging ranges of females in areas of low population density (determined by Oakwood (2002) as one to two females per 100 hectares).

The number of individuals required to maintain a viable Northern Quoll population has not been documented. Notwithstanding the lack of available data, a conservative approach was taken for the assessment of the potential effects of habitat fragmentation on the Northern Quoll, whereby it was estimated that 100 females are required for a viable population. Therefore, considering requirements of minimum population density, an area of 5,000 hectares represents a conservative estimate of viable patch size. Habitat fragmentation was considered to have occurred when patch size was reduced below 5,000 hectares; impacts were assumed to increase with decreasing patch size below this threshold (**Table 24**).

Table 24: Potential impacts of fragmentation of potential Northern Quoll habitat

Patch size	Level of potential impact	Confidence in level of potential impact	Assumptions
3,000-5,000 ha	Low (20%)	Low. The smallest patch size required to maintain a viable population has not been documented.	100 females are required to maintain a viable population. There are two females per 100 ha in low density Northern Quoll populations (based on Oakwood 2002). Habitat suitability is thought to decrease as patch size decreases (King 1989, Oakwood 2002, Rankmore et al 2008, Schmitt et al. 1989).
1,000-3,000 ha	Medium (50%)		
<1,000 ha	High (100%)		

5.3.6 Predation

Feral predators may compete with the Northern Quoll for food, or prey on them (DoE 2013b). Although the significance of this threat to the Northern Quoll is yet to be assessed, feral predators have significantly affected other species of quoll including the Western Quoll and Spotted-tailed Quoll. The Northern Quoll is also considered more vulnerable to predation by the cat and fox than other quoll species due to its smaller size (Hill and Ward 2010). Both cats and foxes are present in the Pilbara, although foxes are absent from the arid Pilbara (Pearson, D., Parks and Wildlife, pers. comm., Parks and Wildlife workshop, 2013).

In parts of the eastern Pilbara, along with western and coastal areas, the current distribution of the Northern Quoll overlaps with that of the fox (King and Smith 1985; Hill and Ward 2010), and competition with, and predation by the fox may be contributing to the decline of the Northern Quoll in this part of its range.

While there is known to be some level of predation throughout the Pilbara generally, including remote areas away from human settlement and including mine activities, 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). 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 25**).

Table 25: Potential impacts to the Northern Quoll 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 increase in the 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).

5.3.7 Mortality from collision with vehicles

Mortality from collision with vehicles was considered as an impact because the Northern Quoll is an opportunistic forager (Hill and Ward 2010) and may scavenge on roadkill (DoE 2013b), so there is a risk of mortality from road vehicle or train strike (the species may become secondary roadkill).

There is a lack of data for roadkill rates for the Northern Quoll; spatio-temporal factors that may drive the incidence of roadkill (such as the presence of hills adjacent to roads/rail, traffic densities, traffic speed, or Northern Quoll densities) have not been documented. However, the probability of a collision resulting in roadkill is likely to increase in locations closer to roads or rail lines. Collisions were considered to potentially affect Northern Quoll habitat suitability at a distance of up to 500 metres, with the greatest effect being within 50 metres (**Table 26**). 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 26: Potential impacts to the Northern Quoll from collision with vehicles

Distance to roads/rail	Level of potential impact	Confidence in level of potential impact	Assumptions
50-500 m	Low (20%)	Medium. The Northern Quoll is known to scavenge on roadkill (DoE 2013b); however, spatio-temporal factors that may drive the incidence of roadkill have not been documented.	Habitat suitability is assumed to decrease as the distance to roads/rail decreases.
<50 m	Medium (50%)		

5.3.8 Grazing pressure

Pastoral use is considered a threat to the Northern Quoll in Western Australia (DoE 2013b). Grazing may alter habitat for the Northern Quoll by reducing ground layer cover and in some cases increasing shrub cover by promoting vegetation thickening and weed invasion (Hill and Ward 2010). Loss of cover may increase the vulnerability of the species to predation, but also increases exposure of vertebrate prey (Hill and Ward 2010). 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 Northern Quoll; however, this was not considered in the application of the potential impacts of grazing.

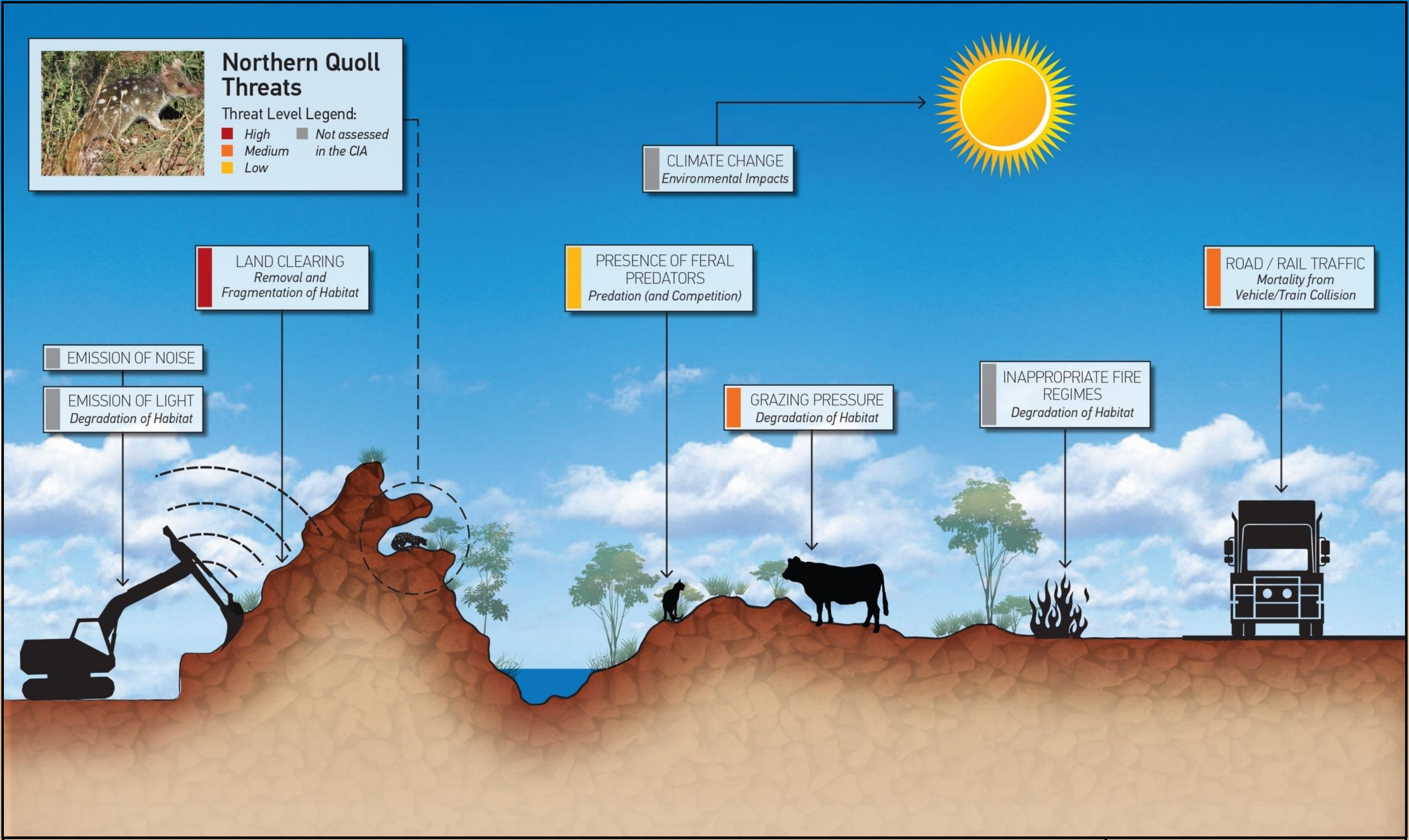
Habitat suitability is expected to reduce as habitat condition is degraded and prey becomes less abundant as grazing pressure increases (**Table 27**). The impact of grazing was applied to the Northern Quoll from a spatial layer for grazing pressure developed for the Pilbara bioregion by ELA. The grazing 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 27: Potential impacts to the Northern Quoll from grazing

<table>
<tr><th>Grazing pressure</th><th>Level of potential impact</th><th>Confidence in level of potential impact</th><th>Assumptions</th></tr>
<tr><td>Low (infrequently grazed)</td><td>Low (20%)</td><td rowspan="2">Medium. The Northern Quoll is likely to be able to withstand some pressure from introduced herbivores, but the specific level of tolerance is not well understood.</td><td rowspan="2">Habitat suitability is expected to reduce as habitat condition is degraded and prey becomes less abundant as grazing pressure increases.</td></tr>
<tr><td>Medium (moderately grazed) or High (heavily grazed)</td><td>Medium (50%)</td></tr>
</table>

5.4 NORTHERN QUOLL CONCEPTUAL DIAGRAM

A conceptual diagram was prepared to depict the Northern Quoll 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 37**). The conceptual diagram shows the potential impacts applied in the CIA and their level of potential impact (High, Medium or Low; Section 5.3). 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 26**); 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.



Northern Quoll conceptual diagram

Figure 37

5.5 RESULTS

Results of the CIA for Northern Quoll habitat suitability are provided in **Table 28** and **Table 29**. **Table 28** provides the area affected by potential impacts associated with existing impacts, future third party mines, and the Full Development Scenario. **Table 29** 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 Northern Quoll habitat suitability in Scenario 1 to Scenario 3 is provided in **Figure 38** to **Figure 40**. 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 41**. The marginal change from one scenario to another, and from the base case to Scenario 1, is provided in **Figure 42** to **Figure 44**.

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 ûupgradedô 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 Northern Quoll extends beyond the Pilbara bioregion and this assessment therefore may overstate the potential impacts to the species if considered across the speciesô entire range.

5.5.1 Existing Impacts

The potential effect of existing impacts was a substantial decrease in Northern Quoll habitat suitability relative to the base case (**Figure 36**, **Figure 38**, **Figure 41** and **Figure 42**). Approximately 1.4 million hectares (91 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), along with 1.5 million hectares (33 per cent) of Habitat Rank 3 being affected and downgraded to less suitable habitat (**Table 28**). Overall, a total of approximately 5.9 million hectares decreased in habitat suitability as a result of existing impacts, the majority of which (approximately 5.8 million hectares) decreased by one Habitat Rank (**Table 29**).

The substantial decrease in habitat suitability from existing impacts is likely due mainly to fragmentation of habitat as a result of extensive development of roads and human settlements in the northern Pilbara (**Figure 8** and **Figure 36**). A reproductive strategy of male semelparity in some populations makes the Northern Quoll particularly susceptible to local extinctions following isolation of populations by habitat fragmentation (Hill and Ward 2010). A strong negative response to habitat fragmentation was observed by Rankmore and Price (2004) when habitat preferences for the Northern Quoll were modelled near Darwin.

To a lesser degree, the effect of potential existing impacts is also likely due to predation and mortality from collision with road vehicles in these same areas (**Figure 8** and **Figure 36**). Although the significance of predation on the Northern Quoll is yet to be assessed, feral predators have significantly affected other species of quoll including the Western Quoll and Spotted-tailed Quoll. The Northern Quoll is also considered more vulnerable to predation by the cat and fox than other quoll species due to its smaller size (Hill and Ward 2010).

Grazing pressure likely had a substantial effect as a large portion of the highest modelled Northern Quoll habitat suitability coincided with areas of Moderate and High grazing pressure (**Figure 36** and **Figure A9**, **Appendix A**). Pastoral use is considered a threat to the Northern Quoll in Western Australia (DoE 2013b). Grazing may alter habitat for the Northern Quoll by reducing ground layer cover and in some cases increasing shrub cover by promoting vegetation thickening and weed invasion (Hill and Ward 2010).

5.5.2 Future third party mines

The potential effect of future third party mines on Northern Quoll habitat suitability was minor as a percentage of the total area of the Pilbara bioregion (**Figure 36**, **Figure 39**, **Figure 41** and **Figure 43**). 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 28**). Overall, a total of approximately 10,000 hectares decreased in habitat suitability as a result of future third party mines, the majority of which (approximately 9,800 hectares) decreased by one Habitat Rank (**Table 29**).

5.5.3 Full Development Scenario

The potential effect of the Full Development Scenario was a minor net positive effect on Northern Quoll habitat suitability (**Figure 36**, **Figure 40**, **Figure 41** and **Figure 44**). There was a potential slight positive (beneficial) effect of the Full Development Scenario in some areas, with approximately 11,000 hectares increasing in habitat suitability by one to two Habitat Ranks and 7,000 hectares decreasing in habitat suitability by one to two Habitat Ranks (**Figure 44**; **Table 29**). This potential positive effect was associated with mine closure in Scenario 3, whereby some of the potential impacts to the Northern Quoll were not applied to closed mines and infrastructure. The Full Development Scenario resulted in a slight decrease in the extent of Habitat Ranks 1 and 2 (less than one per cent) and a slight increase in the extent of Habitat Ranks 3 and 4 (less than one per cent; **Table 28**).

5.5.4 Potential cumulative impacts

The potential cumulative impact to Northern Quoll habitat suitability was a decrease in the extent of the most suitable habitat (Habitat Rank 4) of approximately 1.4 million hectares (91 per cent of the modelled extent in the base case). Existing impacts were the main contributor to this potential impact. The extent of Habitat Rank 3 decreased by approximately 1.5 million hectares (33 per cent of the modelled extent in the base case), mostly as a result of existing impacts. These Habitat Ranks were downgraded into lower ranked habitat; therefore the extent of Habitat Rank 1 and Habitat Rank 2 increased. 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 (**Table 28** and **Table 29**).

Table 28: Area of potential change in Northern Quoll habitat suitability

Habitat Rank	Base case	Area (ha) of potential change*			Potential cumulative impact**
		Existing impacts	Future third party mines	Full Development Scenario	
1	7,920,267	1,714,965 (22%)	9,937 (<1%)	273 (<1%)	1,725,175 (22%)
2	3,822,101	1,184,786 (31%)	-9,742 (<-1%)	-3,882 (<-1%)	1,171,162 (31%)
3	4,497,928	-1,487,946 (-33%)	-194 (<-1%)	3,104 (<1%)	-1,485,036 (-33%)
4	1,552,321	-1,411,805 (-91%)	-1 (<-1%)	504 (<1%)	-1,411,302 (-91%)

*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 29: Area of habitat that increased or decreased by one, two or three ranks, or that did not change between scenarios for the Northern Quoll CIA

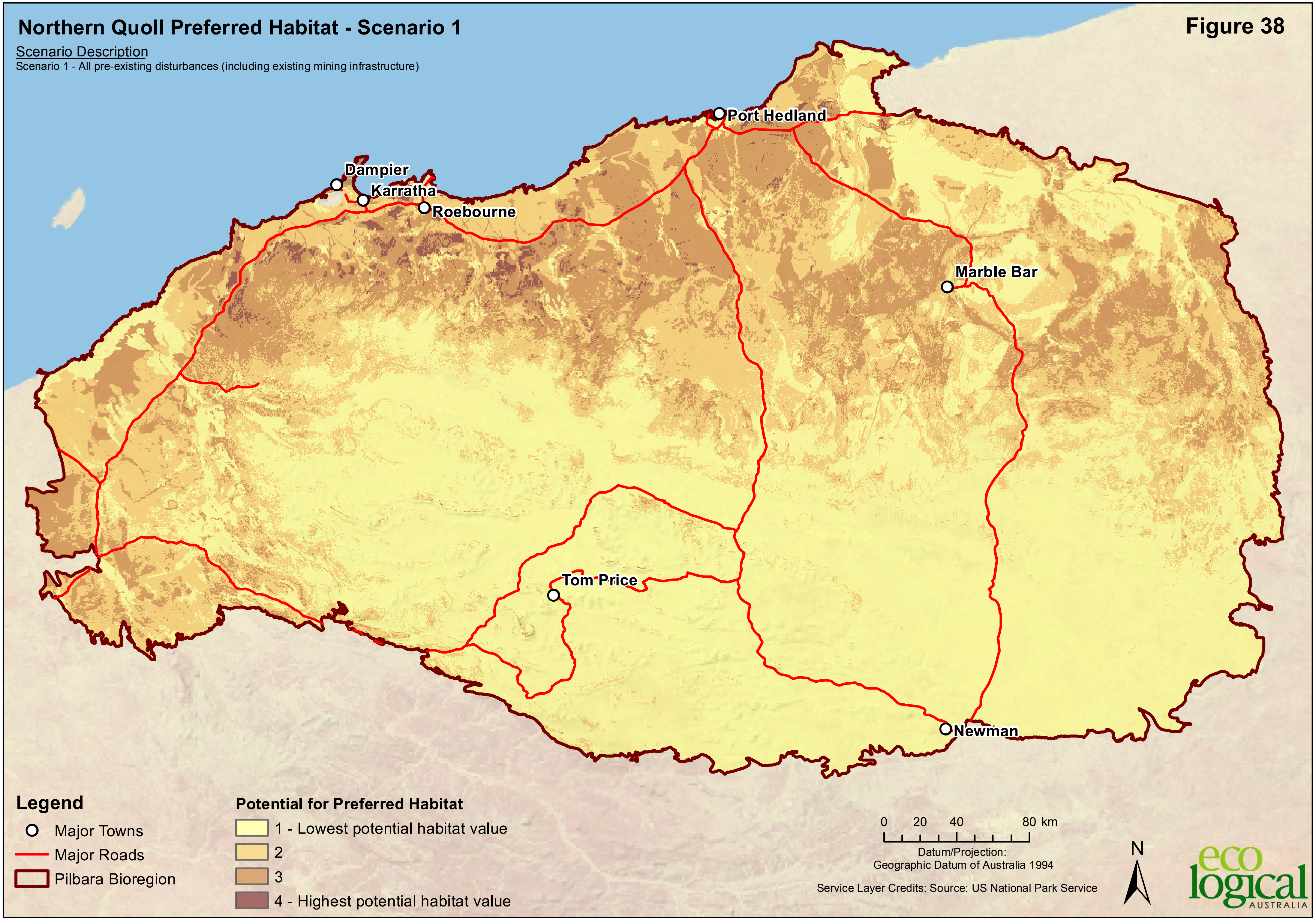
Change in Habitat Rank	Area (ha) of potential change		
	Existing impacts (Base Case to Scenario 1)	Future third party mines (Scenario 1 to Scenario 2)	Full Development Scenario (Scenario 2 to Scenario 3)
+3	0 (0%)	0 (0%)	0 (0%)
+2	0 (0%)	0 (0%)	17 (<1%)
+1	0 (0%)	0 (0%)	10,555 (<1%)
0	11,905,463 (67%)	17,782,656 (~100%)	17,775,318 (~100%)
-1	5,753,792 (32%)	9,789 (<1%)	6,701 (<1%)
-2	127,355 (1%)	171 <1%)	26 (<1%)
-3	6,006 (<1%)	1 (<1%)	0 (0%)

Northern Quoll Preferred Habitat - Scenario 1

Figure 38

Scenario Description

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

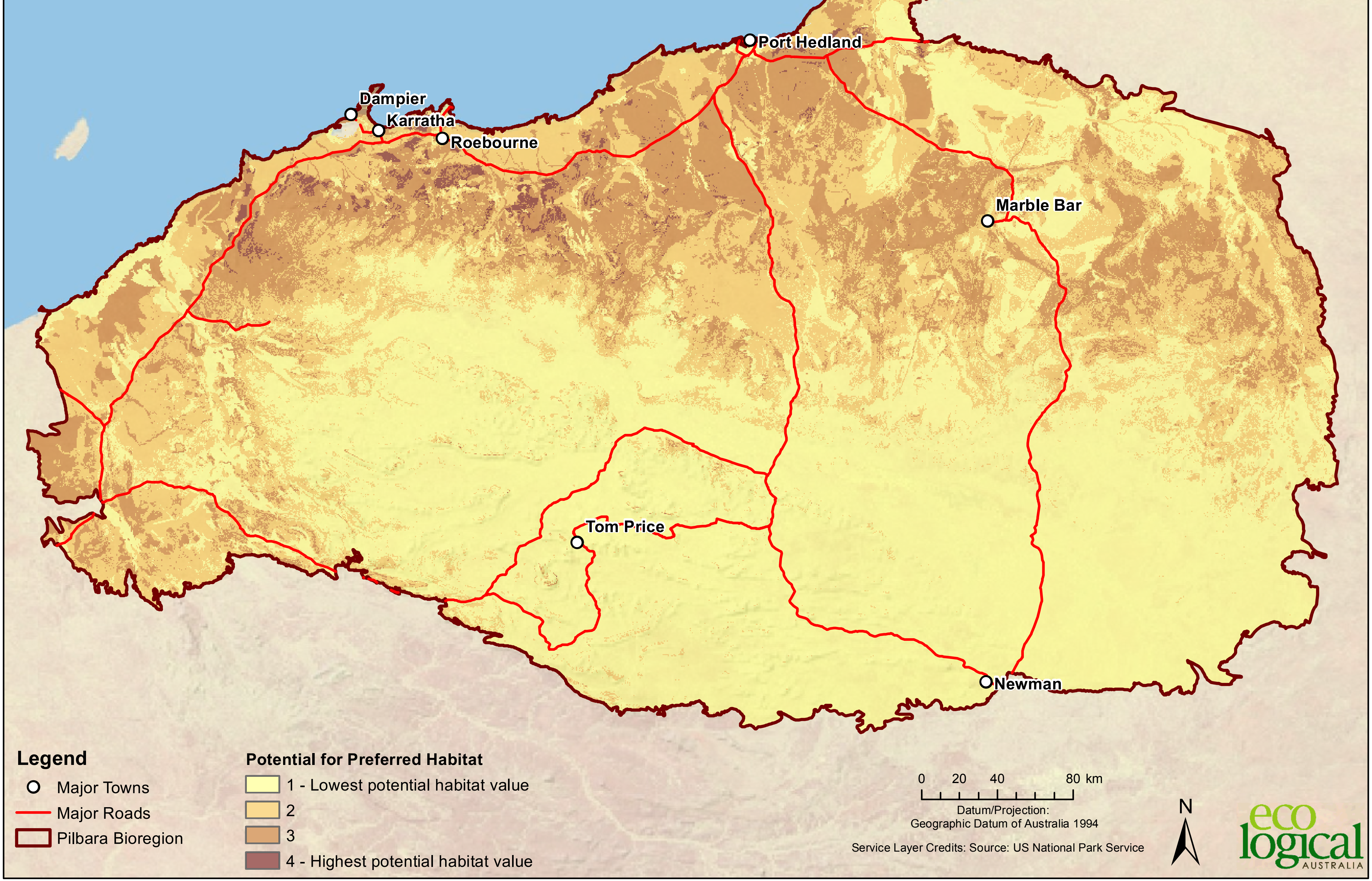


Northern Quoll Preferred Habitat - Scenario 2

Figure 39

Scenario Description

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

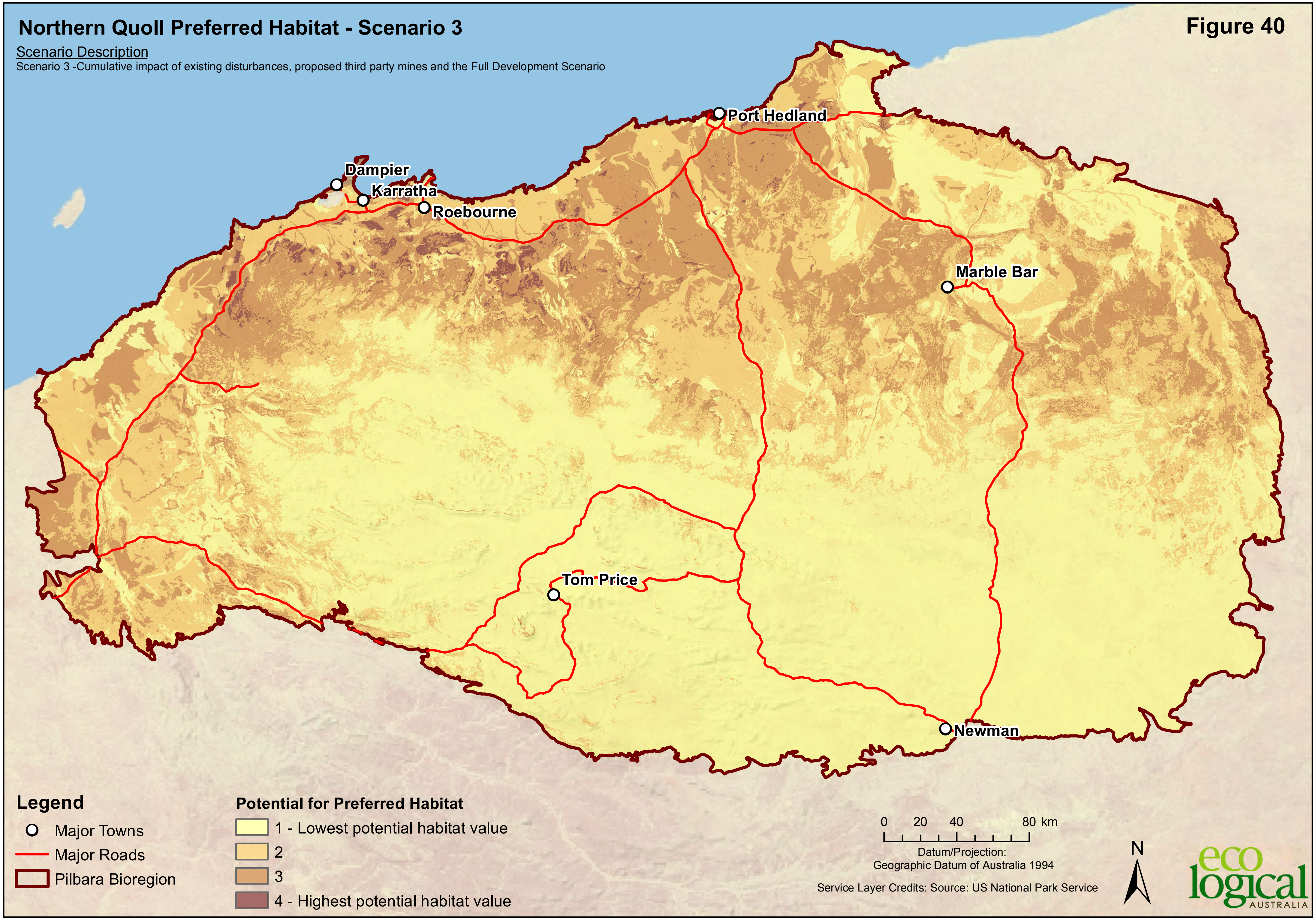


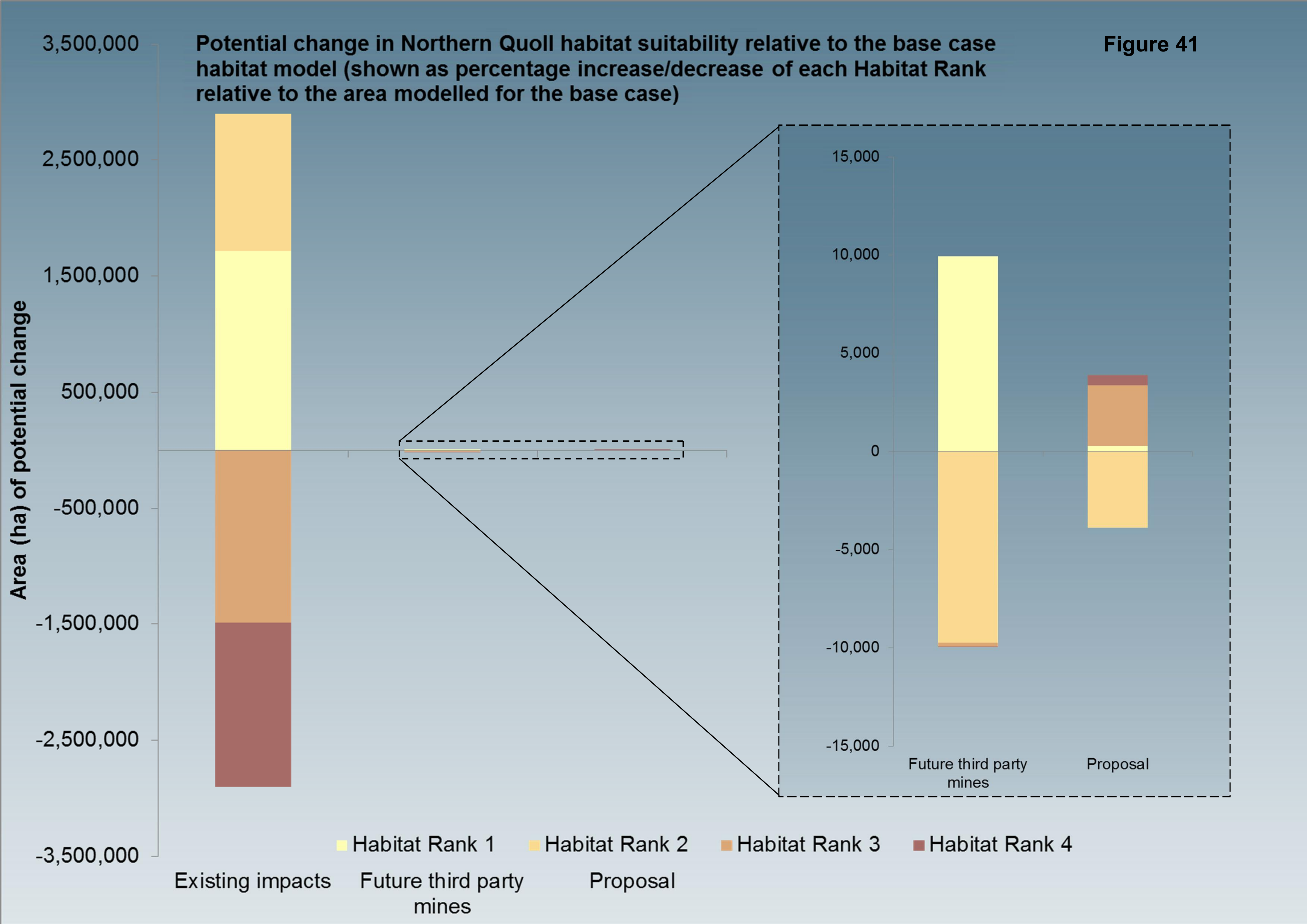
Northern Quoll Preferred Habitat - Scenario 3

Figure 40

Scenario Description

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



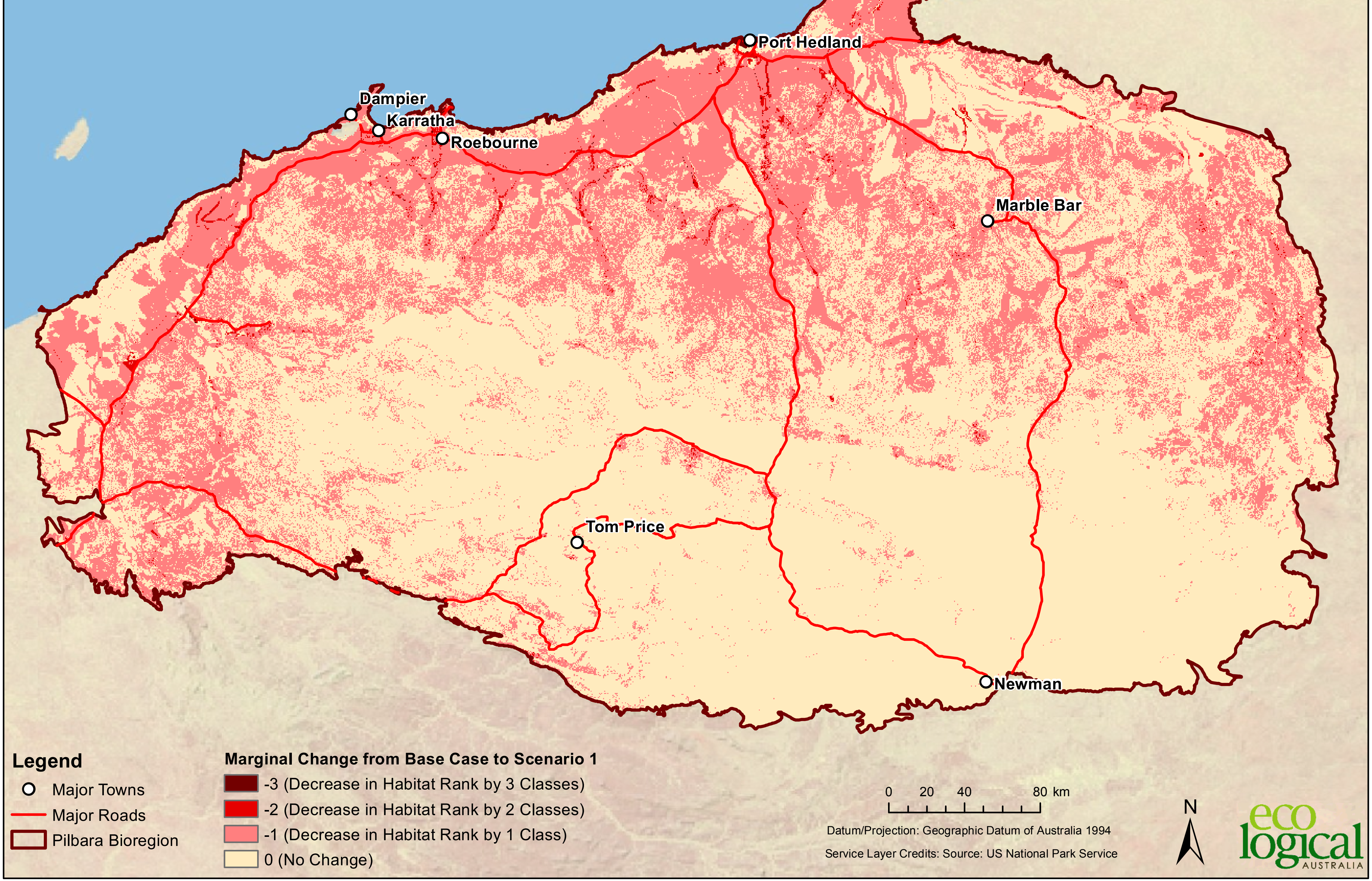

Potential change in Northern Quoll habitat suitability relative to the base case habitat model (shown as percentage increase/decrease of each Habitat Rank relative to the area modelled for the base case)
Figure 41
Area (ha) of potential change
3,500,000
2,500,000
1,500,000
500,000
-500,000
-1,500,000
-2,500,000
-3,500,000
Existing impacts
Future third party mines
Proposal
15,000
10,000
5,000
0
-5,000
-10,000
-15,000
Future third party mines
Proposal
Habitat Rank 1
Habitat Rank 2
Habitat Rank 3
Habitat Rank 4

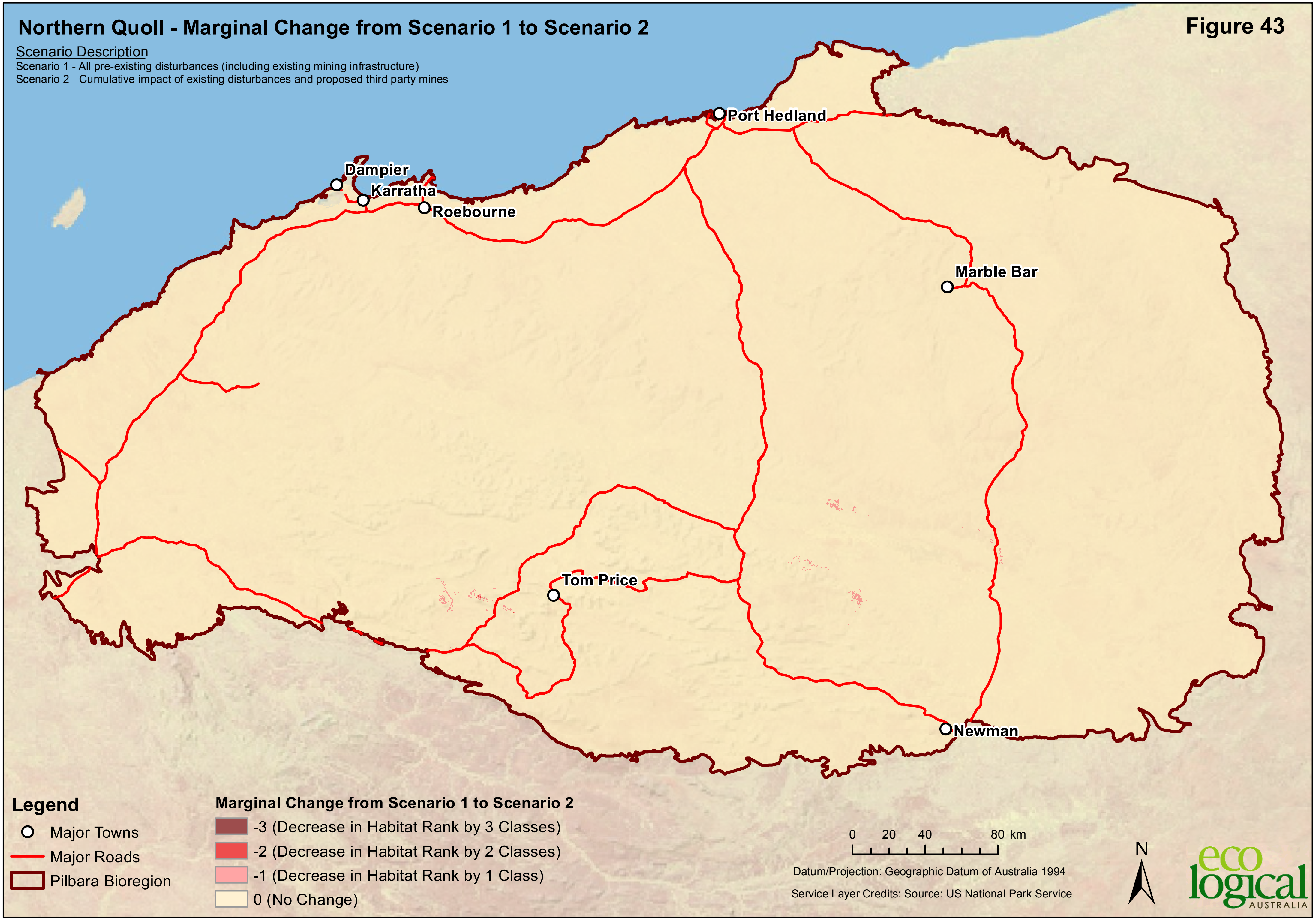
Northern Quoll - Marginal Change from Base Case to Scenario 1

Figure 42

Scenario Description

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




Northern Quoll - Marginal Change from Scenario 1 to Scenario 2
Figure 43
Scenario Description
Scenario 1 - All pre-existing disturbances (including existing mining infrastructure)
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
Marginal Change from Scenario 1 to Scenario 2
-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
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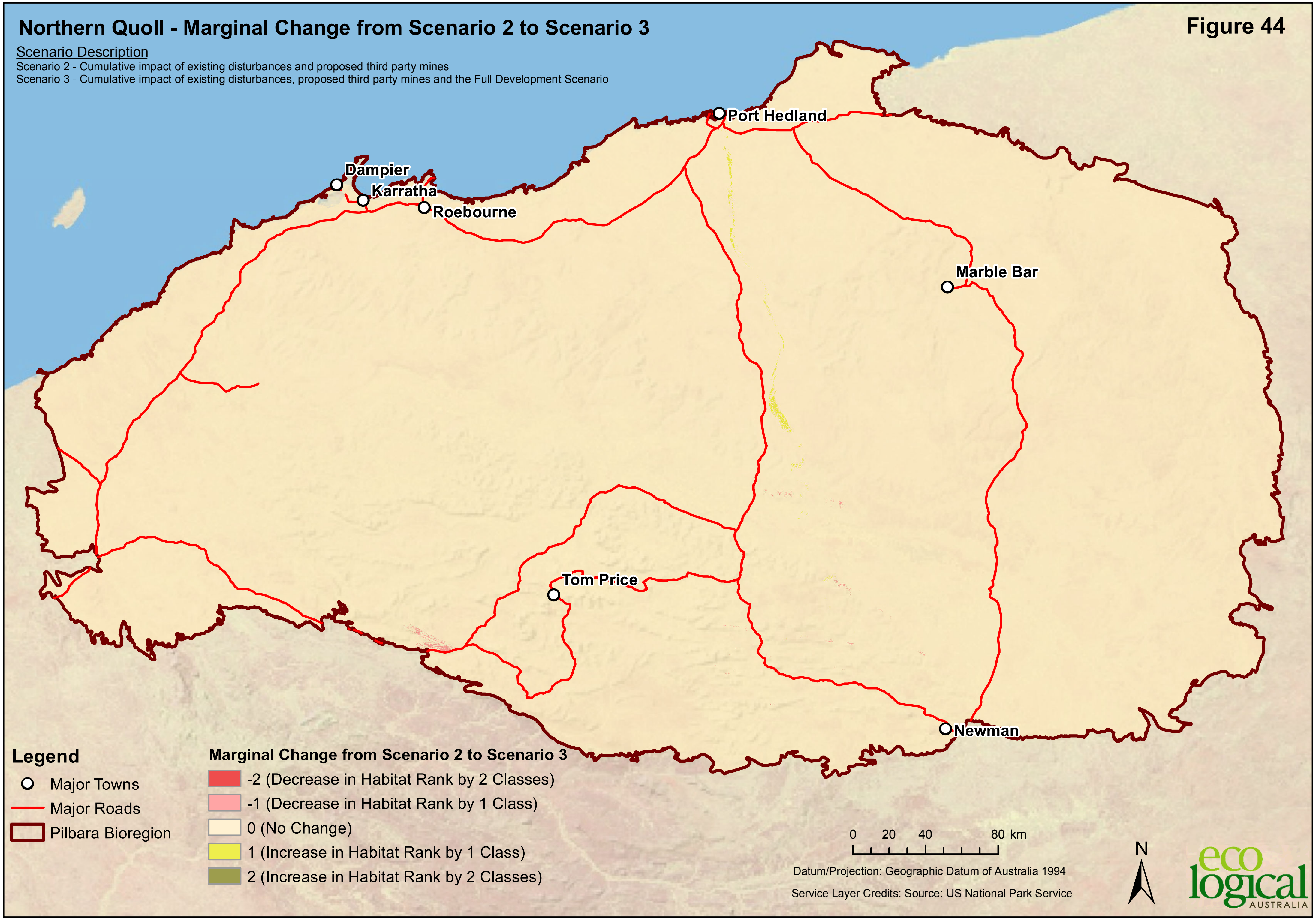
Northern Quoll - Marginal Change from Scenario 2 to Scenario 3

Figure 44

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



6 Pilbara Leaf-nosed Bat

6.1 OVERVIEW

This section provides background information relevant to the assessment of potential cumulative impacts to the Pilbara Leaf-nosed Bat from the Proposal. It provides an overview of key ecological characteristics of the Pilbara Leaf-nosed Bat, 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 including the outcomes of a workshop facilitated by Parks and Wildlife in June 2013. The workshop sought specifically to identify key threats to the Pilbara Leaf-nosed Bat and identify knowledge gaps and research priorities (Armstrong 2013; Bullen 2013; Carter 2013; McKenzie and Bullen 2013; Mutton 2013; Ritchie 2013b; Sustainable Consulting 2013e, 2013f; van Leeuwen 2013c).

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 Pilbara Leaf-nosed Bat is provided in Section 6.3 and was based on a review of the best available literature on the likely susceptibility of the Pilbara Leaf-nosed Bat to each impact, along with an understanding of the speciesô key ecological characteristics as outlined in Section 6.2. Some of the identified threats and potential impacts were excluded from the CIA, the rationale for which is provided in Section 6.3.2.

6.2 SPECIES SYNOPSIS

6.2.1 Description

The Pilbara Leaf-nosed Bat is a moderate-sized bat with relatively small ears and a fleshy nose-leaf[3] structure surrounding the nostrils. The fur is most often bright orange and the wings dark brown (Churchill 2008). The Pilbara Leaf-nosed Bat is the Pilbara form of the Orange Leaf-nosed Bat, which occurs as two disjunct populations in Australia ï one only in the Pilbara bioregion and the other across northern Australia, from the Kimberley in Western Australia to western Queensland. The two populations were historically contiguous (Armstrong 2001), but were separated by the Great Sandy Desert around 30,000 years ago. The populations differ in echolocation call frequency and in snout and nose-leaf measurements (Armstrong and Coles 2007).

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[3] The nose leaf is a thin, broad, membranous fold of skin on the nose of many species of bats.

6.2.2 Conservation status

The Pilbara Leaf-nosed Bat is listed as Vulnerable under the *Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth) (EPBC Act) and Rare or Likely to Become Extinct under Schedule 1 of the *Wildlife Conservation Act 1950* (WA).

6.2.3 Distribution, sub-populations and abundance

The Pilbara Leaf-nosed Bat occurs over an approximate area of 120 million hectares in the Pilbara bioregion, extending southwards into the northern half of the Gascoyne bioregion (DoE 2013b; **Figure 45**, **Figure 46** and **Figure 47**). There have been two estimates by Kyle Armstrong on the home range area (foraging range and roosting habitat) for the Pilbara Leaf-nosed Bat. The first suggests the species has a potential area of 578,300 hectares (Armstrong 2003). This includes areas where bats have been recorded and areas where there is potential habitat based on the presence of suitable cave-forming geology. The second was based on 21 point locations and considered a nightly foraging range of 10 kilometres, and suggested the area of occupancy was 659,400 hectares (K. N. Armstrong, unpublished data, cited in DoE 2013b).

The Pilbara Leaf-nosed Bat occurs in three sub-populations (eastern Pilbara, Hamersley Range and upper Gascoyne), which are separated by flat areas such as the Fortescue and Ashburton valleys, which impede gene flow (Armstrong 2003). The sub-populations can be further separated into individual colonies, which vary in size from 10 to 20,000 individuals, although the latter is exceptional (e.g. Armstrong 2001; Ecologia Environment 2005, 2006a, 2006b). The total number of Pilbara Leaf-nosed Bats is currently unknown due to difficulties in counting individuals.

A recent assessment of data from a range of sources (including mining companies and consultants) indicated a total of 24 maternal or day roost sites occur across the Pilbara bioregion (Bullen 2013). Many of these are not identified in the DoE (2013b) SPRAT database. Of the 24 roosts, five are man-made, 18 are natural caves, and one could not be identified as man-made or a natural cave (Bullen 2013).

6.2.4 Habitat requirements

ROOSTING HABITAT

The Pilbara Leaf-nosed Bat is a poor thermoregulator, exhibiting evaporative water loss of more than double that of other bats (Churchill 2008). Therefore, it has an obligate reliance on caves and underground mines, especially in the Pilbara (Armstrong 2001). Its persistence in the Pilbara depends heavily on the presence of physiologically benign, humid and temperature-stable caves and dis-used mines, which it uses as roosts. These sites provide the necessary narrow temperature and humidity conditions for the species, which range from 28 to 32 ºC and 96 to 100 per cent relative humidity (Churchill 2008). These micro-habitats generally occur deep within rocky hills or underground where humidity is often maintained via ephemeral pools or waterfalls at the cave or mine entrance, or by groundwater when deeper. Armstrong (2001) suggests that the presence of seeps and groundwater pools are the most important factor in determining roost suitability. Churchill (1995) suggested that, in some situations, such as for pregnant females in the Northern Territory, bats may leave caves and become forest dwellers in the wet season. However, there is no evidence of this occurring in the Pilbara and, considering the longer and wetter summer rainfall period in the Northern Territory, any change in bat behaviour in response to rainfall and humidity in the Northern Territory population is unlikely to match bat behaviour in the Pilbara.

The species uses three types of roosts: maternity, diurnal and nocturnal (Bullen 2013; McKenzie and Bullen 2013). The latter two allow it to expand its foraging range. Diurnal roosts are often also used as maternity roosts; although the claim that diurnal and nocturnal roosts never overlap (Bullen 2013) needs to be further substantiated. When roosting, individuals hang from the ceiling or against the cave wall, and separate themselves from others by 10 to 15 centimetres.

Mines that are complex, with adits[4], stopes, and shafts accessible from a main decline, are thought to be suitable as diurnal or maternal roosts (Armstrong 2001). Simple shafts are not inhabited, but structures with wide vertical stopes[5] can be used if the lower levels of the mine include cross cuts and access the water table; simple adits without cross cuts (or with short cross cuts at the same level) might be used as night roosts occasionally (DoE 2013b). Bluff caves, which are common in the Pilbara and form at the base of capping material in breakaway landscapes, are thought to be too unstable for the Pilbara Leaf-nosed Bat because they are shallow and have unstable temperature and humidity (Armstrong 2001).

FORAGING HABITAT

The Pilbara Leaf-nosed Bat can forage in any habitat provided insect biomass is sufficiently high (McKenzie and Bullen 2013), although it is considered to prefer *Triodia* Hummock Grasslands covering low rolling hills and shallow gullies, with scattered river red gum (*Eucalyptus camaldulensis*) along the creeks (Churchill et al. 1988). The species also forages along watercourses, gullies and roads (Churchill 2008). The occurrence of pools of water is a critical component of the Pilbara Leaf-nosed Batõs foraging habitat (Armstrong 2001). For example, in Barlee Range Nature Reserve, the species has been recorded foraging above low shrubs and around pools in gravelly watercourses with *Melaleuca leucodendron* (Armstrong 2001).

6.2.5 Home range, migration and movement

The distance travelled by the Pilbara Leaf-nosed Bat is likely to be limited by the availability of diurnal and nocturnal roosts, which allow the species to disperse from roost sites to foraging areas (a network of roost sites may be used to access additional foraging habitat). Individuals are thought to travel at least 10 kilometres from roosting sites when foraging. This range may increase slightly during the summer rainfall season when humidity and temperature conditions may temporarily allow less frequent night foraging roosts; however, there is a lack of data to verify this (Molhar 2007; Specialised Zoological 2009; Outback Ecology 2012; Bullen 2013).

Assuming a normal foraging range of 10 kilometres in a single night, a circular area of about 32,000 hectares can be expected around each roosting site, although the actual foraging area may be limited by the amount of suitable habitat (K.N. Armstrong unpublished). Recent investigations of the

[4] An adit is a generally horizontal entrance or passageway leading into an underground mine or deposit, usually used for access or drainage.

[5] A stope is a linear vertical excavation that usually follows a vein deposit.

genetics of Pilbara Leaf-nosed Bat have demonstrated that females show high site fidelity in comparison to males. Females do not move to new locations to breed, and also do not disperse far outside the breeding season (Armstrong 2013).

6.2.6 Breeding

Females of the species become reproductively mature at seven months, and males at 16 to 18 months (DoE 2013b; McKenzie and Bullen 2013). Pairs mate in July, and females give birth to a single young from late December to early January, which is weaned by the end of February (Churchill 2008). The number of maternity (breeding) caves in the Pilbara is not known.

6.2.7 Feeding and foraging

Unlike other leaf-nosed bats, the Pilbara Leaf-nosed Bat is a high energy bat which uses rapid flight and abrupt turns to catch prey. It cannot enter torpor, and as such, must feed every night (McKenzie and Bullen 2013). The energetic requirements of the species are unknown; however, females are likely to have different metabolic needs during breeding and non-breeding seasons (McKenzie and Bullen 2013).

The Pilbara Leaf-nosed Bat forages in low zigzag flight patterns through gorges, over watercourses, and over *Triodia* grassland, within a few centimetres to a few metres of the ground. It is an opportunistic insectivore and its prey consists primarily of moths (70 per cent) and beetles (17 per cent), but also includes other insects such as termites, ants, wasps, mantids, bugs, flies and cockroaches (Churchill 2008). During summer, the period of maximum rainfall in the Pilbara, the species displays an increased preference for flying termites (Churchill 2008).

Distribution of the Pilbara Leaf-nosed Bat as modelled by DoE (2013b)

Figure 45

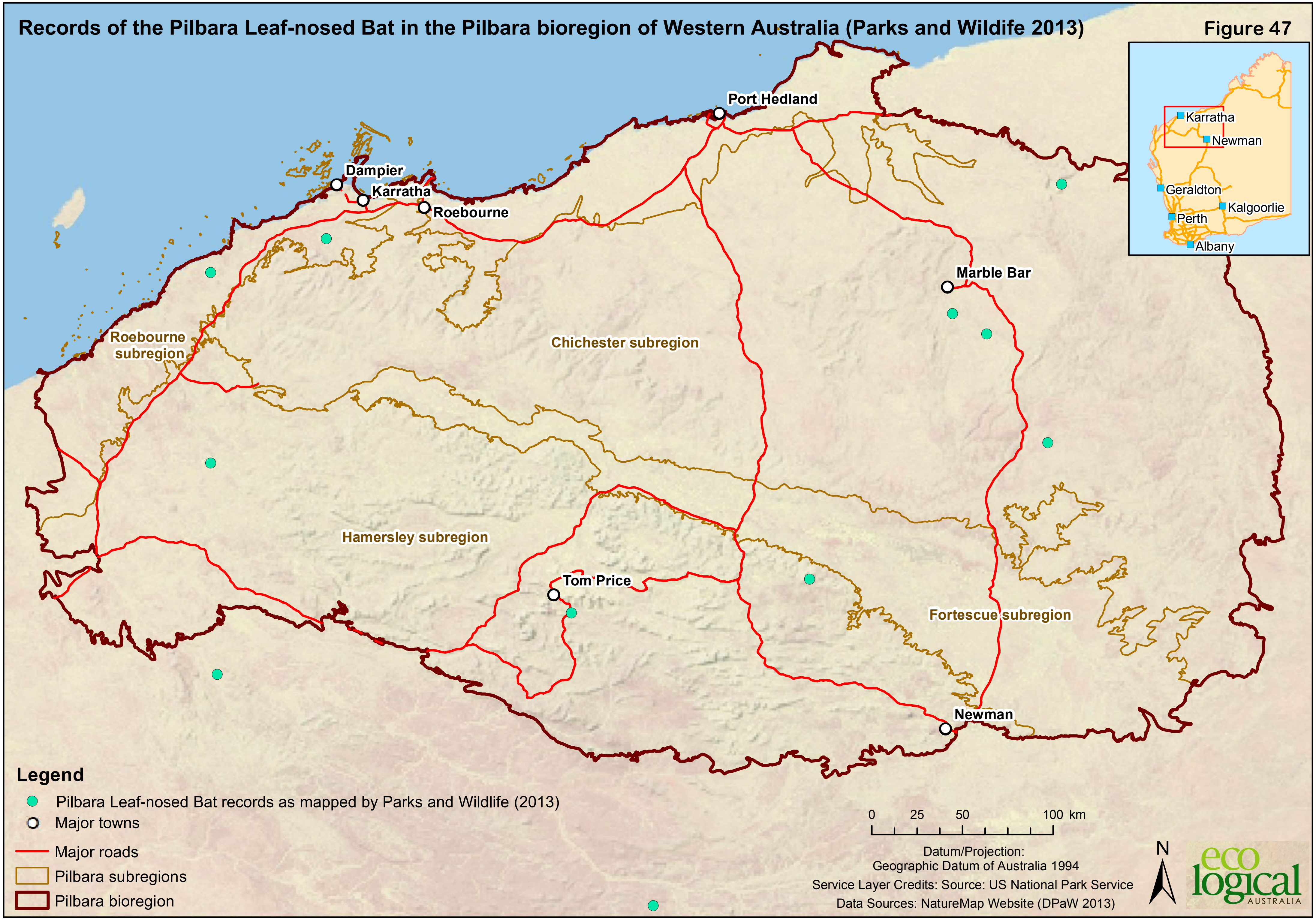
Datum/Projection:
Geographic Datum of Australia 1994
Service Layer Credits: Source: US National Park Service
Data Sources: SPRAT Database (DoE 2013b)

Legend

Pilbara Leaf-nosed Bat distribution as modelled by DoE (2013b)

Records of the Pilbara Leaf-nosed Bat in Western Australia (Parks and Wildlife 2013)

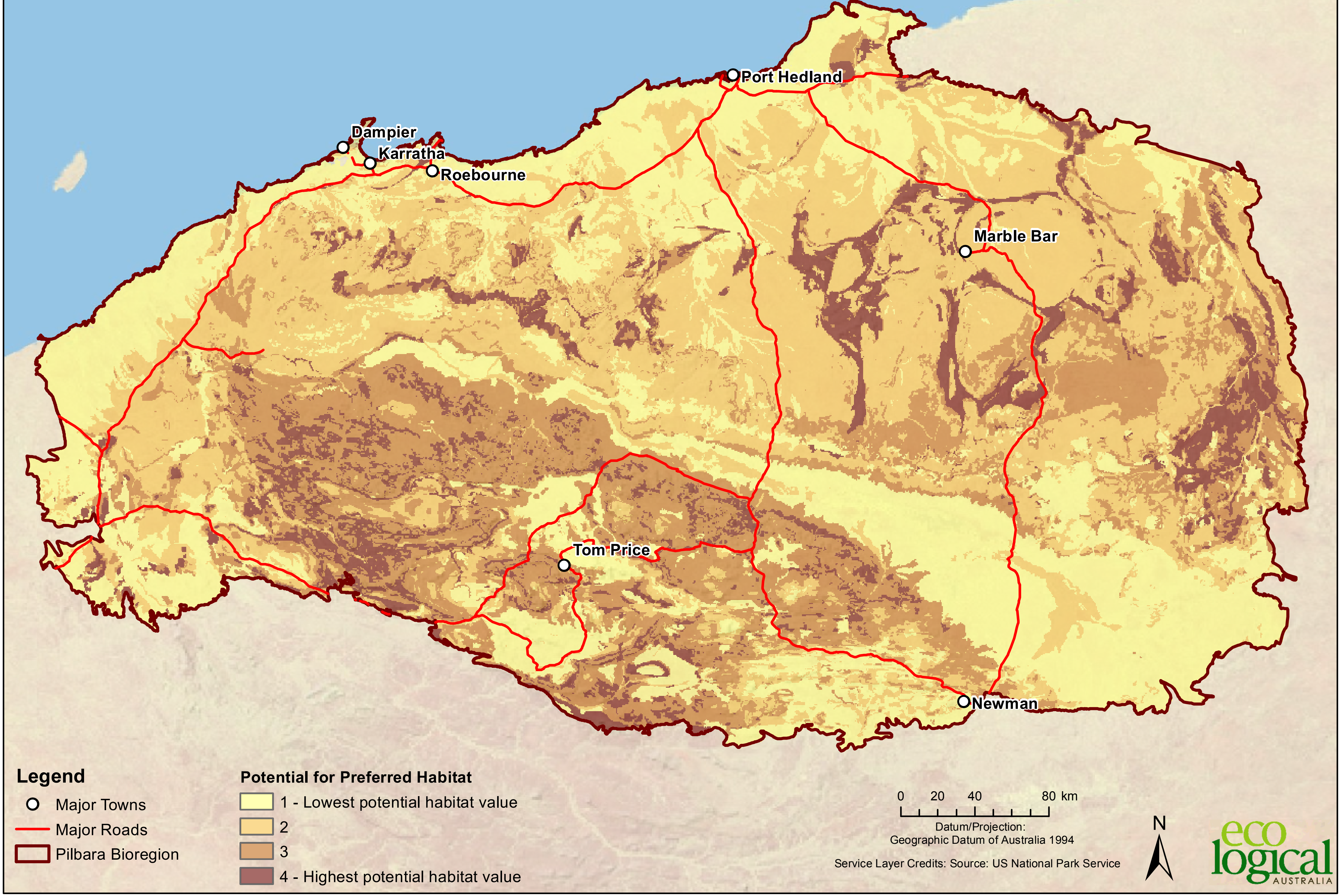
Figure 46

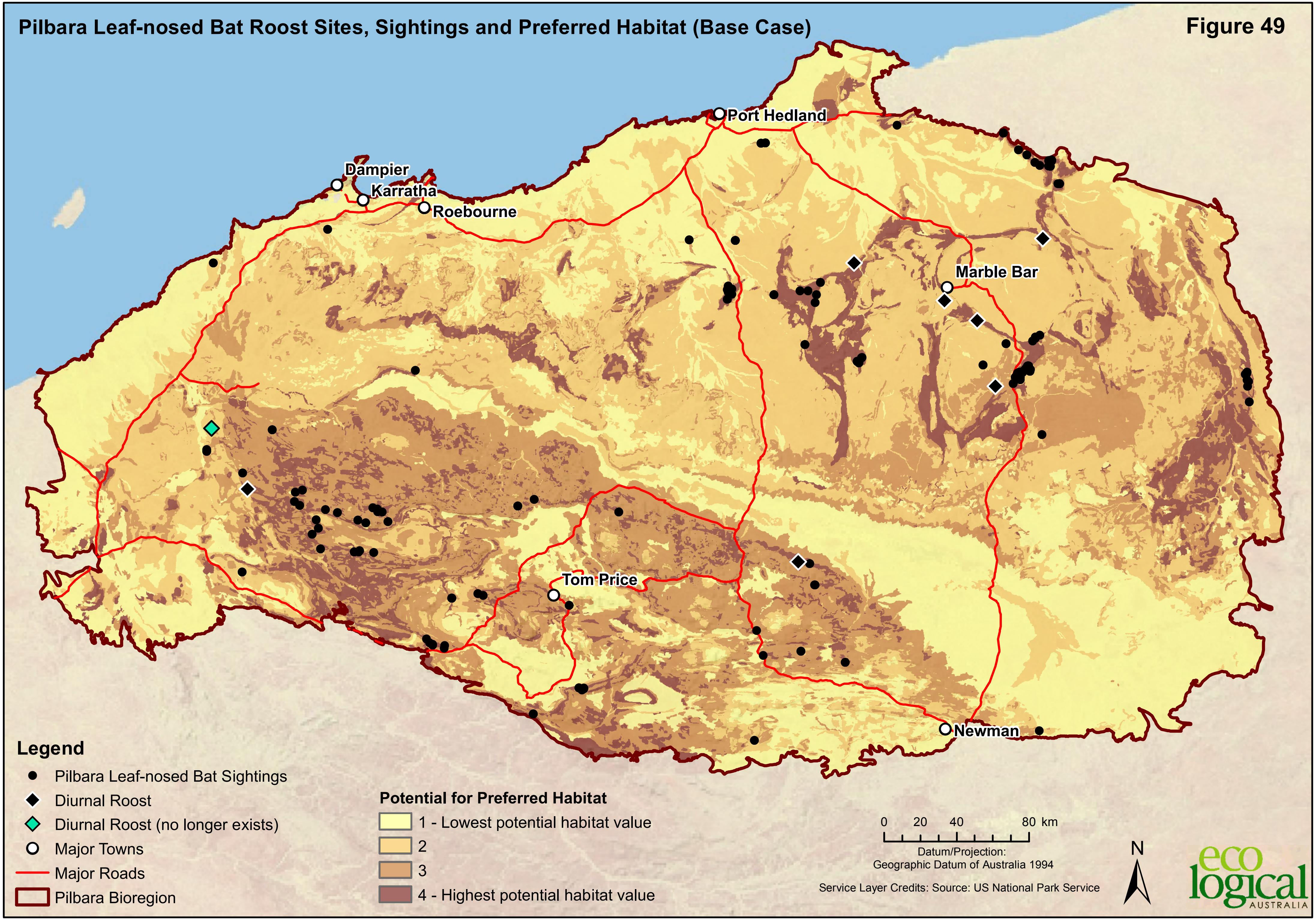


Records of the Pilbara Leaf-nosed Bat in the Pilbara bioregion of Western Australia (Parks and Wildlife 2013)

Figure 47

Pilbara Leaf-nosed Bat Preferred Habitat - Base Case **Figure 48**





Pilbara Leaf-nosed Bat Roost Sites, Sightings and Preferred Habitat (Base Case)
Figure 49
Port Hedland
Dampier
Karratha
Roebourne
Marble Bar
Tom Price
Newman
Legend
Pilbara Leaf-nosed Bat Sightings
Diurnal Roost
Diurnal Roost (no longer exists)
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
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6.3 METHODS

6.3.1 Base layers considered

The Pilbara Leaf-nosed Bat CIA considered relative probability of potential habitat (habitat suitability) modelled by ELA (2015), as summarised in **Table 30** 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 30**; **Figure 48**). Approximately two-thirds of the Pilbara bioregion was modelled as less than 30 per cent relative habitat suitability (Habitat Ranks 1 and 2; **Table 30**), with areas of higher habitat suitability concentrated within mesas and breakaways in the eastern Pilbara and Hamersley Ranges (**Table 30**; **Figure 48**).

This assessment also considered a dataset of confirmed diurnal roost locations provided by Dr Kyle Armstrong of Specialised Zoological. The dataset contained the location of nine known roosts, one of which was outside the Pilbara bioregion and was not considered. Of the remaining eight records, six were active roosts located in mines, one was an active roost in a natural cave and one was a mine roost that no longer exists. These eight diurnal roost locations are shown in **Figure 49**, along with all records used by ELA (2015) to generate the Pilbara Leaf-nosed Bat model of habitat suitability. Of the eight diurnal roosts located in the Pilbara bioregion, five were included by ELA (2015) in the development of the Pilbara Leaf-nosed Bat model of habitat suitability. The remaining three records were not available at the time of the ELA (2015) modelling.

The methods outlined in this section apply to the analysis conducted using the ELA (2015) model of Pilbara Leaf-nosed Bat habitat suitability. Brief additional discussion is provided in the results section on the proximity of the confirmed diurnal roost locations to existing iron ore mines, future third party iron ore mines and the Proposal.

Table 30: Classification and ranking applied to the Pilbara Leaf-nosed Bat habitat model

Model value	Habitat Rank	Habitat suitability	Area (ha) in Pilbara Leaf-nosed Bat habitat model
70-100%	4	Highest probability of potential habitat	1,623,283 (9%)
30-70%	3	↓	4,233,754 (24%)
10-30%	2		6,569,572 (37%)
0-10%	1	Lowest probability of potential habitat	5,372,377 (30%)

6.3.2 Identification of key threats

Known and perceived threats to the Pilbara Leaf-nosed Bat are identified in the SPRAT database (DoE 2013b; **Table 31**). A Pilbara Leaf-nosed Bat workshop facilitated by Parks and Wildlife in June 2013 also identified threats to the species (Sustainable Consulting 2013e) (**Table 31**).

Table 31: Key threats to the Pilbara Leaf-nosed Bat

Threat	Source	
	DoE (2013b)	Parks and Wildlife workshop
Habitat loss, or degradation (e.g. mining of natural roosts, mine collapse, flooding, and temperature and humidity changes)	✓	✓
Habitat fragmentation	-	✓
Degradation / reduction of foraging habitats	-	✓
Natural predators	✓	-
Mine development/site rehabilitation (including reworking of old mines)	✓	✓
Human disturbance/entry to roosts	✓	✓
Mortality from collision with vehicles	✓	✓
Disturbance of natural roosts, such as due to blasting in adjacent workings	✓	✓
Lowering of water table with associated impacts on roosts	-	✓
Cumulative effects	-	✓
Climate change	✓	-

Of the aforementioned threats, the following were excluded from the CIA:

- Loss of suitable roosts due to flooding of dis-used mines ï this is either a natural process and not likely to be significantly influenced by the Proposal, or due to mine site water management and is more amenable to being addressed through site-specific water management measures for relevant sites, rather than regional-scale assessment as part of the CIA.
- Loss (evacuation) of suitable roosts due to human entry of roosts and capture of bats, e.g. for scientific research or environmental monitoring programs ï this is unlikely to be significantly influenced by the Proposal and is instead a key threat that should be noted in the planning and implementation of scientific research and environmental monitoring programs.
- Loss of suitable roost habitat due to sealing/destroying of old mine shafts and horizontal adits during site rehabilitation, as well as potential for mortality if bats are present when the structure is sealed/destroyed ï this is more amenable to being addressed through site-specific rehabilitation and closure planning for relevant sites, rather than regional-scale assessment as part of the CIA.
- Natural predators ï this is a natural process and is not considered likely to be significantly influenced by the Proposal.
- Climate change ï 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.

The Cane Toad is not listed as a known or potential threat to the Pilbara Leaf-nosed Bat 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). Based on the aerial hunting behaviour and insectivorous diet of the Pilbara Leaf-nosed Bat (Section 6.2.7), this species is considered unlikely to prey on the Cane Toad, and therefore unlikely to ingest Cane Toad toxin. Therefore, the predicted future establishment of the Cane Toad in the Pilbara is considered unlikely to result in a significant negative impact to the Pilbara Leaf-nosed Bat. Several Pilbara fauna species that potentially prey on the Pilbara Leaf-nosed Bat (such as the Pilbara Olive Python; DoE 2013b) are also known to prey on frogs and therefore potentially Cane Toads. Therefore, the future establishment of the Cane Toad in the Pilbara bioregion may result in a net reduction in predation by native species on the Pilbara Leaf-nosed Bat.

The potential effects of noise, light and vibration on the Pilbara Leaf-nosed Bat were also considered for inclusion in the CIA as, while not listed as key threats to the species (but may be inferred in some cases; for example, disturbance of natural roosts due to blasting in adjacent workings is likely due at least in part to vibration, or noise), 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 Pilbara Leaf-nosed Bat, the extent to which the species may be affected by noise, light, or vibration 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, light and vibration were not applied to the Pilbara Leaf-nosed Bat in the CIA. Limitations associated with noise and light are discussed in Section 8.1.2.

In the case of vibration, levels of vibration within caves can be affected by activities such as road works and clearing; however, research shows that bats are not always flushed from the caves as a result (Young et al. 2014). The DoE (2013b) states that "blasting in any structure is likely to cause evacuation of the Pilbara Leaf-nosed Bat" from its roost; however, it is not stated whether such evacuation would be as a result of vibration, noise, or some other factor. A recent comprehensive trial conducted by Rio Tinto suggests blasting is not likely to be a significant source of disturbance to the Pilbara Leaf-nosed Bat if appropriate measures are in place (including a buffer if required). The trial was completed in October 2013 and documented the behavioural response of the Pilbara Leaf-nosed Bat to blasting and vibration disturbance at its proposed Koodaideri iron ore mine, located approximately 110 kilometres west-north-west of Newman (Biota 2013; Rio Tinto 2013). The trial involved the use of explosive charges of incrementally-increasing intensity and proximity to an underground roost located at the proposed Koodaideri mining area, which supported a Pilbara Leaf-nosed Bat colony comprising over 430 individuals. Results of the trial were related to measures of behavioural response in the resident bats during daylight hours, when the Pilbara Leaf-nosed Bat is largely quiescent. The nominal threshold vibration level of 10 millimetres per second peak particle velocity adopted in the trial (based primarily on available standards for humans) was exceeded at the roost by one of the six trial blasts; however, there was no evidence that any of the blasts significantly disturbed the colony as none of the blasts resulted in most, or all, bats taking flight within the underground roost (Biota 2013; Rio Tinto 2013). On this basis, vibration was excluded from the CIA.

6.3.3 Potential impacts applied

In consideration of the key threats identified and the available data (Section 6.3.2), the potential impacts applied in the Pilbara Leaf-nosed Bat CIA were:

- removal of habitat;
- mortality from collision with vehicles;

- degradation of habitat as a result of change in hydrology/hydrogeology.

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 6.3.4 to 6.3.6). 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.

6.3.4 Removal of habitat

The removal or loss of suitable roosting habitat is a key threat to the Pilbara Leaf-nosed Bat and includes natural roosts, such as underground caves, as well as artificial roosts, such as dis-used mine shafts and horizontal adits. Loss of roosting habitat can occur in a variety of ways, such as collapse or flooding of dis-used mines, as well as mining activities such as open cutting of underground mines, exploration drilling and blasting. It can result in mortality of individuals present when the roost collapses, or is sealed/destroyed, or due to heat and water loss by individuals that attempt to locate alternative roosting habitat, or by individuals that relocate to roosting habitat with less suitable microclimatic conditions. The potential loss of foraging habitat is also a threat to the Pilbara Leaf-nosed Bat, albeit one that is considered less significant than loss of suitable roosting habitat as the species can forage in any habitat provided insect biomass is sufficiently high (McKenzie and Bullen 2013). 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 32**).

Table 32: Potential impacts of removal of potential Pilbara Leaf-nosed Bat 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.

6.3.5 Mortality from collision with vehicles

The Pilbara Leaf-nosed Bat is often observed foraging along roads at night (Churchill 2008). Its foraging height of less than three metres makes it vulnerable to collision with cars and many records of the species are of road kills (DoE 2013b). The species displays a curiosity for light sources (DoE 2013b) and may be attracted to head lights (Armstrong 2013). Intermittent incidences of mortality from collision with vehicles are unlikely to significantly affect the population size of the Pilbara Leaf-nosed Bat; however, an increase in the number of roads or a larger volume of traffic may contribute to local decline in areas near roosting or foraging sites (DoE 2013b).

There is a lack of data for roadkill rates for the Pilbara Leaf-nosed Bat; spatio-temporal factors that may drive the incidence of roadkill (such as the presence of roosts adjacent to roads/rail, traffic densities, traffic speed, or Pilbara Leaf-nosed Bat densities) have not been documented. However, the probability of a collision resulting in roadkill is likely to increase in locations closer to roads or rail lines. Collisions were considered to potentially affect Pilbara Leaf-nosed Bat habitat suitability at a distance of up to

500 metres (**Table 33**). 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 33: Potential impacts to the Pilbara Leaf-nosed Bat from collision with vehicles

Proximity to roads/rail	Level of potential impact	Confidence in level of potential impact	Assumptions
<500 m	Low (20%)	Medium. There are some anecdotal accounts of this species being attracted to road clearings, and attracted to artificial lighting, potentially increasing susceptibility to vehicle strike (Armstrong 2013; DoE 2013b).	Habitat suitability is assumed to decrease as the distance to roads/rail decreases.

6.3.6 Change in hydrology/hydrogeology

Hydrological change may affect the Pilbara Leaf-nosed Bat through reduced available surface water, which supports the speciesô prey (insects) and most likely also is a source of drinking water. The occurrence of pools of water is a critical component of the Pilbara Leaf-nosed Batôs foraging habitat (Armstrong 2001). There is no documented information on the importance of surface drinking water for the Pilbara Leaf-nosed Bat; however, anecdotal accounts from field observations suggest that this species requires surface water for drinking, and water sources in proximity to day roost caves are therefore likely to be important (Armstrong 2013). Data are not available on the maximum distance that the Pilbara Leaf-nosed Bat will fly from its day roost cave before it requires a drink of water; however, based on a foraging range of 10 kilometres from a roost, the species is likely to require at least one drinking water source within this range. Water sources closer to the roost may be more critical than water sources further away. Surface water pools that provide drinking and feeding habitat for the Pilbara Leaf-nosed Bat may be derived from surface runoff or spring seepage following rainfall, or may be groundwater-fed. Therefore, changes to both surface water and groundwater regimes may alter the suitability of foraging habitat for the species.

Changes to groundwater regimes may also affect the speciesô roosting habitat if changes to the groundwater table affect the humidity of the roost. Armstrong (2001) suggests the presence of seeps or groundwater pools is the most important factor in determining roost suitability; groundwater is considered important to maintain stable temperature and high humidity regimes of roost caves, and Pilbara Leaf-nosed Bat roosts are often associated with groundwater seeps (Armstrong 2001; DoE 2013b). Reduced groundwater supply, e.g. due to mine pit dewatering, may reduce roost humidity, potentially to a point where the roost is no longer inhabitable by the species (DoE 2013b).

Potential impacts to the Pilbara Leaf-nosed Bat were estimated based on groundwater and surface water change potential modelled by BHP Billiton Iron Ore (2015) (**Table 34** and **Table 35**; **Appendix A**).

Table 34: Potential impacts to the Pilbara Leaf-nosed Bat from groundwater drawdown

Groundwater change potential	Level of potential impact	Confidence in level of potential impact	Assumptions
Medium to High	Low (20%)	Medium. Groundwater is	Dewatering activities can reduce roost

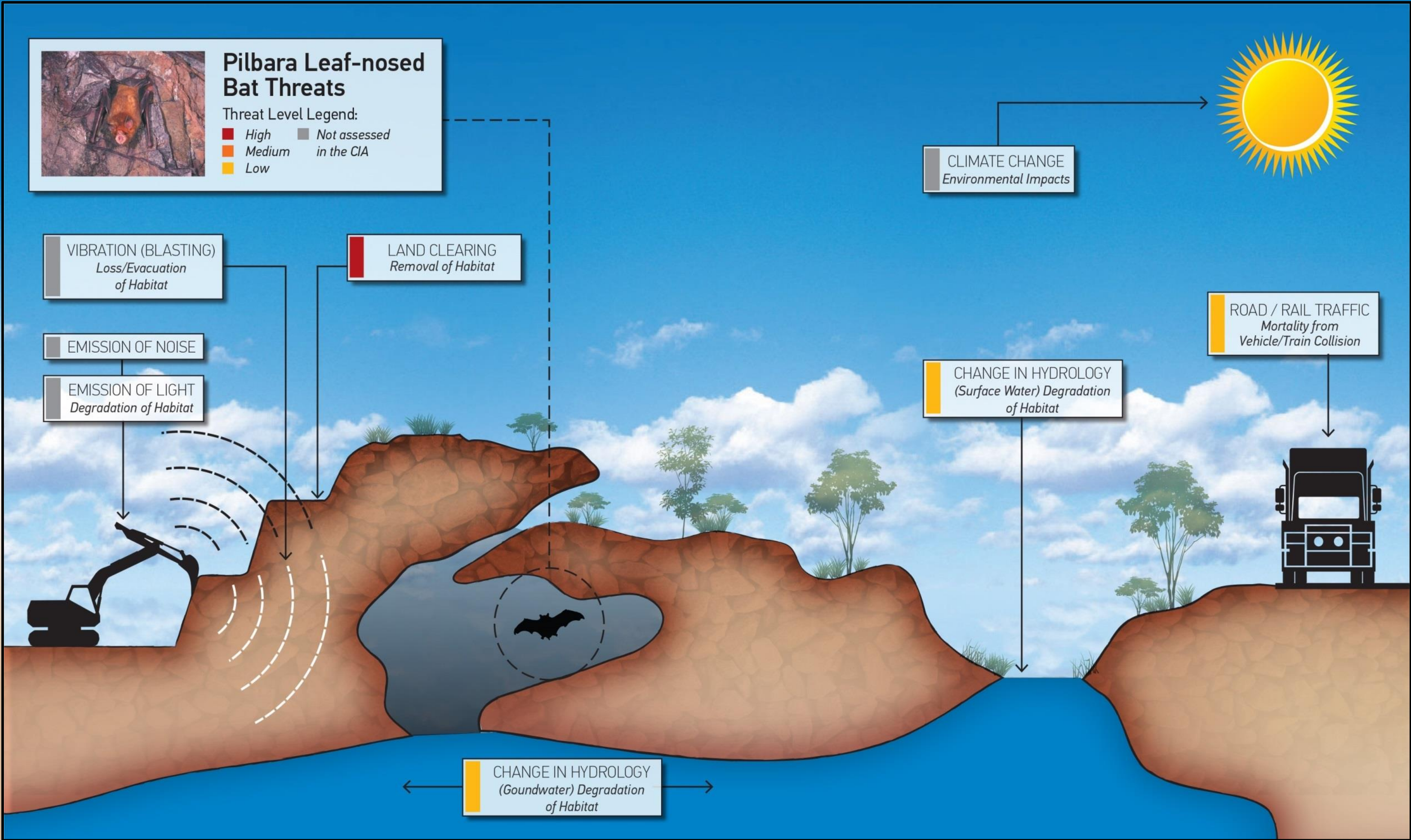
Groundwater change potential	Level of potential impact	Confidence in level of potential impact	Assumptions
		considered a factor in helping to maintain stable temperature and high humidity regimes of roost caves (Armstrong 2001).	cave humidity. At least some of the surface water bodies within the affected area are sustained wholly or partly by aquifer discharge.

Table 35: Potential impacts to the Pilbara Leaf-nosed Bat from reduced surface water availability

Surface water change potential	Impact	Confidence in level of impact	Assumptions
Medium to High	Low (20%)	Medium. The occurrence of pools of water is a critical component of the Pilbara Leaf-nosed Bat's foraging habitat (Armstrong 2001). Documented foraging habitats in the Pilbara all include some component of available surface water, e.g. creeks, watercourses, or pools (DoE 2013b).	Surface water is considered important for feeding and drinking.

6.4 PILBARA LEAF-NOSED BAT CONCEPTUAL DIAGRAM

A conceptual diagram was prepared to depict the Pilbara Leaf-nosed Bat 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 50**). The conceptual diagram shows the potential impacts applied in the CIA and their level of potential impact (High, Medium or Low; Section 6.3). The conceptual diagram also shows some of the potential impacts considered, but not applied in the CIA, such as noise and light.



Pilbara Leaf-nosed Bat conceptual diagram

Figure 50

6.5 RESULTS

Results of the CIA for Pilbara Leaf-nosed Bat habitat suitability are provided in **Table 36** and **Table 37**. **Table 36** provides the area affected by potential impacts associated with existing impacts, future third party mines, and the Full Development Scenario. **Table 37** 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 Pilbara Leaf-nosed Bat habitat suitability in Scenario 1 to Scenario 3 is provided in **Figure 51** to **Figure 53**. 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 54**. The marginal change from one scenario to another, and from the base case to Scenario 1, is provided in **Figure 55** to **Figure 57**.

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 úpgradedô 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).

Figures showing the eight confirmed diurnal roosts within the Pilbara bioregion in relation to existing BHP Billiton Iron Ore and third party mines, future third party mines and the Full Development Scenario are provided as **Figure 58**, **Figure 59** and **Figure 60** respectively.

6.5.1 Existing impacts

The potential effect of existing impacts on Pilbara Leaf-nosed Bat habitat suitability relative to the base case was minor as a percentage of the total area of the Pilbara bioregion (**Figure 48**, **Figure 51**, **Figure 54** and **Figure 55**). There was a slight decrease in the extent of Habitat Rank 3 (46,000 hectares; less than one per cent) and Habitat Rank 4 (28,000 hectares; less than two per cent) and a slight increase in the extent of Habitat Ranks 1 and 2 (less than one per cent; **Table 36**). Overall, a total of approximately 119,000 hectares decreased in habitat suitability as a result of existing impacts, the majority of which (approximately 86,000 hectares) decreased by one Habitat Rank (**Table 37**).

None of the eight confirmed diurnal roosts within the Pilbara bioregion are located near the existing BHP Billiton Iron Ore and third party mines considered in the CIA (**Figure 58**).

6.5.2 Future third party mines

The potential effect of future third party mines on Pilbara Leaf-nosed Bat habitat suitability was minor as a percentage of the total area of the Pilbara bioregion (**Figure 48**, **Figure 52**, **Figure 54** and **Figure 56**). There was a slight decrease in the extent of Habitat Ranks 3 and 4 (less than one per cent) and a slight increase in the extent of Habitat Ranks 1 and 2 (less than one per cent) (**Table 36**). Overall, a total of approximately 24,000 hectares decreased in habitat suitability as a result of future third party mines, the majority of which (16,500 hectares) decreased by two Habitat Ranks (**Table 37**).

There was a potential slight positive (beneficial) effect of future third party mines in some areas, with a total of approximately 81 hectares increasing in habitat suitability by one Habitat Rank (**Table 37**). The potential positive effect in these areas was associated with a reduction in the extent of impacts associated with ecohydrological change potential mapped by BHP Billiton Iron Ore (2015).

Of the eight confirmed diurnal roosts within the Pilbara bioregion, only the Koodaideri roost is located near one of the proposed future third party iron ore mines considered in the CIA (**Figure 59**). Identification and management of the potential impacts to this roost are reported on in detail in the Public Environmental Review document and Response to Submissions document for the Koodaideri Iron Ore Mine and Infrastructure Project (State Assessment Number 1933; EPBC Act Reference Number 2012/6422).

6.5.3 Full Development Scenario

The potential effect of the Full Development Scenario on Pilbara Leaf-nosed Bat habitat suitability was minor as a percentage of the total area of the Pilbara bioregion (**Figure 48**, **Figure 53**, **Figure 54** and **Figure 57**). There was a slight decrease in the extent of Habitat Ranks 2, 3 and 4 (less than two per cent) and a slight increase in the extent of Habitat Rank 1 (less than two per cent) (**Table 36**). Overall, a total of approximately 85,000 hectares decreased in habitat suitability as a result of the Full Development Scenario, the majority of which (57,000 hectares) decreased by two Habitat Ranks (**Table 37**).

There was a potential slight positive (beneficial) effect of the Full Development Scenario in some areas, with approximately 4,000 hectares increasing in habitat suitability by one Habitat Rank (**Figure 57**; **Table 37**). This potential positive effect was associated with mine closure in Scenario 3, whereby some of the potential impacts to the Pilbara Leaf-nosed Bat were not applied to closed mines and infrastructure, along with changes in the extent of impacts associated with ecohydrological change potential mapped by BHP Billiton Iron Ore (2015).

None of the eight confirmed diurnal roosts within the Pilbara bioregion are located near the Proposal mining operations (**Figure 60**).

6.5.4 Potential cumulative impacts

The potential cumulative impact to Pilbara Leaf-nosed Bat habitat suitability was a decrease in the extent of the most suitable habitat (Habitat Rank 4) of approximately 39,000 hectares (two per cent of the modelled extent in the base case), mostly as a result of existing impacts. The extent of Habitat Rank 3 decreased by approximately 122,000 hectares (three per cent of the modelled extent in the base case), mostly as a result of the Full Development Scenario. These Habitat Ranks were downgraded into lower ranked habitat; therefore the extent of Habitat Rank 1 increased; there was negligible change in the extent of Habitat Rank 2 (**Table 36** and **Table 37**).

Table 36: Area of potential change in Pilbara Leaf-nosed Bat habitat suitability

Habitat Rank	Base case	Area (ha) of potential change*			Potential cumulative impact**
		Existing impacts	Future third party mines	Full Development Scenario	
1	5,363,584	59,511 (1%)	21,780 (<1%)	80,595 (2%)	161,886 (3%)
2	6,569,440	14,455 (<1%)	251 (<1%)	-15,271 (<-1%)	-565 (<-1%)
3	4,233,653	-46,290 (-1%)	-17,030 (<-1%)	-59,048 (-2%)	-122,368 (-3%)
4	1,623,238	-27,676 (-2%)	-5,001 (<-1%)	-6,275 (<-1%)	-38,952 (-2%)

*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 37: Area of habitat that increased or decreased by one, two or three ranks, or that did not change between scenarios for the Pilbara Leaf-nosed Bat 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%)	81 (<1%)	4,283 (<1%)
0	17,670,501 (99%)	17,765,471 (~100%)	17,700,431 (~100%)
-1	85,926 (<1%)	3,846 (<1%)	20,842 (<1%)
-2	25,236 (<1%)	16,501 (<1%)	57,444 (<1%)

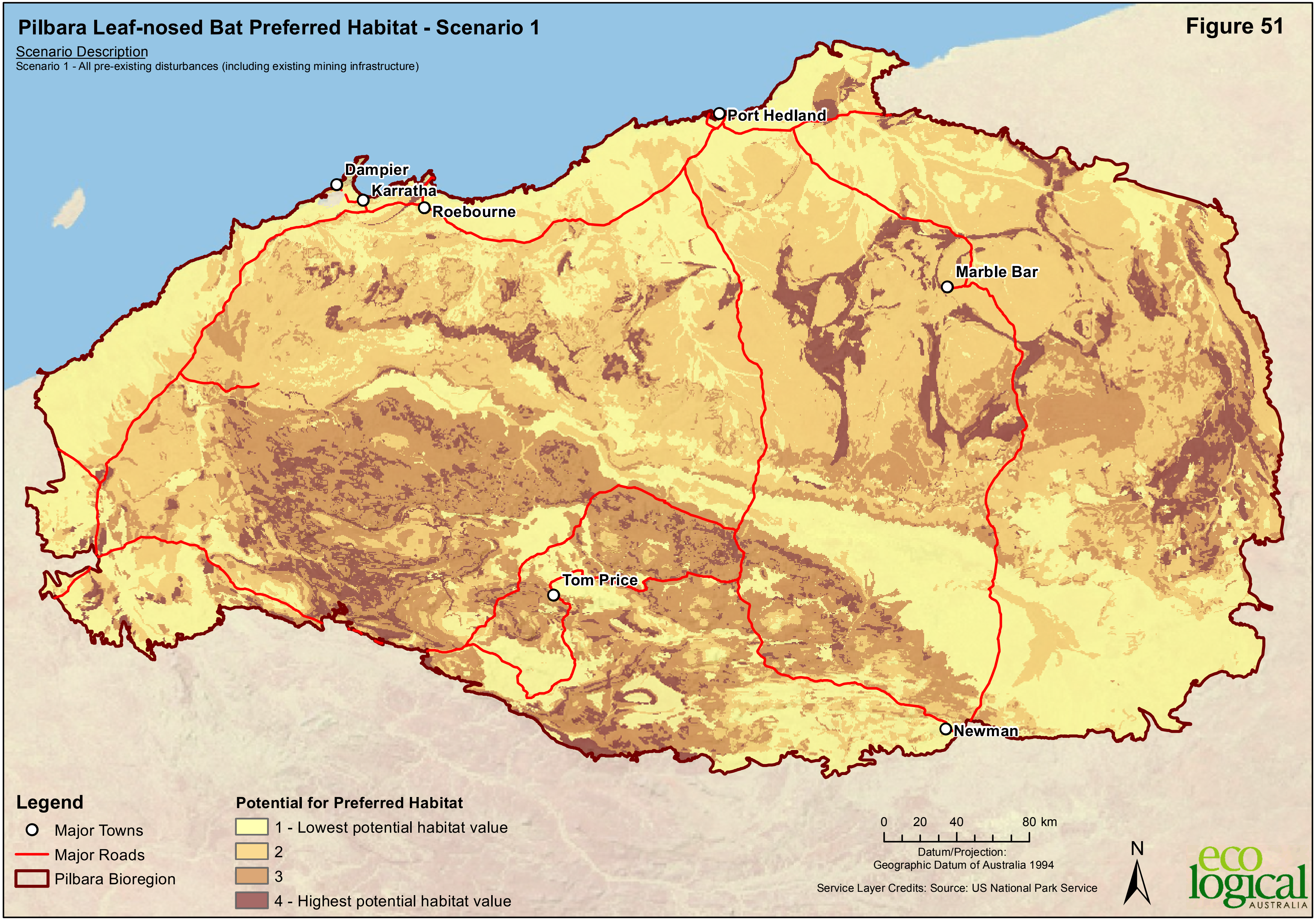
Change in Habitat Rank	Area (ha) of potential change		
	Existing impacts (Base Case to Scenario 1)	Future third party mines (Scenario 1 to Scenario 2)	Full Development Scenario (Scenario 2 to Scenario 3)
-3	8,251 (<1%)	4,015 (<1%)	6,915 (<1%)

Pilbara Leaf-nosed Bat Preferred Habitat - Scenario 1

Figure 51

Scenario Description

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

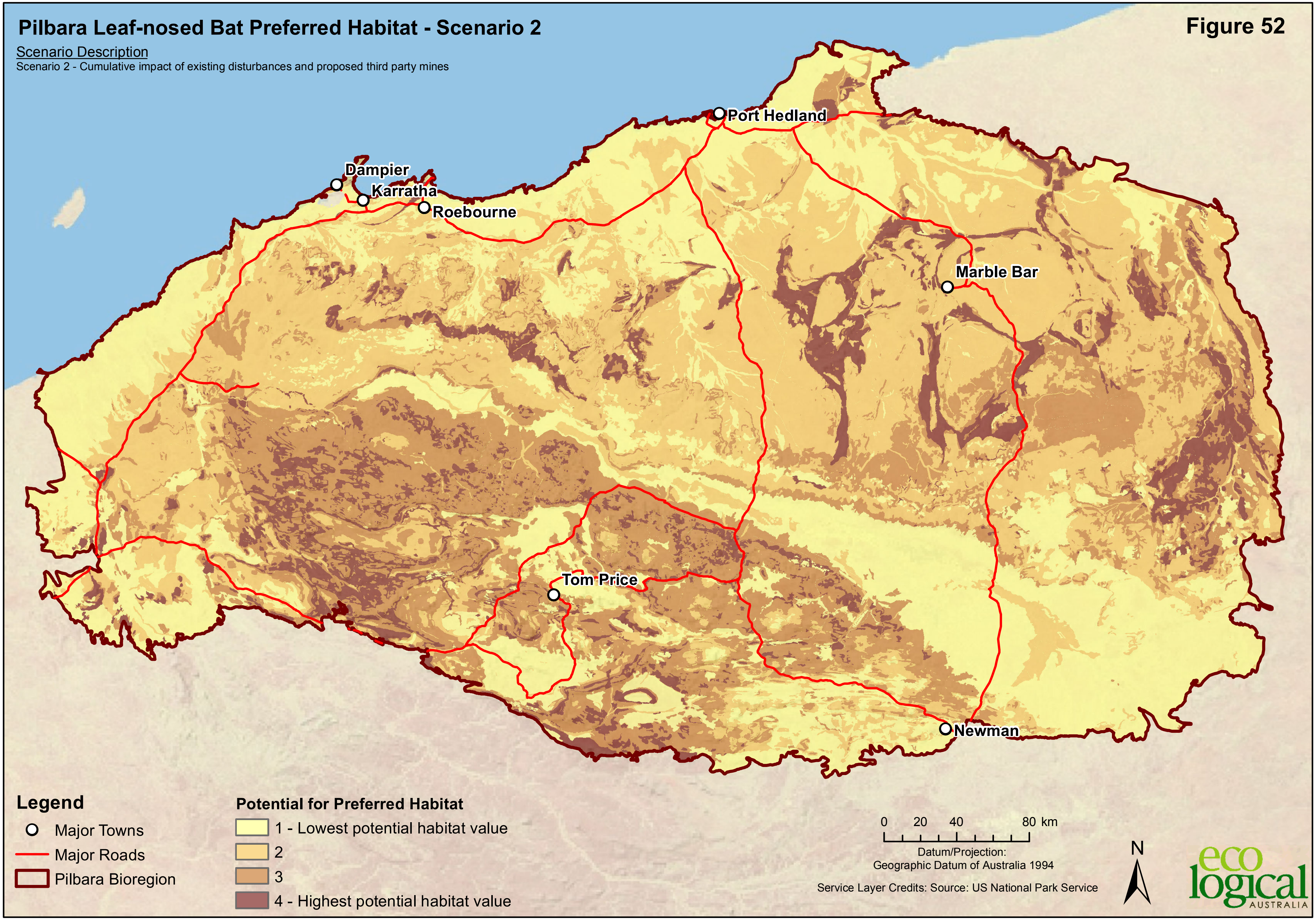


Pilbara Leaf-nosed Bat Preferred Habitat - Scenario 2

Figure 52

Scenario Description

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

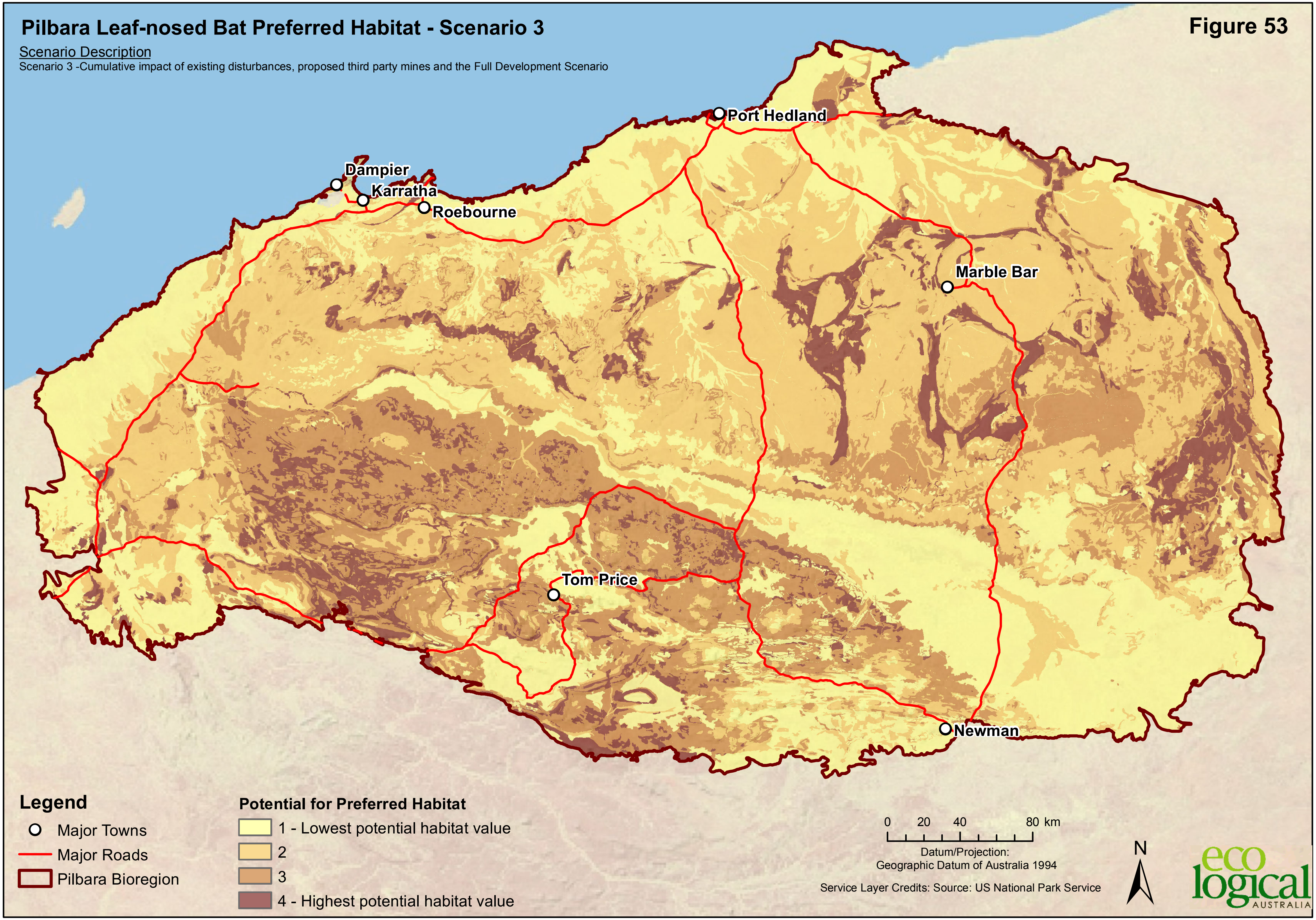


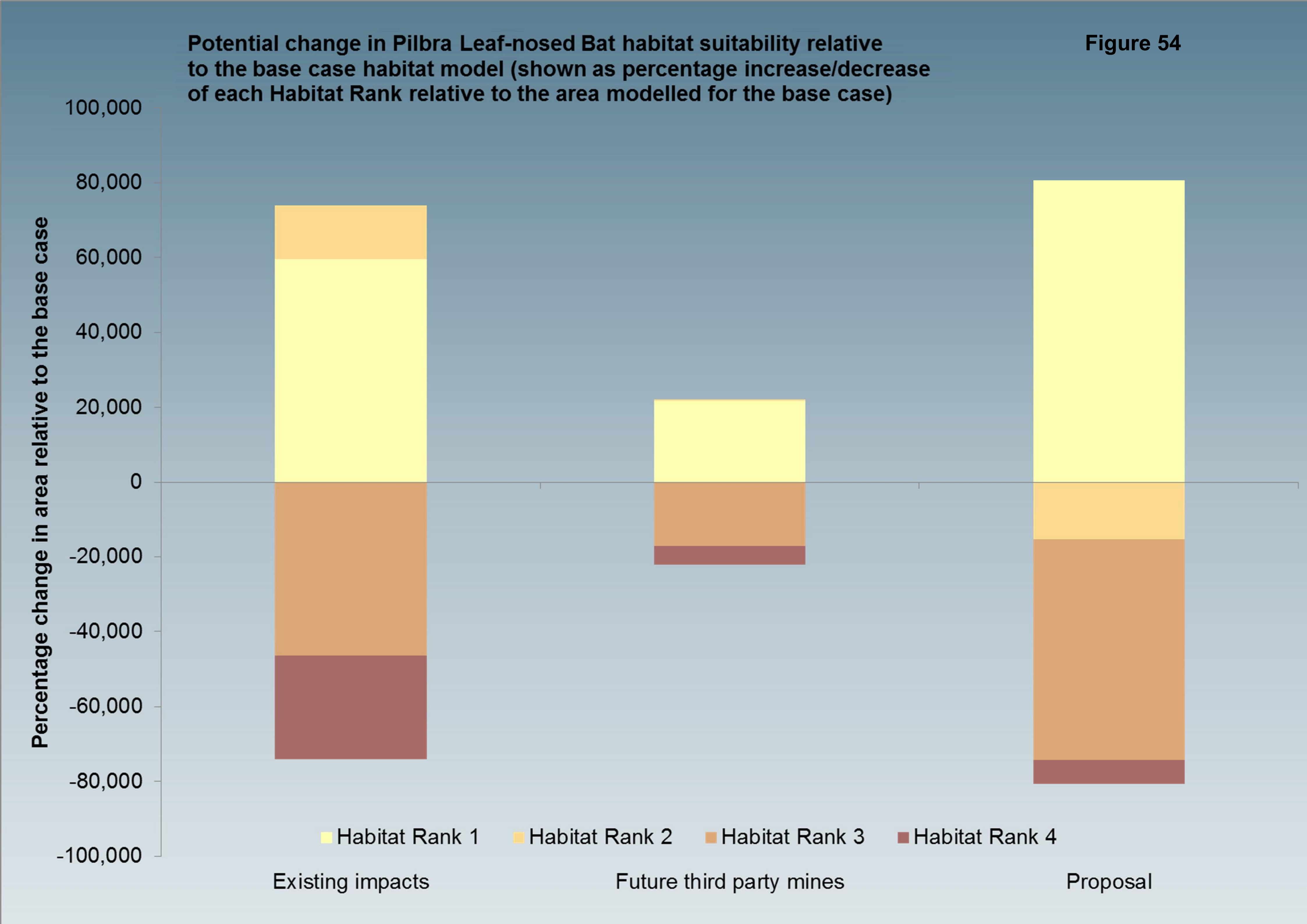
Pilbara Leaf-nosed Bat Preferred Habitat - Scenario 3

Figure 53

Scenario Description

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



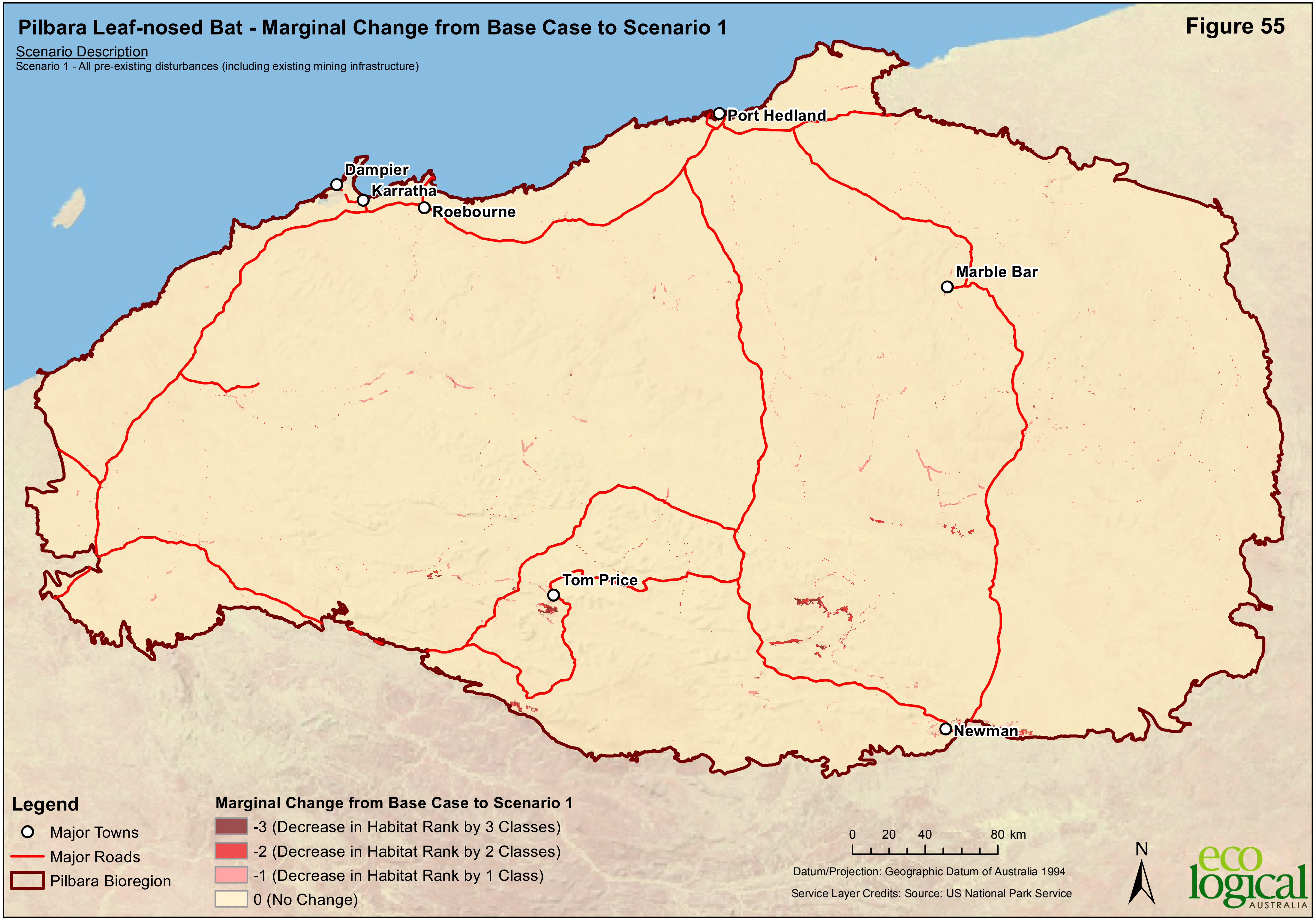

Potential change in Pilbra Leaf-nosed Bat habitat suitability relative to the base case habitat model (shown as percentage increase/decrease of each Habitat Rank relative to the area modelled for the base case)
Figure 54
Percentage change in area relative to the base case
100,000
80,000
60,000
40,000
20,000
0
-20,000
-40,000
-60,000
-80,000
-100,000
Habitat Rank 1
Habitat Rank 2
Habitat Rank 3
Habitat Rank 4
Existing impacts
Future third party mines
Proposal

Pilbara Leaf-nosed Bat - Marginal Change from Base Case to Scenario 1

Figure 55

Scenario Description

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



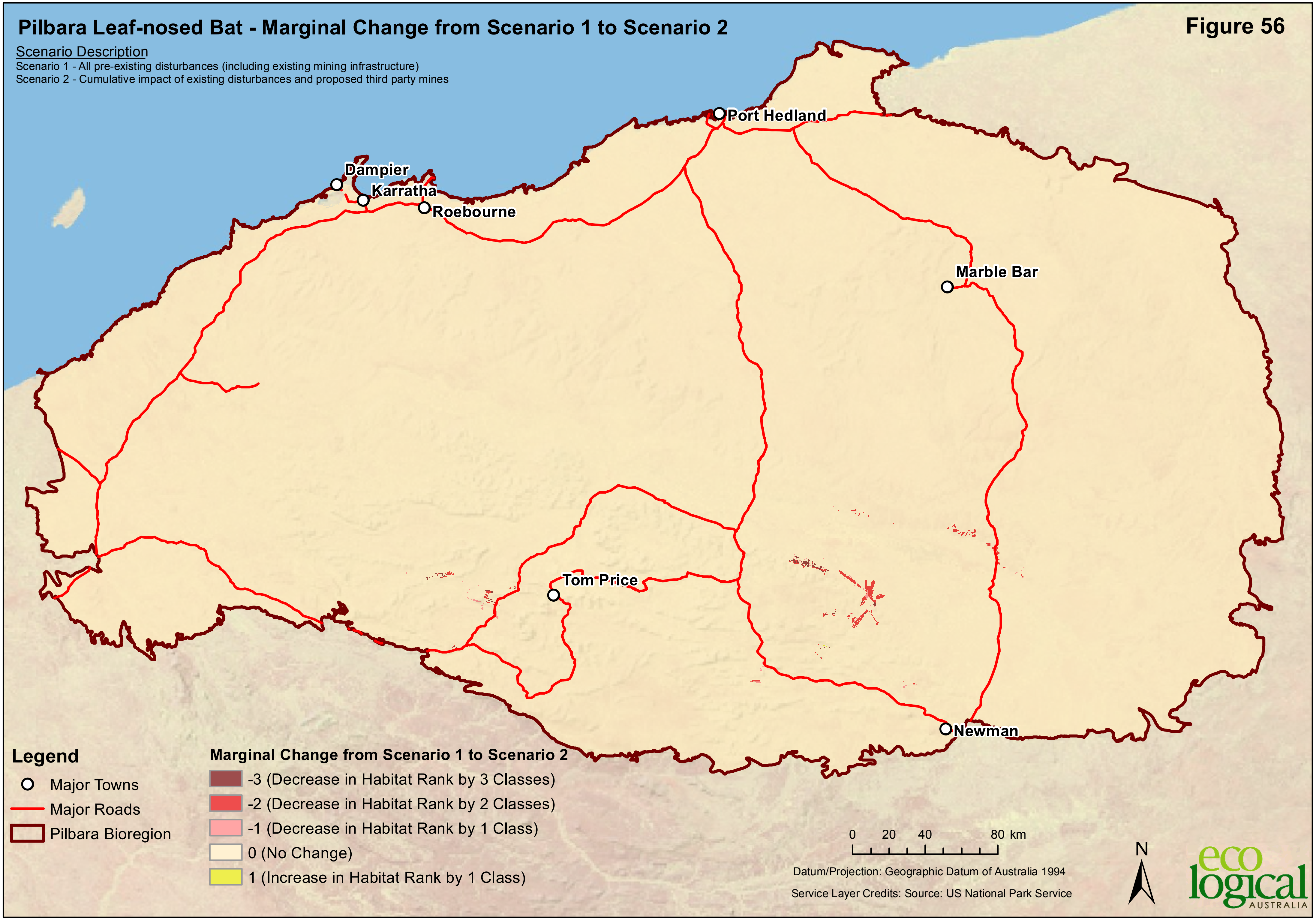
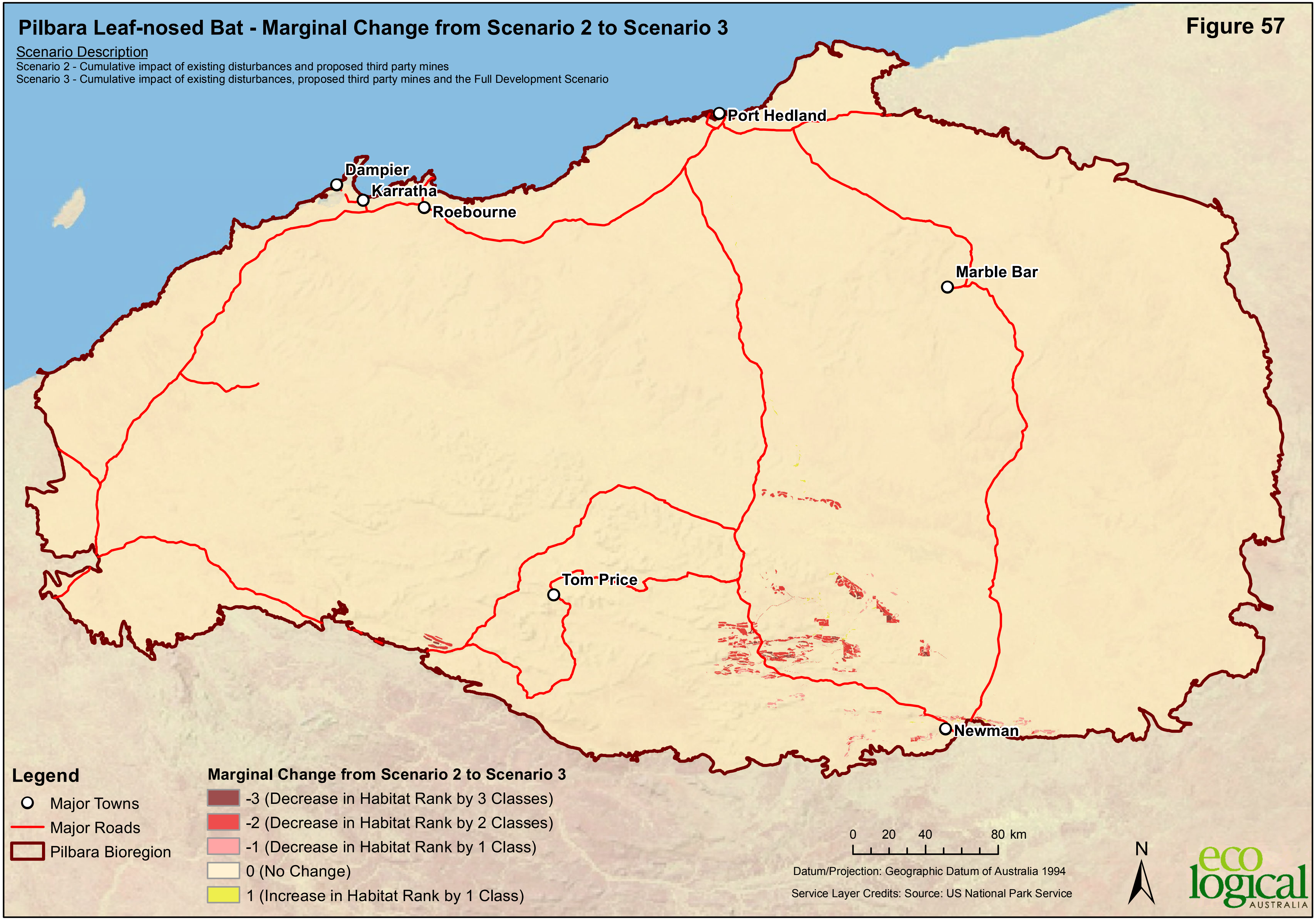


Figure 56

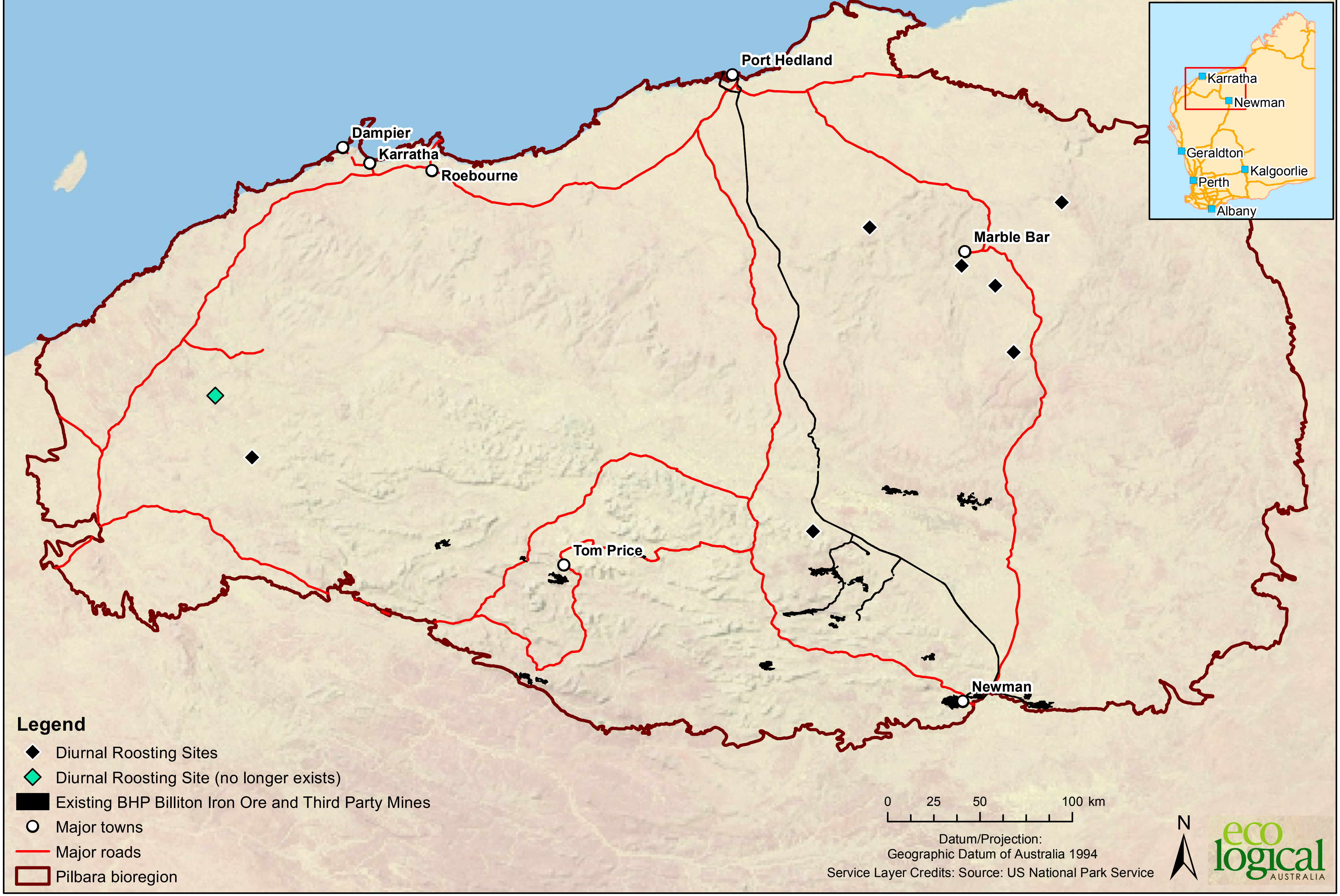
Pilbara Leaf-nosed Bat - Marginal Change from Scenario 1 to Scenario 2



Pilbara Leaf-nosed Bat - Marginal Change from Scenario 2 to Scenario 3
Figure 57
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
-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)
1 (Increase in Habitat Rank by 1 Class)
0 20 40 80 km
N
Datum/Projection: Geographic Datum of Australia 1994
Service Layer Credits: Source: US National Park Service
eco logical AUSTRALIA

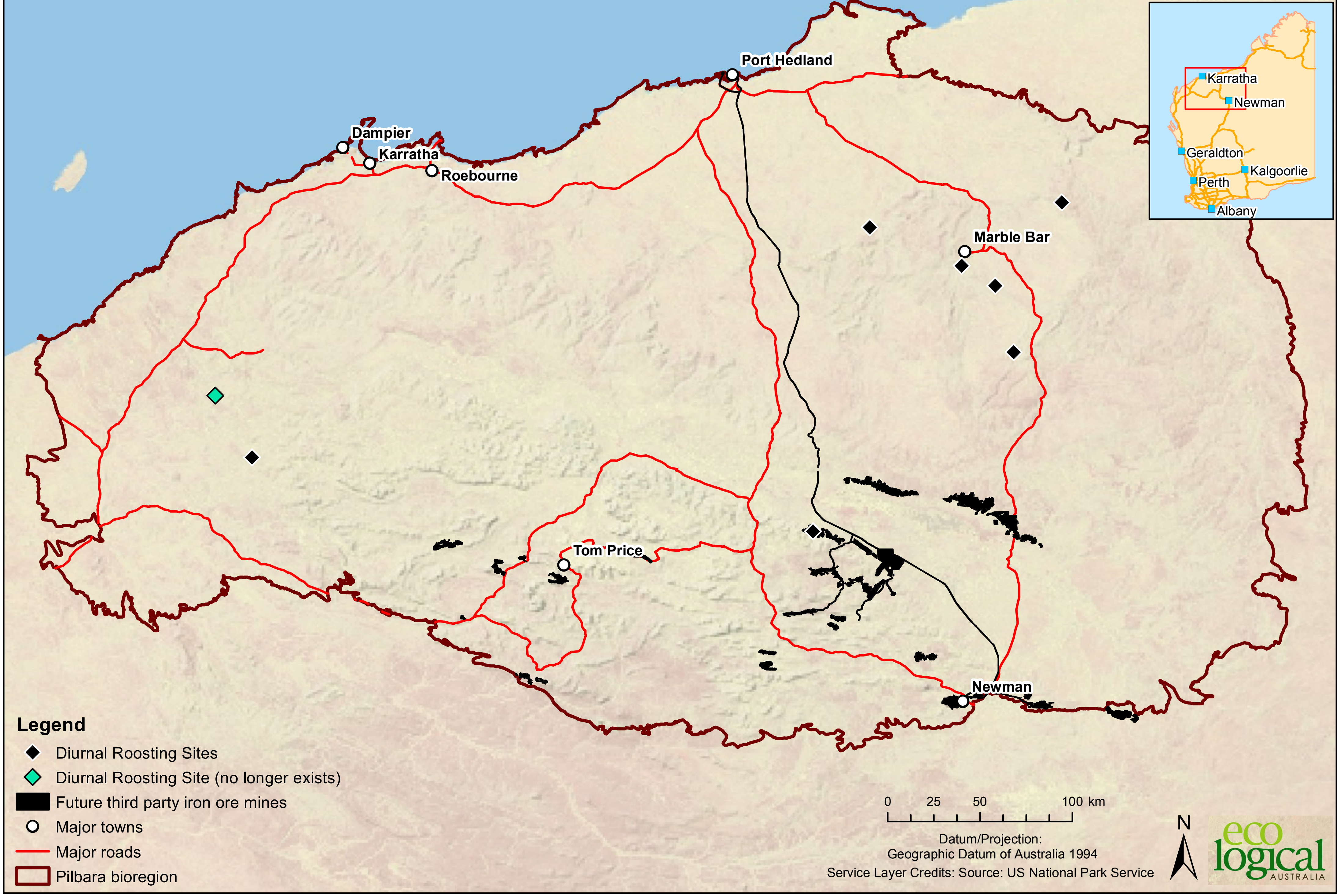
Pilbara Leaf-nosed Bat Diurnal Roost Sites - Existing BHP Billiton Iron Ore and Third Party Mines

Figure 58



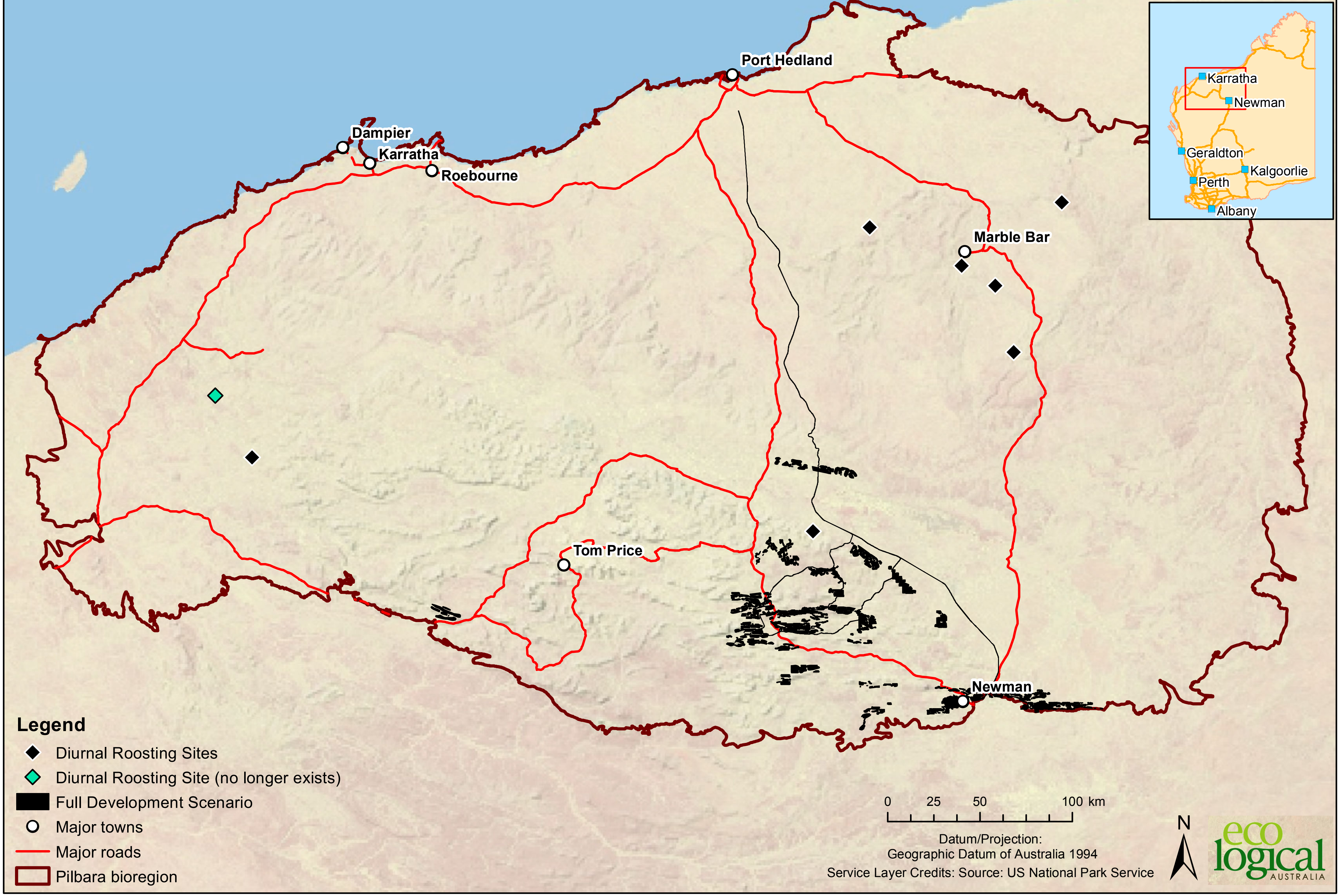
Pilbara Leaf-nosed Bat Diurnal Roost Sites - Future Third Party Mines

Figure 59



Pilbara Leaf-nosed Bat Diurnal Roost Sites - Full Development Scenario

Figure 60



7 Pilbara Olive Python

7.1 OVERVIEW

This section provides background information relevant to the assessment of potential cumulative impacts to the Pilbara Olive Python from the Proposal. It provides an overview of key ecological characteristics of the Pilbara Olive Python, 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, including the outcomes of a workshop facilitated by Parks and Wildlife in December 2013. The workshop sought specifically to identify key threats to the Pilbara Olive Python and identify knowledge gaps and research priorities (Ellis 2013; Heidrich 2013b; Pearson 2013a, 2013b; Spencer and Pearson 2013; Sustainable Consulting 2013g, 2013h; van Leeuwen 2013d).

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 Pilbara Olive Python is provided in Section 7.3 and was based on a review of the best available literature on the likely susceptibility of the Pilbara Olive Python to each impact, along with an understanding of the speciesô key ecological characteristics as outlined in Section 7.2. Some of the identified threats and potential impacts were excluded from the CIA, the rationale for which is provided in Section 7.3.2.

7.2 SPECIES SYNOPSIS

7.2.1 Description

The Pilbara Olive Python is a large, terrestrial snake in the Boidae family. The species can grow to 4.5 metres in length, but is more commonly encountered at 2.5 metres (Pearson 2003). Two subspecies of the Olive Python are recognised. The nominate subspecies (*L. olivaceus olivaceus)* occurs from the Kimberley across northern Australia to the western side of Cape York and south to approximately Longreach in Queensland (Cogger 2000). The Pilbara subspecies (*L. olivaceus barroni*) can be differentiated from the Kimberley subspecies by fewer midbody scale rows and more ventral scale rows (Smith 1981).

7.2.2 Conservation status

The Pilbara Olive Python 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).

7.2.3 Distribution

The Pilbara Olive Python is described by the DoE (2013b) as being restricted to ranges within the Pilbara bioregion (**Figure 61**), although an apparently isolated population occurs south on Mount Augustus in the Gascoyne bioregion (Bush and Maryan 2011) and additional records exist in the north-eastern Carnarvon bioregion (**Figure 62** and **Figure 63**). The population in the Gascoyne bioregion may be associated with the Ashburton River system, where the species has also been recorded. Within the Pilbara bioregion, the species has been recorded from the Hamersley Range, Dampier Archipelago, Pannawonica, Millstream, Tom Price, Burrup Peninsula, and 70 kilometres east of Port Hedland (DoE 2013b); the species is also known from riparian areas along the Fortescue drainage (Doughty et al. 2011).

7.2.4 Habitat requirements

In the warmer months, the Pilbara Olive Python has a strong preference for riparian habitats (Doughty et al. 2011). Waterholes and billabongs form an important component of the speciesôhabitat, as it is able to ambush prey that drink there (Pearson 2003; DoE 2013b). The Pilbara Olive Python attains relatively high densities along the paperbark and River Red Gum lined billabongs of the Fortescue River (Pearson 2003), as well as other major creeks and rivers throughout its Pilbara range. It is also known from around permanent pools and mesas of the Robe River valley, and the Millstream spring system (Rio Tinto 2011). At Tom Price, the Pilbara Olive Python has been observed around sewage ponds and a recreational lake (Pearson 2003) and sheltering in railway embankments (DoE 2013b).

Outside the warmer months, the Pilbara Olive Python utilises rocky habitats such as escarpments, mesas, overburden heaps (at Pannawonica), and caves and gorges (Doughty et al. 2011). It is often found on top of, or underneath, rocks, or sheltering under spinifex (Tutt et al. 2004).

7.2.5 Home range, migration and movement

The Pilbara Olive Python has home range between 85 and 450 hectares (DoE 2013b) and moves around frequently within this range (Pearson 2003). Males travel up to four kilometres during the mating period in search of females and return to their home ranges in October (Pearson 2003). Like most pythons, the species is slow-moving, and many have died on roads because their initial response to the vibrations of an approaching vehicle is to remain still (Pearson 2003). This response may also make them vulnerable to trains if they need to cross rail lines, although no evidence from train strike has been documented.

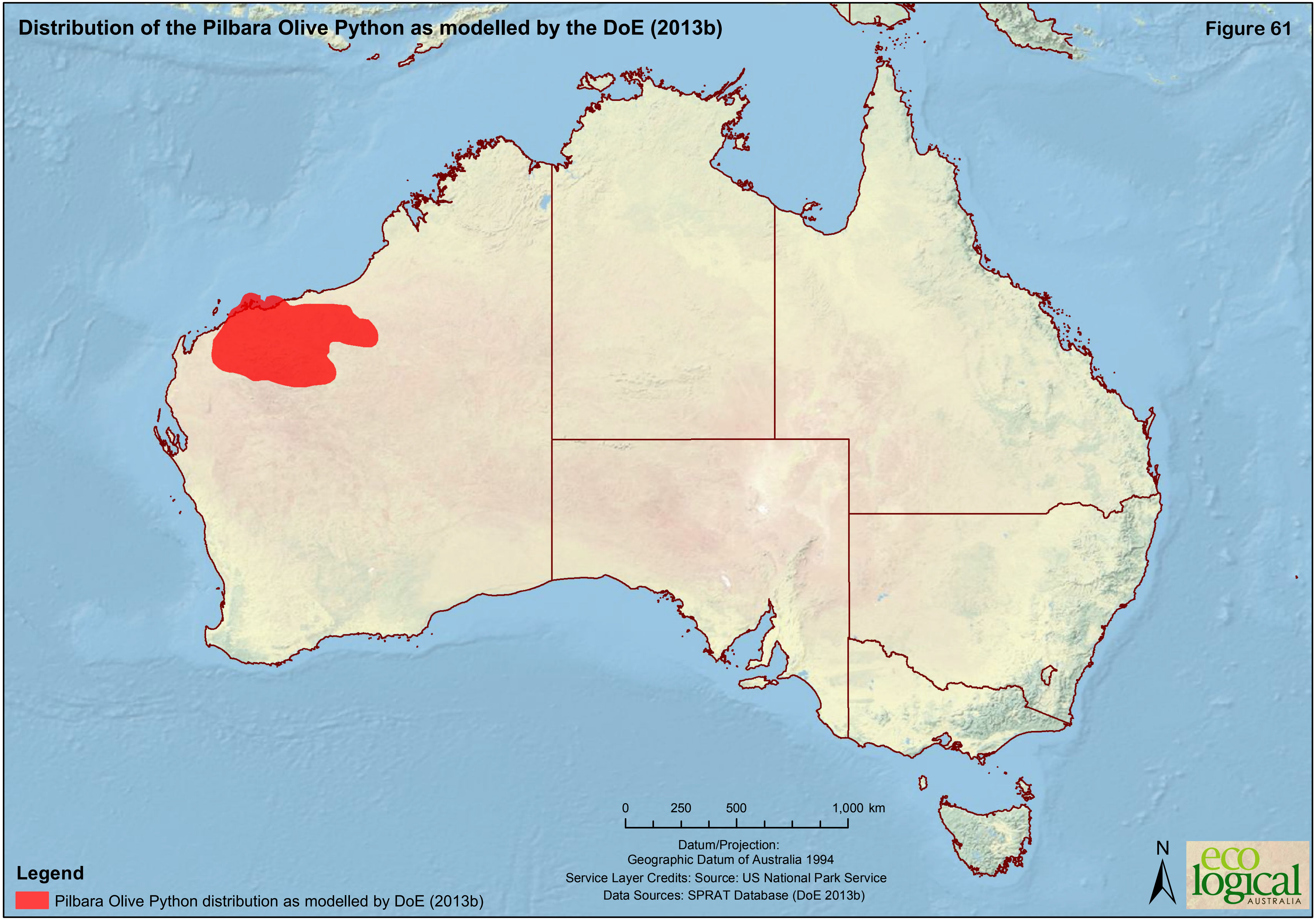
7.2.6 Breeding

The Pilbara Olive Python commences breeding between June and August. Females of other python species use pheromones to attract males, and this may also occur in the Pilbara Olive Python (Pearson 2003). Once a mate has been found, the pair shelter together for up to three weeks in a cave or crevice, probably mating several times before the male returns to its home range (Pearson 2003). Females lay eggs in October in nests under large slabs of rock well away from water (Pearson 2003). Little has been documented on incubation or average number of young for the Pilbara Olive Python, but, like other pythons, the species would likely incubate maternally by coiling around eggs to assist the incubation process, by maintaining eggs at a constant temperature which is likely to be approximately 31 to 32 °C. Eggs hatch in January, after which young disperse to search for food (DoE 2013b).

7.2.7 Feeding

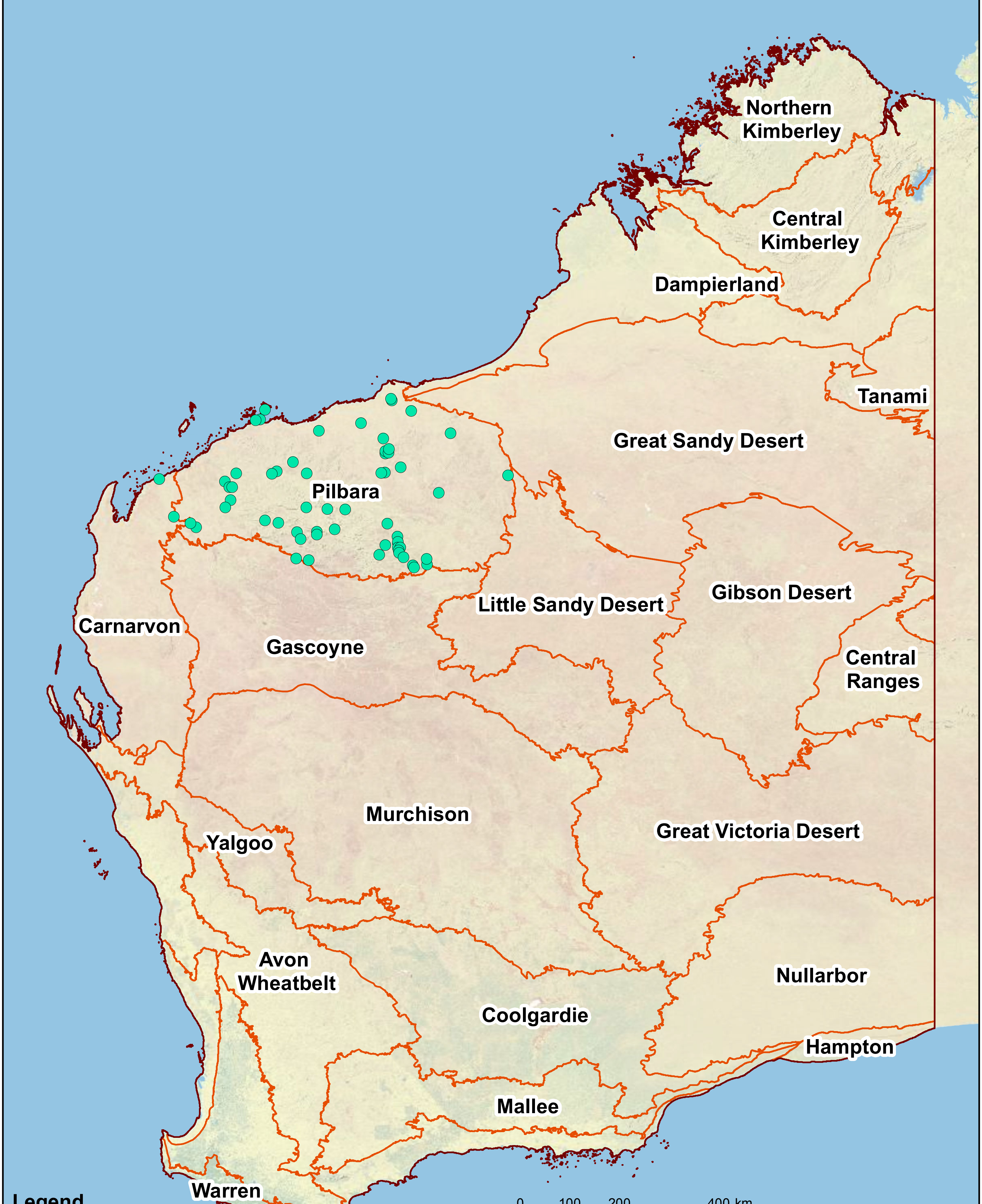
The diet of the adult Pilbara Olive Python includes rock wallabies, euros, fruit bats, ducks, corellas and spinifex pigeons (Pearson 2003). Juveniles are thought to eat reptiles, frogs, small mammals and small birds (Pearson 2003). The species is a capable swimmer and is able to strike its prey from a submerged position. The python also lays in wait to ambush prey along animal trails and the water's edge (DoE 2013b; Pearson 2003).

Distribution of the Pilbara Olive Python as modelled by the DoE (2013b) — **Figure 61**



Records of the Pilbara Olive Python in Western Australia (Parks and Wildlife 2013)

Figure 62

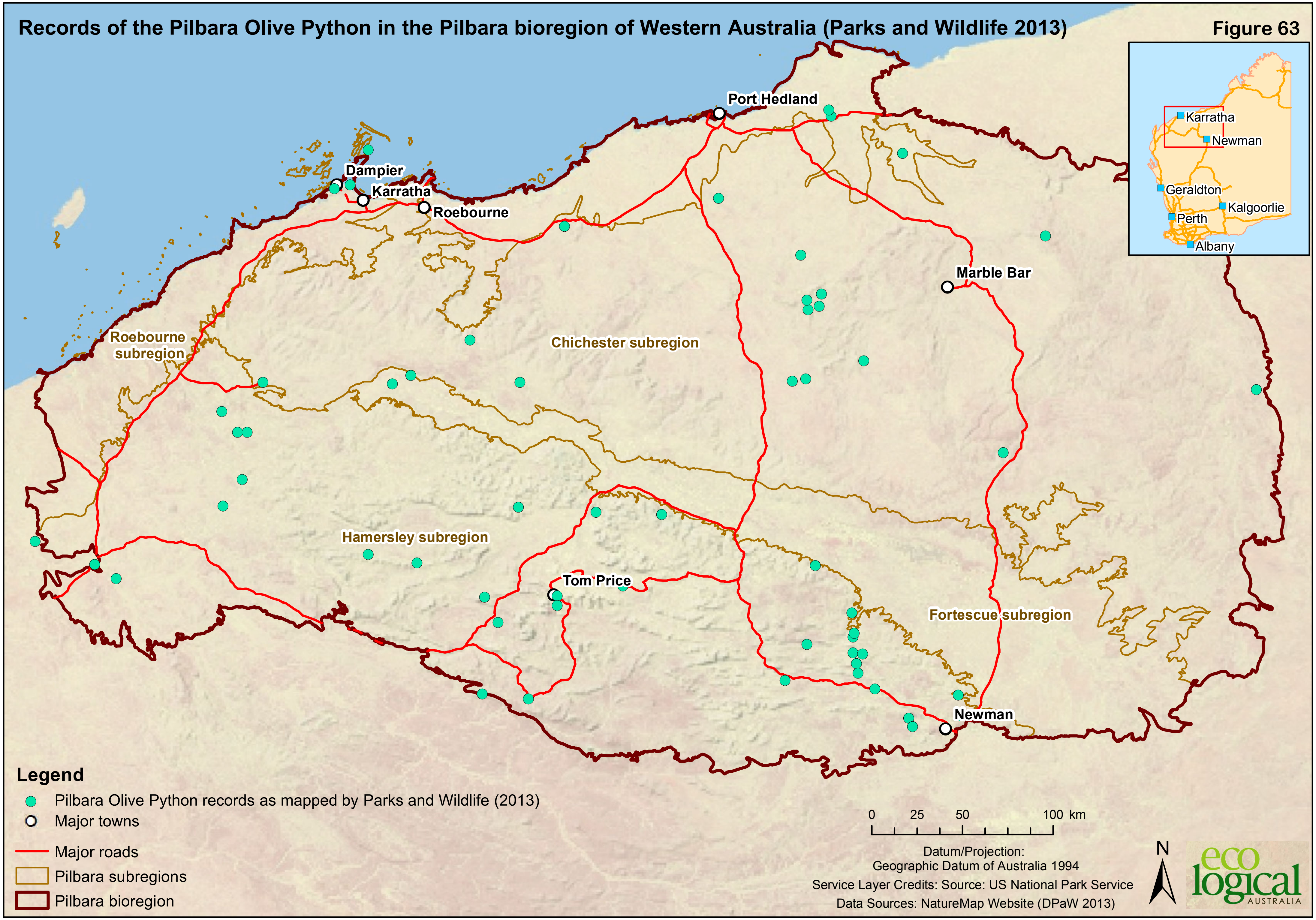


Legend

- Pilbara Olive Python records as mapped by Parks and wildlife (2013)
- 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)

ecological AUSTRALIA


Records of the Pilbara Olive Python in the Pilbara bioregion of Western Australia (Parks and Wildlife 2013)
Figure 63
Karratha
Newman
Geraldton
Kalgoorlie
Perth
Albany
Port Hedland
Dampier
Karratha
Roebourne
Marble Bar
Roebourne subregion
Chichester subregion
Hamersley subregion
Tom Price
Fortescue subregion
Newman
Legend
Pilbara Olive Python records as mapped by Parks and Wildlife (2013)
Major towns
Major roads
Pilbara subregions
Pilbara bioregion
0 25 50 100 km
N
Datum/Projection:
Geographic Datum of Australia 1994
Service Layer Credits: Source: US National Park Service
Data Sources: NatureMap Website (DPaW 2013)
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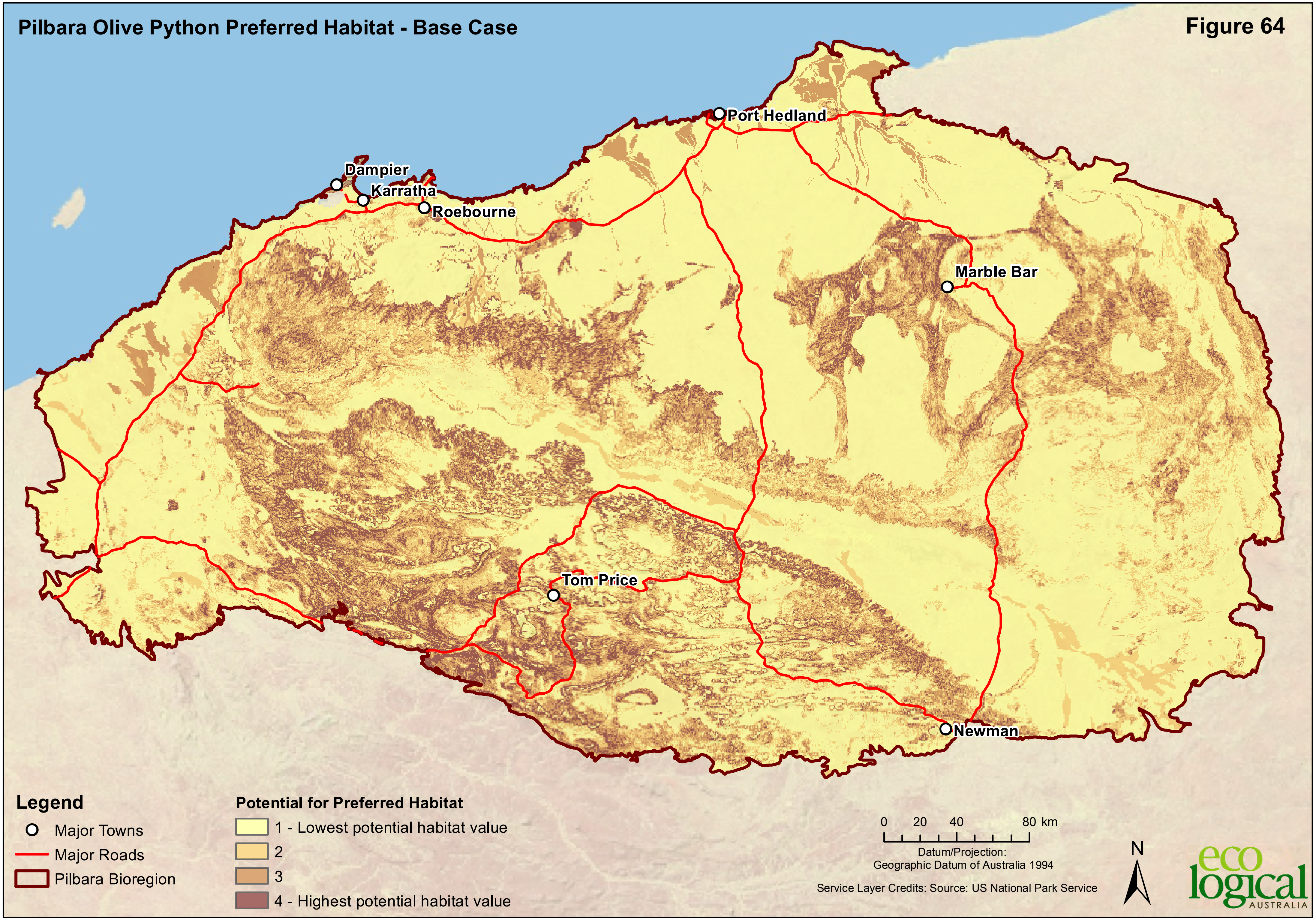
Pilbara Olive Python Preferred Habitat - Base Case

Figure 64



7.3 METHODS

7.3.1 Base layer considered

The Pilbara Olive Python CIA considered relative probability of potential habitat (habitat suitability) modelled by ELA (2015), as summarised in **Table 38** 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 38**; **Figure 64**). The majority (60 per cent) of the Pilbara bioregion was modelled as lowest potential habitat suitability for the Pilbara Olive Python, with area of higher habitat suitability mostly concentrated in the ranges of the southern and central Pilbara, as well as in the north-east Pilbara around Marble Bar (**Table 38**; **Figure 64**).

Table 38: Classification and ranking applied to the Pilbara Olive Python habitat model

Model value	Habitat Rank	Habitat suitability	Area (ha) in Pilbara Olive Python habitat model
70-100%	4	Highest probability of potential habitat	1,126,500 (6%)
30-70%	3	↓	2,948,403 (17%)
10-30%	2		3,100,368 (17%)
0-10%	1	Lowest probability of potential habitat	10,609,870 (60%)

7.3.2 Identification of key threats

Known and perceived threats to the Pilbara Olive Python are identified in the SPRAT database (DoE 2013b) and the TSSC (2008) approved conservation advice for the species (**Table 39**). A Pilbara Olive Python workshop facilitated by Parks and Wildlife in December 2013 also identified threats to the species (**Table 39**).

Table 39: Key threats to the Pilbara Olive Python

Threat	Source		
	DoE (2013b)	TSSC (2008)	Parks and Wildlife workshop
Major fire events/altered fire regimes	✓	-	-
Feral predators (competition/predation)	✓	✓	✓
Habitat loss/degradation from mining and infrastructure	✓	✓	✓
Habitat loss/degradation from grazing pressure	-	-	✓
Mortality from vehicle strike	✓	✓	-
Human interaction (i.e. deliberate killing due to misidentification as venomous snake)	✓	✓	-

In addition, the following potential impacts were considered for inclusion in the Pilbara Olive Python CIA:

- Fragmentation of habitat.
- Change in hydrology/hydrogeology.
- Climate change.
- Cane Toads.

The following were excluded from the CIA:

- Mortality from false human identification ï this is considered unlikely to significantly affect the subspecies (Pearson 2013a). In addition, this is expected to seldom occur in the vicinity of mine sites and mining infrastructure (as relevant to the CIA) given the education of mine site personnel in relation to conservation significant fauna, including identification of species such as the Pilbara Olive Python, that forms part of standard induction procedures.
- Inappropriate fire regimes ï consideration of fire regime is important in the context of the CIA; 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) 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 Pilbara Olive Python 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. Limitations associated with fire are discussed in Section 8.1.2.
- Climate change ï 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.
- Cane Toads ï the Pilbara bioregion is currently beyond the range of the Cane Toad; however, this species is predicted to become extensive throughout the Pilbara in the future (Kearney et al. 2008), and this view appears to be the consensus among scientists familiar with the Pilbara. Tingley et al. (2012) developed a model that predicts the Cane Toad will spread from the Kimberley to the Pilbara bioregion of Western Australia within 51 years through a coastal corridor between Broome and Port Hedland. They predict the spread of the Cane Toad will occur due to the presence of artificial water bodies, which will act as critical points for breeding, enabling the distribution of the Cane Toad to extend through the arid environment between the Kimberley and the Pilbara. While the Cane Toadõs predicted future occurrence in the Pilbara is recognised, the interactions with, and impacts to, wildlife are complex and there are limited data available to extrapolate potential future impacts of the Cane Toad within the Pilbara. Therefore, the potential future effects of the Cane Toad on the Pilbara Olive Python were not applied in the CIA. There is very little information on the diet of the Pilbara Olive Python, particularly for juveniles. Adult Pilbara Olive Pythons are known to prey primarily on mammals and birds, and the juveniles are suspected to feed on at least a proportion of lizards and frogs (Pearson 2003). There is likely to be a degree

of potential exposure of Pilbara Olive Pythons to Cane Toads in the future, given the overlap of preferred habitat such as gorges and creeks of the two species. There is also potential for opportunistic feeding of juvenile Pilbara Olive Pythons on toads at these riparian habitats.

The potential effects of noise and light on the Pilbara Olive Python 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 Pilbara Olive Python, 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 Pilbara Olive Python in the CIA. Limitations associated with noise and light are discussed in Section 8.1.2.

7.3.3 Potential impacts applied

In consideration of the key threats identified and the available data (Section 7.3.2), the potential impacts applied in the Pilbara Olive Python CIA were:

- removal of habitat;
- fragmentation of habitat;
- predation;
- mortality from collision with vehicles;
- degradation of habitat as a result of:
  - grazing pressure;
  - change in hydrology/hydrogeology.

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 7.3.4 to 7.3.9). 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.

7.3.4 Removal of habitat

The removal of habitat may result in the loss of breeding and foraging/hunting habitat, and a reduction in the speciesô distribution. Further, it may displace animals, which jeopardises reproduction and can result in mortality or extinction of local populations; isolation of populations and reduced gene flow; and increased predation by, or competition with feral animals. Removal of habitat was rated as a 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 40**). Mining activities can mitigate the potential impact of natural habitat loss through creation of artificial habitats. Such artificial habitats may be created during mining operations, such as sewage treatment ponds, or by post-mining landforms designed, for example, to allow for the formation of temporary or permanent pools of water.

The Pilbara Olive Python has been observed to use artificial water sources, such as the Tom Price sewage treatment ponds and recreational lakes, along with overburden heaps and railway embankments at the Mesa J Iron Ore Mine near Pannawonica (Pearson 2003). The Pilbara Olive Python may therefore still be able to utilise cleared and highly disturbed areas where suitable habitat features are present; however, as a conservative approach was taken in the CIA, potential habitat utilisation in cleared areas was not considered.

Table 40: Potential impacts of removal of potential Pilbara Olive Python 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. The creation of artificial mining and post-mining habitats is not considered. Edge effects are not considered for this impact.

7.3.5 Fragmentation of habitat

Habitat fragmentation could isolate Pilbara Olive Python populations, reduce genetic connectivity 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. Technical information on identification of habitat patches and application of fragmentation in the CIA is provided in Section 3.3.5. Mining and linear infrastructure have the potential to fragment Pilbara Olive Python habitat if clearing reduces habitat connectivity, or infrastructure presents an obstacle to movement or dispersal.

Consideration of the Pilbara Olive Pythonõs habitat requirements in the warmer months is important in the context of habitat fragmentation as, during these times, the Pilbara Olive Python has a strong preference for riparian habitats (Doughty et al. 2011). Habitat quality is also strongly influenced by the presence of waterholes and billabongs (Pearson 2003; DoE 2013b). 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 information from the SPRAT database, which states that the Pilbara Olive Pythonõs home range may be as large as 450 hectares (DoE 2013b). Habitat fragmentation was considered to have occurred when patch size was reduced below

450 hectares; impacts were assumed to increase with decreasing patch size below this threshold (**Table 41**).

Table 41: Potential impacts of fragmentation of potential Pilbara Olive Python habitat

Patch size	Level of potential impact	Confidence in level of potential impact	Assumptions
200-450 ha	Low (20%)	Low. The patch size required for breeding has not been documented.	A patch is a disconnected segment of habitat which includes at least some area of core foraging/breeding habitat such as a major river or rocky gorge (likely to be linear within the patch), but may also include non-core habitat. The Pilbara Olive Python's home range is 450 ha (based on DoE 2013b). Habitat suitability is considered to decrease as patch size decreases.
100-200 ha	Medium (50%)		
<100 ha	High (100%)		

7.3.6 Predation

The main identified threats to the Pilbara Olive Python include predation by the cat and feral dog (dog; *Canis lupus*) (DoE 2013b; Ellis 2013; Sustainable Consulting 2013g, 2013h). The fox may play a role in predation of Burrup Peninsula (coastal) populations of the Pilbara Olive Python, but is absent from the arid Pilbara (Pearson 2013b). Feral predators may play a role in the decline of the Pilbara Olive Python through predation, particularly of juveniles, as well as predation of the Pilbara Olive Python's food sources (such as quolls and rock-wallabies; Ellis 2013; Pearson 2013a; TSSC 2008; DoE 2013b). The loss of prey is likely to be of particular concern to the Pilbara Olive Python in coastal areas, where the fox is more prevalent (TSSC 2008).

While there is likely to be some level of 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). 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 42**).

Table 42: Potential impacts to the Pilbara Olive Python from predation

Proximity to human settlement/ road/ power line	Level of potential impact	Confidence in level of potential impact	Additional 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 increase in the 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).

7.3.7 Mortality from collision with vehicles

Rail and road networks potentially increase the chance of Pilbara Olive Python mortality through collision. Vehicle strikes are likely to occur as the Pilbara Olive Python moves across roads, between shelters and forage sites and especially when males are in search of females in the breeding season (Fitzgerald, M., pers. comm., 2014).

There is a lack of road mortality literature specific to the Pilbara Olive Python, or other reptiles in the Pilbara bioregion; however, studies on other large snakes have been undertaken elsewhere. In a Texas study, road-associated mortality of large snakes reduced populations by at least 50 per cent within 450 metres of gravel roads (Rudolph et al. 1999). The roads in the Rudolph et al. (1999) study were unsealed and had fewer than 100 vehicles passing over them per day, which is similar to many roads in the Pilbara.

Impacts of road and rail mortality were estimated based on the proximity of roads/rail to potential Pilbara Olive Python habitat. Collisions were considered to potentially affect Pilbara Olive Python habitat suitability at a distance of up to 500 metres, with the greatest effect being within 50 metres (**Table 43**). 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 43: Potential impacts to the Pilbara Olive Python from collision with vehicles

Proximity to roads/rail	Level of potential impact	Confidence in level of potential impact	Additional assumptions
50-500 m	Low (20%)	Medium. There are some anecdotal data available on road kill mortality and injury associated with vehicle strike. Vehicle strikes are likely to occur as the Pilbara Olive Python moves across roads, between shelters and forage sites and especially when males are in search of females in the breeding season (Fitzgerald, M., pers. comm., 2014).	Habitat suitability is assumed to decrease as the distance to roads/rail decreases.
<50 m	Medium (50%)		

7.3.8 Grazing pressure

Pastoral use may alter habitat for the Pilbara Olive Python and its prey by reducing ground cover and in some cases increasing shrub cover by promoting vegetation thickening and weed invasion, e.g. as observed for the Northern Quoll by Hill and Ward (2010); quolls are a known food source for the Pilbara Olive Python (e.g. TSSC 2008). Loss of cover may also increase the vulnerability of the Pilbara Olive Python to predation, in particular for juveniles. Some level of habitat disturbance appears to be tolerated by the Pilbara Olive Python based on its occurrence within the Ashburton and Fortescue Rivers. 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 Pilbara Olive Python; however, this was not 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 44**). The impact of grazing was applied to the Pilbara Olive Python 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 44: Potential impacts to the Pilbara Olive Python from grazing

Grazing pressure	Level of potential impact	Confidence in level of potential impact	Assumptions
Low (infrequently grazed), Medium (moderately grazed), or High (heavily grazed)	Low (20%)	Medium. The Pilbara Olive Python is likely to be able to withstand some pressure from cattle grazing, 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.

7.3.9 Change in hydrology/hydrogeology

Changes in natural surface water flows and quality, and impacts to groundwater through mining activities may affect the Pilbara Olive Python through impacts to the speciesô foraging habitat. The Pilbara Olive Python is known to utilise riparian habitats, waterholes and billabongs to ambush prey attracted to the water (Pearson 2003; Doughty et al. 2011; DoE 2013b). In relation to mining activities, pit dewatering and extraction of groundwater may lead to a decline in the water level, or drying of waterholes, thereby leading to a loss of foraging habitat. The Pilbara Olive Python may be affected by groundwater drawdown through reduced availability of groundwater-fed surface water (**Table 45**), and by interception of surface runoff and a reduced catchment area directing runoff to water bodies (**Table 46**). Potential impacts to the Pilbara Olive Python were estimated based on groundwater and surface water change potential data by BHP Billiton Iron Ore (2015) (**Appendix A**).

Table 45: Potential impacts to the Pilbara Olive Python from groundwater drawdown

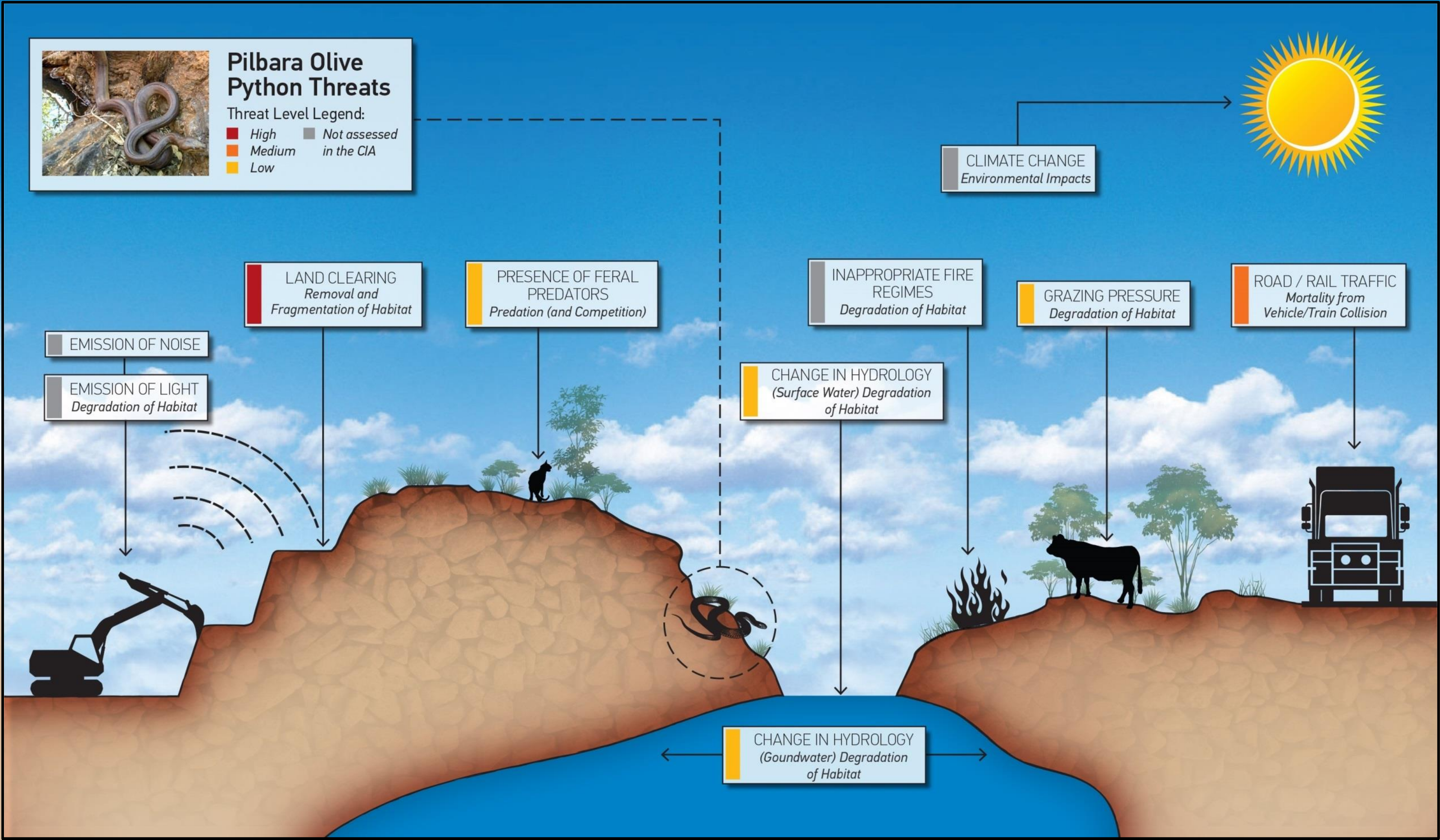
Groundwater change potential	Level of potential impact	Confidence in level of potential impact	Assumptions
High	Low (20%)	Medium. The Pilbara Olive Python is known to utilise riparian habitats, waterholes and billabongs to ambush prey attracted to the water (Pearson 2003; Doughty et al. 2011; DoE 2013b). Some of these surface waterbodies may be sustained by groundwater discharge.	At least some of the surface water bodies within the affected area are sustained wholly or partly by aquifer discharge.

Table 46: Potential impacts to the Pilbara Olive Python from reduced surface water availability

Surface water change potential	Level of potential impact	Confidence in level of potential impact	Assumptions
Medium to High	Low (20%)	Low. The Pilbara Olive Python is known to utilise riparian habitats, waterholes and billabongs to ambush prey attracted to the water (Pearson 2003; Doughty et al. 2011; DoE 2013b).	Surface water is considered important for foraging.

7.4 PILBARA OLIVE PYTHON CONCEPTUAL DIAGRAM

A conceptual diagram was prepared to depict the Pilbara Olive Python 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 65**). The conceptual diagram shows the potential impacts applied in the CIA and their level of potential impact (High, Medium or Low; Section 7.3). 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 43**); 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.



Pilbara Olive Python conceptual diagram	Figure 65

7.5 RESULTS

Results of the CIA for Pilbara Olive Python habitat suitability are provided in **Table 47** and **Table 48**. **Table 47** provides the area affected by potential impacts associated with existing impacts, future third party mines, and the Full Development Scenario. **Table 48** 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 Pilbara Olive Python habitat suitability in Scenario 1 to Scenario 3 is provided in **Figure 66** to **Figure 68**. 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 69**. The marginal change from one scenario to another, and from the base case to Scenario 1, is provided in **Figure 70** to **Figure 72**.

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).

7.5.1 Existing impacts

The potential effect of existing impacts was a substantial decrease in Pilbara Olive Python habitat suitability relative to the base case (**Figure 64**, **Figure 66**, **Figure 69** and **Figure 70**). Approximately 837,000 hectares (74 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 47**). Overall, a total of approximately 2.5 million hectares decreased in habitat suitability as a result of existing impacts, the majority of which (approximately 2.4 million hectares) decreased by one Habitat Rank (**Table 48**).

The substantial decrease in habitat suitability from existing impacts was predominantly a downgrading of Habitat Rank 4 to Habitat Rank 3 throughout and to the north of the Hamersley Ranges, and to the west of Marble Bar (**Figure 64**, **Figure 66** and **Figure 70**). This was likely due to a combination of development of roads, human settlements, or mines in these areas, contributing to:

- Habitat fragmentation ï Low to High potential impact applied in the CIA for habitat patches smaller than 450 hectares. The minimum patch size used in the CIA was determined based on information from DoE (2013b), which states that the Pilbara Olive Pythonõs home range may be as large as 450 hectares.
- Predation ï Low impact applied in the CIA within two kilometres of human settlements, roads/tracks and power lines. The main identified threats to the Pilbara Olive Python include predation by the cat and dog (DoE 2013b; Ellis 2013; Sustainable Consulting 2013g, 2013h). Predation, or loss of prey, from the fox may also be of concern in the coastal Pilbara (TSSC 2008;

Pearson 2013b). Feral predators may play a role in the decline of the Pilbara Olive Python through predation, particularly of juveniles, as well as predation of the Pilbara Olive Python's food sources (such as quolls and rock-wallabies; Ellis 2013; Pearson 2013a; TSSC 2008; DoE 2013b).

- Mortality from collision with vehicles ï Low to Medium impact applied in the CIA within 500 metres of roads and rail lines. Rail and road networks potentially increase the chance of Pilbara Olive Python mortality through collision. Vehicle strikes are likely to occur as the Pilbara Olive Python moves across roads, between shelters and forage sites and especially when males are in search of females in the breeding season (Fitzgerald, M., pers. comm., 2014).

7.5.2 Future third party mines

The potential effect of future third party mines on Pilbara Olive Python habitat suitability was minor as a percentage of the total area of the Pilbara bioregion (**Figure 64**, **Figure 67**, **Figure 69** and **Figure 71**). 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 47**). Overall, a total of approximately 23,500 hectares decreased in habitat suitability as a result of future third party mines, the majority of which (approximately 17,900 hectares) decreased by one Habitat Rank (**Table 48**).

There was a potential slight positive (beneficial) effect of future third party mines in some areas, with a total of approximately 44 hectares increasing in habitat suitability by one Habitat Rank (**Table 48**). The potential positive effect in these areas was associated with a reduction in the extent of impacts associated with ecohydrological change potential mapped by BHP Billiton Iron Ore (2015).

7.5.3 Full Development Scenario

The potential effect of the Full Development Scenario on Pilbara Olive Python habitat suitability was minor as a percentage of the total area of the Pilbara bioregion (**Figure 64**, **Figure 68**, **Figure 69** and **Figure 72**). There was a potential slight positive (beneficial) effect of the Full Development Scenario in some areas, with a total of approximately 18,000 hectares increasing in habitat suitability by one to two Habitat Ranks and 75,000 hectares decreasing in habitat suitability by one to three Habitat Ranks (**Figure 72**; **Table 48**). This potential positive effect was associated with mine closure in Scenario 3, whereby some of the potential impacts to the Pilbara Olive Python were not applied to closed mines and infrastructure, along with changes in the extent of impacts associated with ecohydrological change potential mapped by BHP Billiton Iron Ore (2015). The Full Development Scenario resulted in a slight decrease in the extent of Habitat Ranks 2, 3 and 4 (less than two per cent) and a slight increase in the extent of Habitat Rank 1 (less than one per cent; **Table 47**).

7.5.4 Potential cumulative impacts

The potential cumulative impact to Pilbara Olive Python habitat suitability was a decrease in the extent of the most suitable habitat (Habitat Rank 4) 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 extent of Habitat Rank 3 decreased by approximately 172,000 hectares (six per cent of the modelled extent in the base case), mostly due to existing impacts. These Habitat Ranks were downgraded into lower ranked habitat; therefore the extent of Habitat Ranks 1 and 2 increased. 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 (**Table 47** and **Table 48**).

Table 47: Area of each Habitat Rank in the base case and Scenarios 1 to 4 for the Pilbara Olive Python habitat model

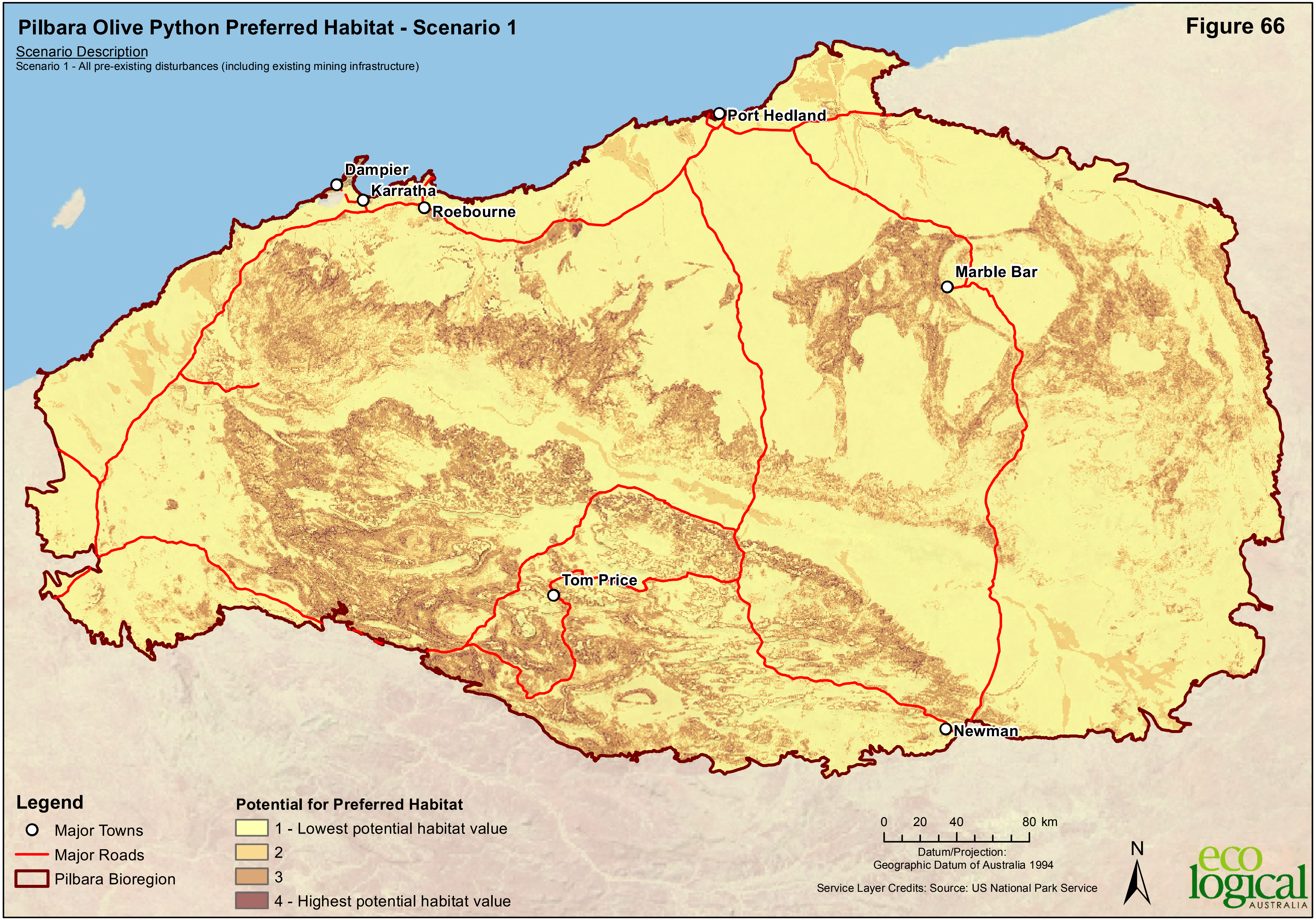
Habitat Rank	Base case	Area (ha) of potential change*			Potential cumulative impact**
		Existing impacts	Future third party mines	Full Development Scenario	
1	10,609,870	692,748 (7%)	16,983 (<1%)	60,394 (<1%)	770,125 (7%)
2	3,100,368	284,425 (9%)	-6,809 (<-1%)	-35,155 (-1%)	242,462 (8%)
3	2,948,403	-139,760 (-5%)	-7,869 (<-1%)	-23,897 (<-1%)	-171,525 (-6%)
4	1,126,500	-837,414 (-74%)	-2,305 (<-1%)	-1,344 (<-1%)	-841,062 (-75%)

*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 48: Area of habitat that increased or decreased by one, two or three ranks, or that did not change between scenarios for the Pilbara Olive Python 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%)	77 (<1%)
+1	0 (0%)	44 (<1%)	18,004 (<1%)
0	15,313,058 (86%)	17,761,569 (~100%)	17,692,303 (~100%)
-1	2,441,980 (14%)	17,851 (<1%)	46,265 (<1%)
-2	24,954 (<1%)	5,376 (<1%)	26,605 (<1%)
-3	5,149	300	1,887

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%)	(<1%)	(<1%)

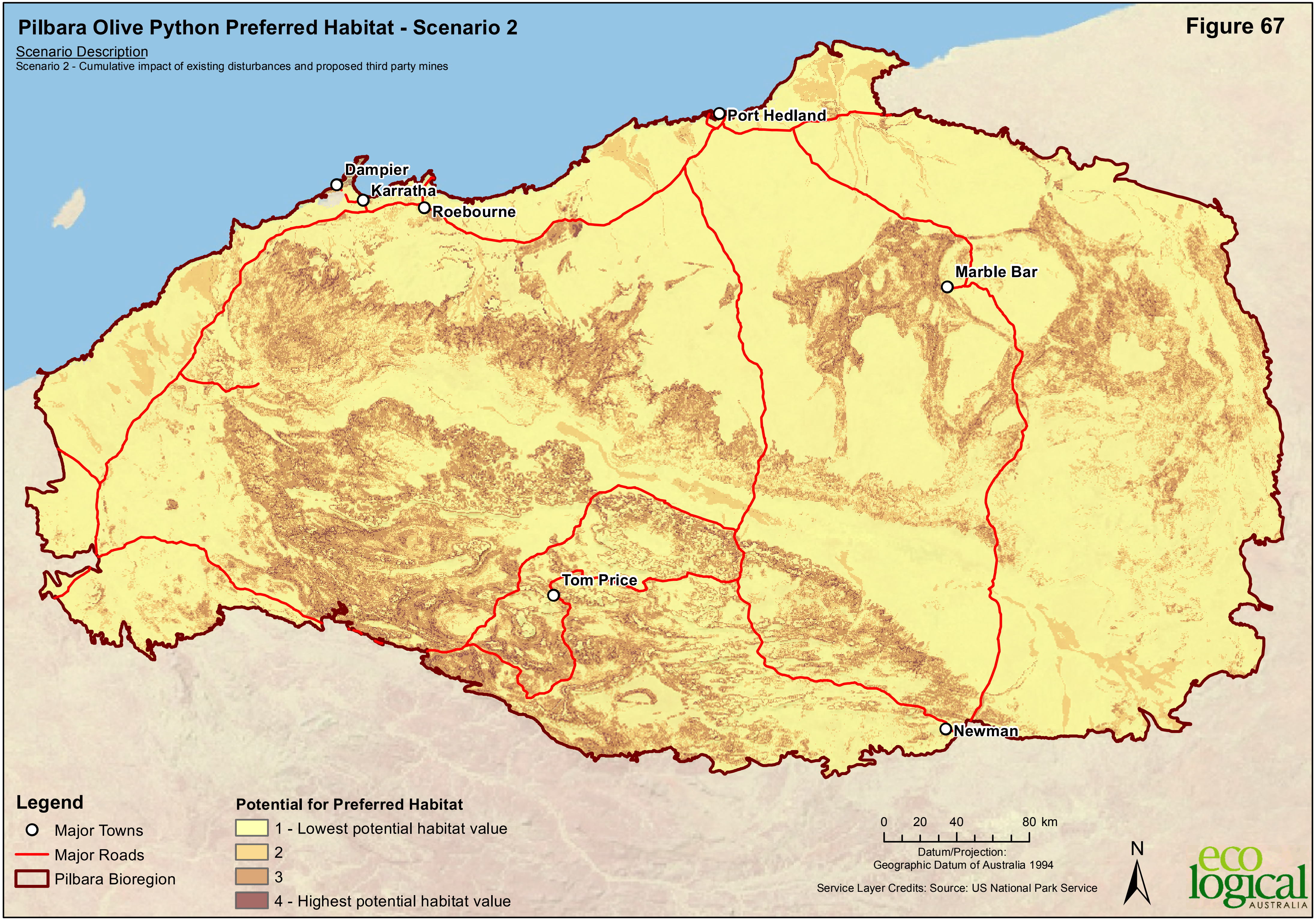

Pilbara Olive Python Preferred Habitat - Scenario 1
Figure 66
Scenario Description
Scenario 1 - All pre-existing disturbances (including existing mining infrastructure)
Port Hedland
Dampier
Karratha
Roebourne
Marble Bar
Tom Price
Newman
Legend
Major Towns
Major Roads
Pilbara Bioregion
Potential for Preferred 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

Pilbara Olive Python Preferred Habitat - Scenario 2

Figure 67

Scenario Description

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



Pilbara Olive Python Preferred Habitat - Scenario 3

Figure 68

Scenario Description

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

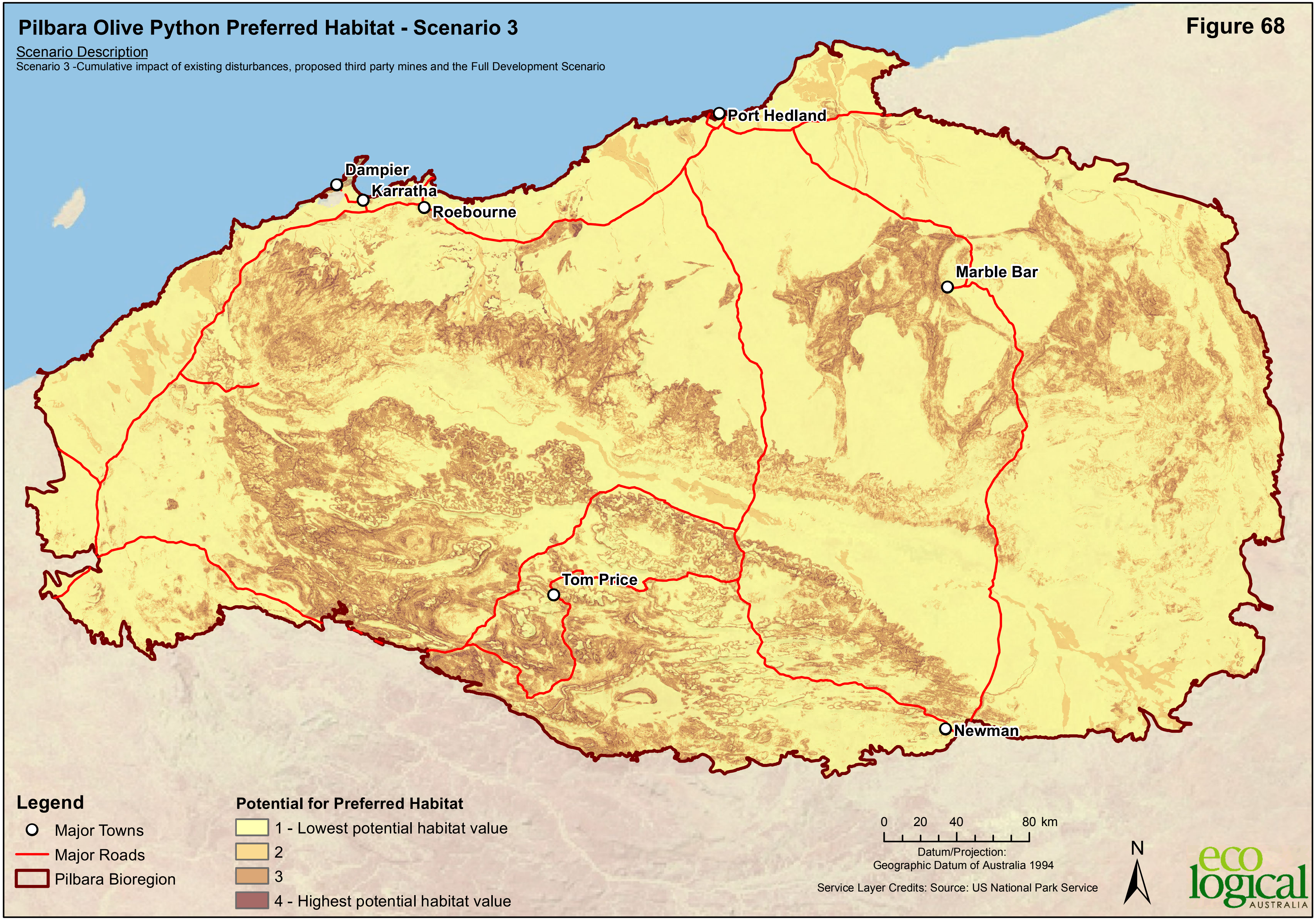
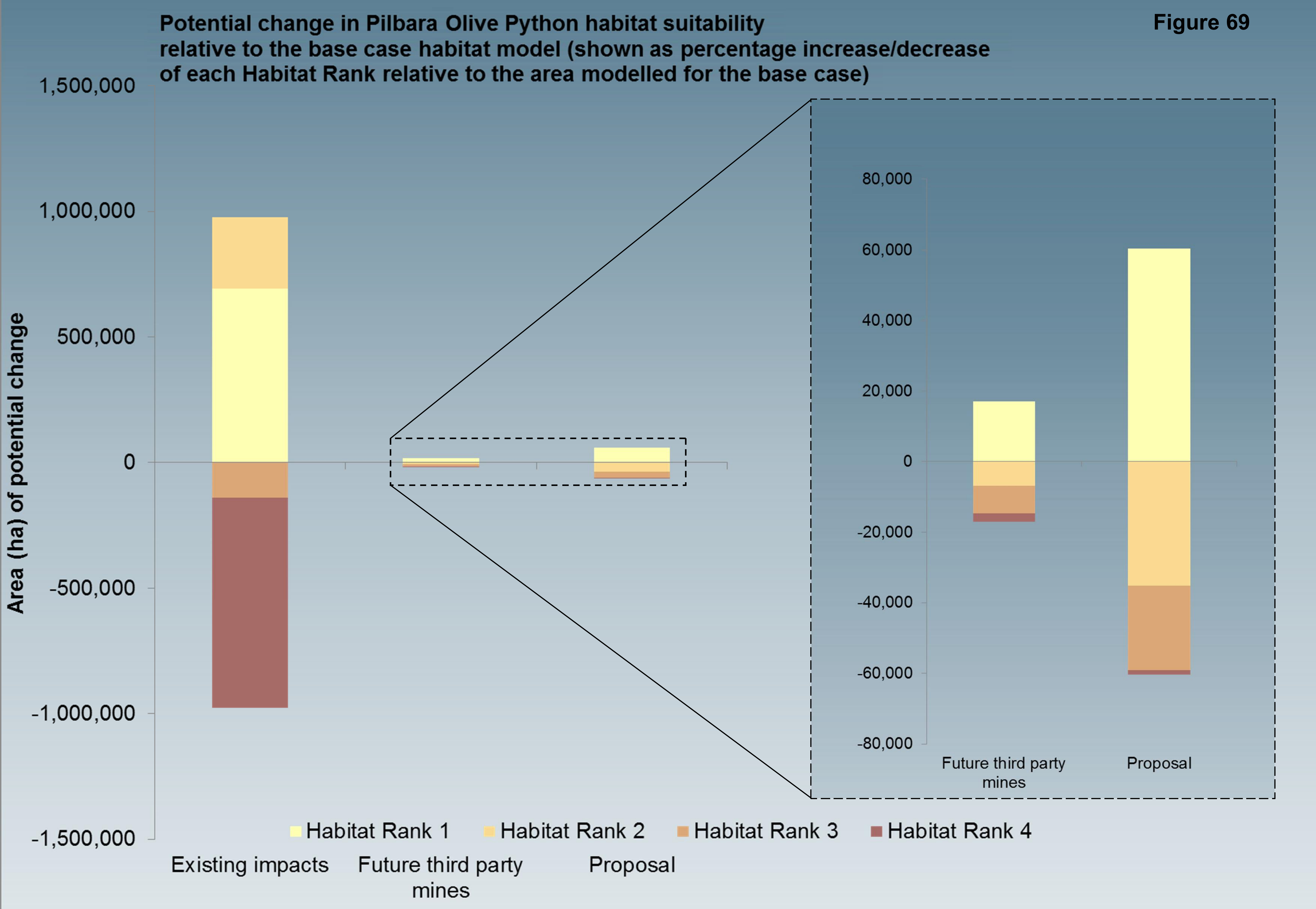


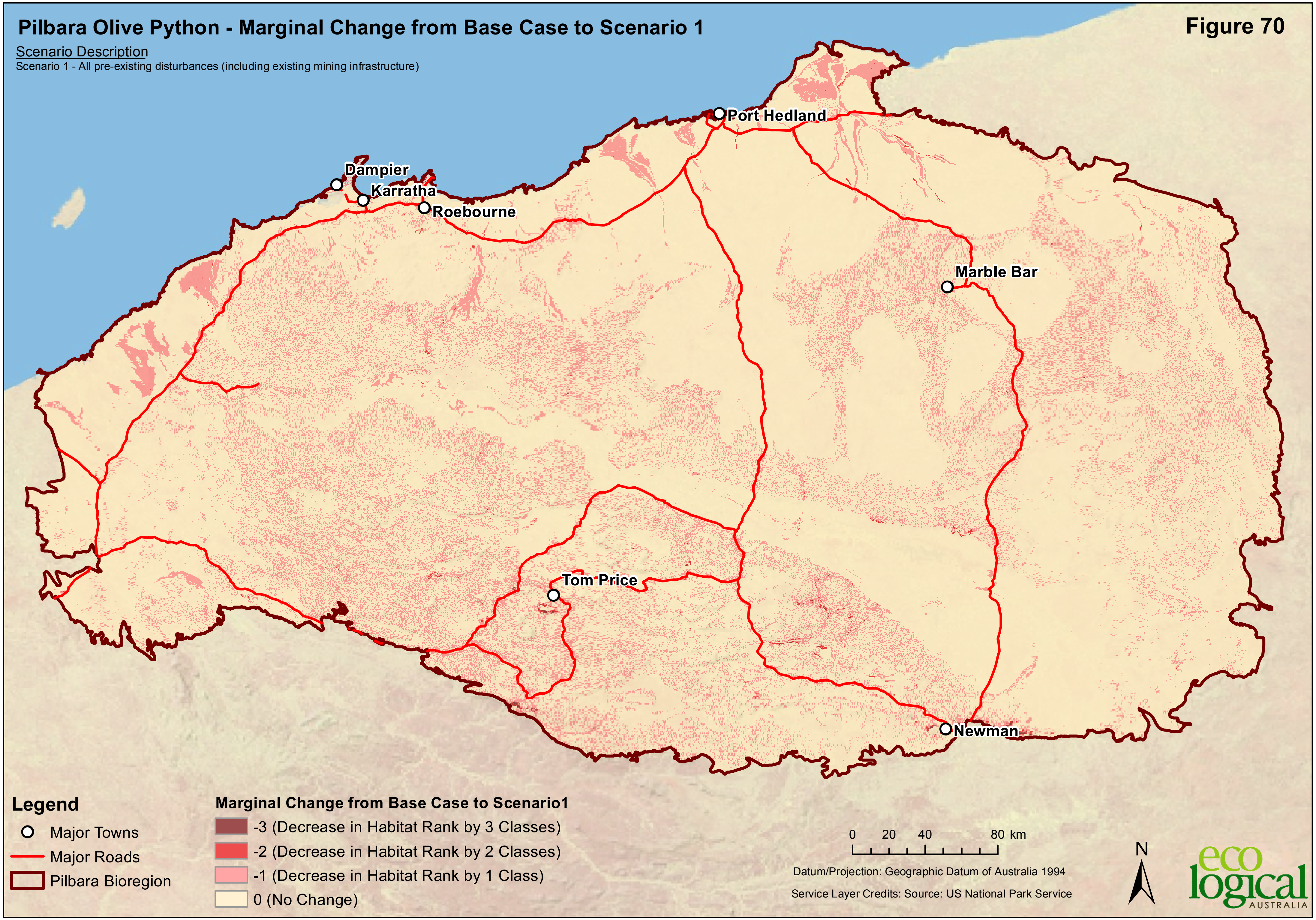
Figure 69



Potential change in Pilbara Olive Python 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)
Area (ha) of potential change
1,500,000
1,000,000
500,000
0
-500,000
-1,000,000
-1,500,000
Existing impacts
Future third party mines
Proposal
80,000
60,000
40,000
20,000
0
-20,000
-40,000
-60,000
-80,000
Future third party mines
Proposal
Habitat Rank 1
Habitat Rank 2
Habitat Rank 3
Habitat Rank 4

Pilbara Olive Python - Marginal Change from Base Case to Scenario 1

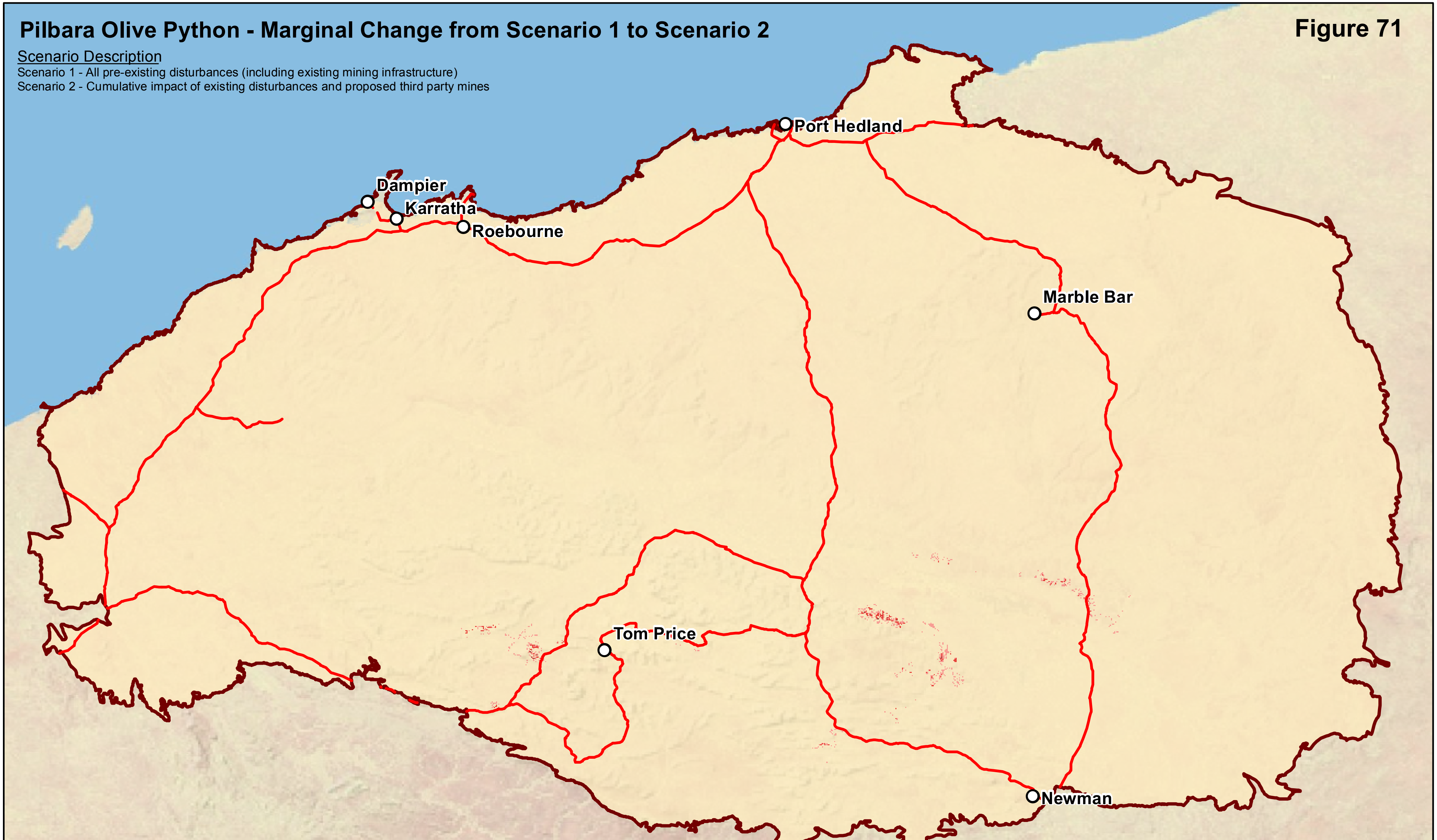
Figure 70



Pilbara Olive Python - Marginal Change from Scenario 1 to Scenario 2

Figure 71

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
- -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)
- 1 (Increase in Habitat Rank by 1 Class)

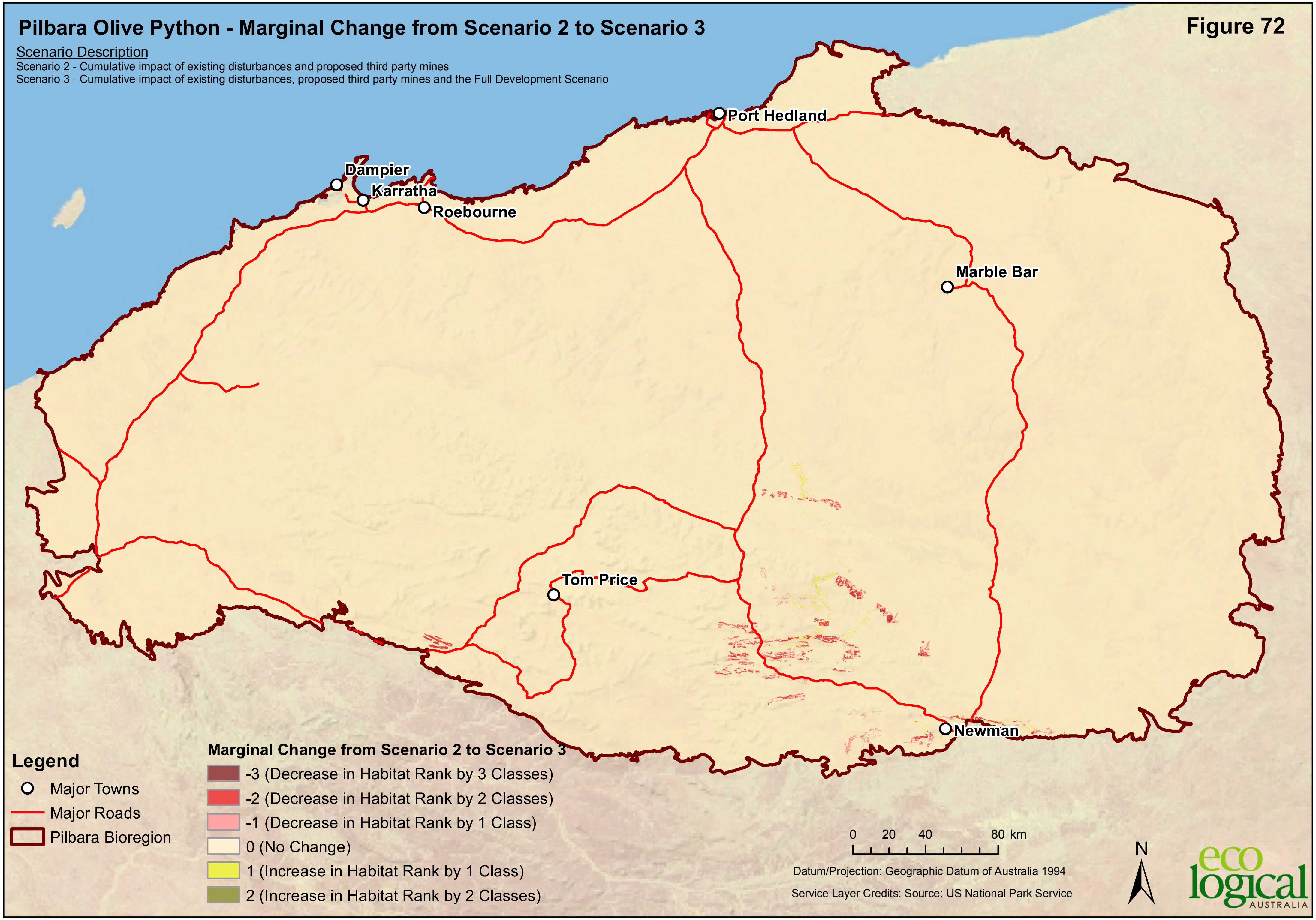
0 20 40 80 km

Datum/Projection: Geographic Datum of Australia 1994

Service Layer Credits: Source: US National Park Service

N

eco logical AUSTRALIA



Pilbara Olive Python - Marginal Change from Scenario 2 to Scenario 3
Figure 72
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
-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)
1 (Increase in Habitat Rank by 1 Class)
2 (Increase in Habitat Rank by 2 Classes)
0 20 40 80 km
Datum/Projection: Geographic Datum of Australia 1994
Service Layer Credits: Source: US National Park Service
N
eco logical AUSTRALIA

8 Key information gaps

While information gaps have been identified and documented, it is considered that this assessment provides a robust approach to the consideration of cumulative impacts at a regional scale and is suitable to inform the strategic environmental assessment of the Proposal as it provides regional context for impacts to the relevant MNES. This is the first time such an assessment has been conducted in the Pilbara and represents a step-change in the approach to cumulative impacts in the bioregion. Over time, many of the gaps may be addressed, which would allow refinement of any future cumulative impact assessment.

Information gaps exist for each of the major components of the CIA. Where information gaps were identified, a conservative estimate was used. Information gaps were identified in relation to:

- the base layers used: namely the MNES habitat models developed by ELA (2015);
- the data available to apply impacts;
- the methods used to apply impacts, including uncertainty in relation to estimated levels of potential impacts.

8.1.1 Key information gaps related to base layers

With regard to the base layers used, limitations of the base layers are summarised in **Table 5** and described in more detail in **Appendix A**.

Key information gaps with respect to the MNES habitat models are:

- Limited species presence data, particularly for the Greater Bilby (only 21 records), which may have limited the predictive power of the modelling. As part of the peer review process, Dr. Rick Southgate, the Greater Bilby subject matter expert on the peer review panel (Section 2.7), specifically noted more Greater Bilby records are now available in the Parks and Wildlife NatureMap database (http://naturemap.dec.wa.gov.au) than were used in the ELA (2015) modelling. The additional records extend along the railway line towards Port Hedland (Southgate, R., pers. comm., 2015). These records were not available at the time of the ELA (2015) modelling. Dr Southgate considered that inclusion of the additional records ñwould most probably alter the predictive modelling and the key defining attributes considerablyò (Southgate, R., pers. comm., 2015). While inclusion of additional records would generally increase the robustness of any model, the ELA (2015) ecological evaluation of the Greater Bilby model determined that it was a good match to the expected distribution and perceived core habitat areas of the species.
- Survey effort and, therefore, the records of species observations are likely to have been biased to particular areas, predominantly mining tenements. This could have caused the model to only predict areas with the same environmental space as the area surveyed, and not predict other areas of potential habitat (or predict it with a weaker return) where survey has not occurred at all, or has occurred with less intensity or success. Species presence record bias is particularly pertinent to the Northern Quoll, for which there was strong clustering in the northern Pilbara, which may have underestimated potential habitat in the southern Pilbara.
- Lack of species absence data, requiring the use of inherently less powerful pseudo-absence data.

- Lack, or poor quality of data for environmental variables, particularly the lack of a dedicated soil dataset, which may have limited the predictive power of the modelling for the Greater Bilby in particular, which is known to exhibit distinct preferences for specific soil types for burrow construction.
- Lack of scientific design and inconsistent survey design of the surveys that collected the species data. Species presence and absence data from a dedicated regional survey program that surveyed the range of environments would likely have produced more robust (but not necessarily substantially different) results.
- Highly-specific species requirements limit the modelling procedure, such as for the Pilbara Leaf-nosed Bat, which is highly-dependent on suitable roosting caves. The model predicts the landscape where suitable cave habitat and foraging habitat may exist (which is considered appropriate); however, cannot predict the actual location and suitability of these features.

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 ‘good’, ‘good-moderate’ or ‘moderate’ predictions of potential habitat, where designations of ‘good’ indicate that the results were of the highest standard and designations of ‘good-moderate’ and ‘moderate’ indicate lower performance or increasing departure from expected results, but still considered suitable results. Designations of ‘low’ would reflect results unsuitable for further modelling; however, no species received this designation for any evaluation criteria (ELA 2015).

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.

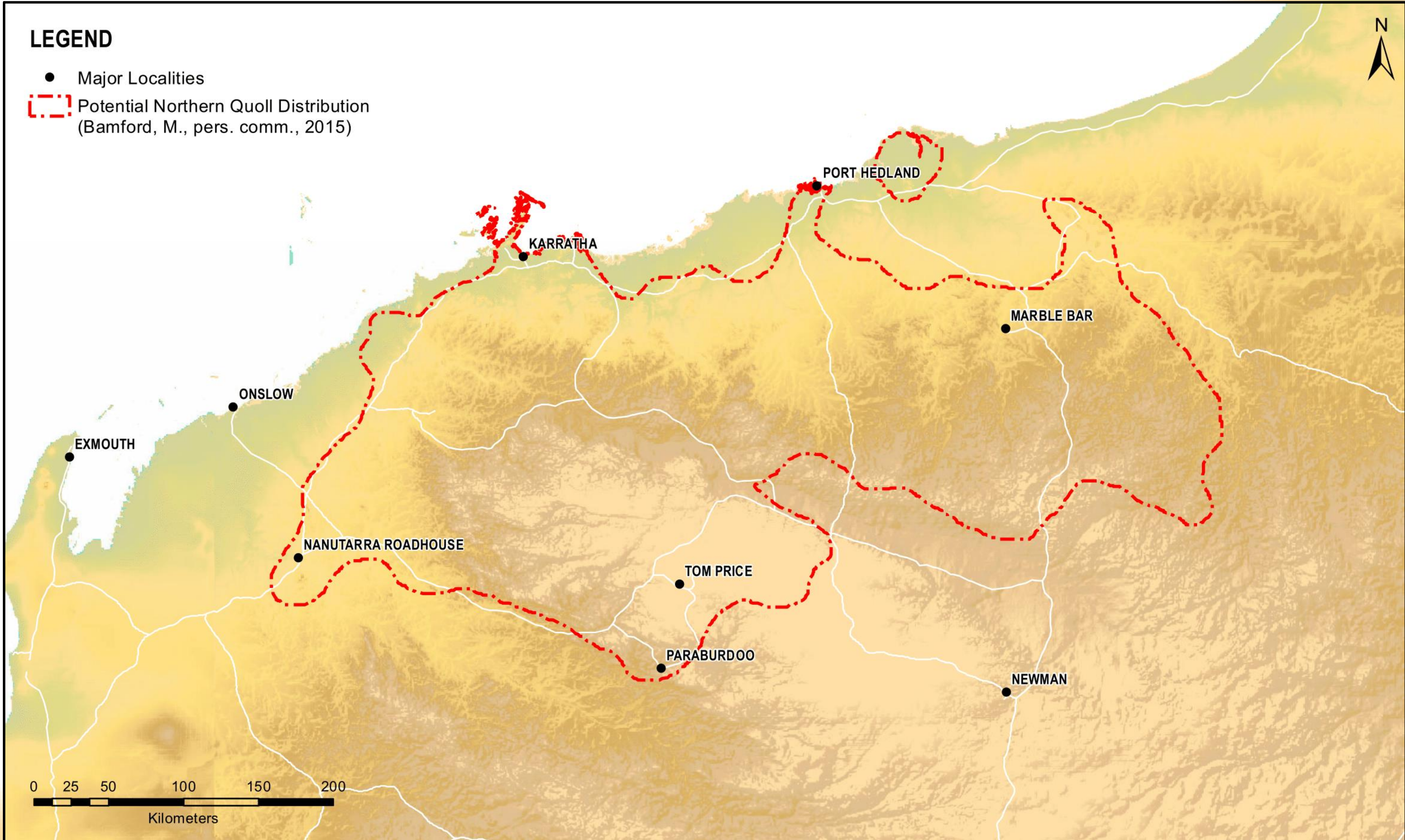
The MNES habitat models have been subject to extensive review by a specialist peer review panel (Section 2.7) and were generally accepted by peer reviewers as being suitable for use in the CIA, with some reservation. With respect to each MNES:

- For the Greater Bilby, “there is considerable habitat model uncertainty because the model has been derived from few (21) locations and 9 of these are clustered” (Southgate, R., pers. comm., 2015). There is now “a greater number of bilby locations recorded (in NatureMap) extending along the railway toward Port Hedland than were used in the modelling. Inclusion of these would most probably alter the predictive modelling and the key defining attributes considerably” (Southgate, R., pers. comm., 2015). “The cumulative impact likely to occur with the expansion of mining has been difficult to access based on the assessment conducted. This will remain the case until a more robust indication of distribution and extent of habitat suitability can be defined and the description of the threat layer is better resolved” (Southgate, R., pers. comm., 2015).
- There are no major concerns with the species presence records, pseudo-absence records and environmental variables used to develop the Hamersley Lepidium habitat model (van Etten, E., pers. comm., 2015). There is potential for pseudo-absences to be better aligned with actual absences from floristic surveys; however, the use of a larger and broader set of absences is unlikely to change the predictions to any major degree (van Etten, E., pers. comm., 2015).

- Dr. Mike Bamford provided an alternative schematic map for the Northern Quoll (**Figure 73**), indicating alternative locations for the Northern Quoll. Although this CIA has been based on the best available data, the alternative map provided by Dr. Bamford illustrates that knowledge of species habitat and distribution will continue to evolve as further baseline surveys are undertaken and data points are made publicly available. The Northern Quoll distribution provided by Dr. Bamford aligns with the majority of the most suitable habitat (Habitat Rank 4) modelled by ELA (2015) (**Figure 36**).
- For the Pilbara Leaf-nosed Bat, ñmost important habitats (i.e. those landscapes with the highest potential to provide caves deep enough for the species) seem to have been captured in the modelò; however, ñthe addition of other flat or non-cave forming landscapes ranked highly as habitat has the chance to add noiseò (Armstrong, K., pers. comm., 2015). ñDespite some methodological shortcomings, the (Pilbara Leaf-nosed Bat habitat model) was a reasonable hypothesis for the distribution of the (Pilbara Leaf-nosed Bat). While some areas in the model seemed to be unjustifiably uprated in importance as habitat, the model as a whole seemed to include most terrains likely to be the most important in terms of providing roosting habitatò (Armstrong, K., pers. comm., 2015).
- The datasets and other inputs used in the Pilbara Olive Python CIA ñare generally fit-for-purpose, considering the objectives of the studyé and other uncertainties explicitly acknowledged in the documentò (Fitzgerald, M., pers. comm., 2015).

Key information gaps with respect to the third party footprints are as follows:

- The third party footprints take into account only existing mines (including those under environmental assessment), as future third party mines are not known.
- The third party footprints do not take into account the type of footprint due to the level of detail available from the aerial imagery.
- 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 mining operation could occur. This is 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.



Potential distribution of Northern Quoll core habitat as mapped by Dr Mike Bamford	Figure 73

8.1.2 Key information gaps related to impact data

Key impact data information gaps relate to non-mining impacts, rather than mining impacts, given the high level of certainty associated with the mining footprint data used in the CIA. Assumptions, exclusions and special considerations related to mining data are provided in Section 2.5.

Key information gaps related to data available to apply non-mining impacts are:

- lack of fire data and a suitable framework with which to apply impacts of fire across the bioregion, and lack of fauna-specific noise modelling data, which resulted in exclusion of these impacts from the CIA;
- lack of information on the likely impact of climate change on any particular component of biodiversity.

While not necessarily a key gap in the context of the CIA, development of better datasets for some of the non-mining impacts applied in the CIA could refine the outcome of the CIA, such as data on feral predator distribution and abundance, the spatial extent and intensity of grazing across the bioregion, and the extent and density of weed infestations across the bioregion.

Key considerations in relation to fire, noise, light and climate change are outlined in the following sections.

FIRE

Alteration of fire regimes was identified as a key threat to the Greater Bilby, Northern Quoll and Pilbara Olive Python (Sections 3.3.2, 5.3.2 and 7.3.2). 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). Consequently, 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) 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, Northern Quoll and Pilbara Olive Python habitat suitability in the Pilbara bioregion (DoE 2013b).

Historically, lightning and burning by Aboriginal people were the main causes of fire in spinifex dominated grasslands. In more recent times, most fires have been started by lightning strike, although human-caused ignitions are significant near settlements, on pastoral leases and along travel routes (Burrows et al. 2006). The fire risks associated with mining in the Pilbara are currently managed primarily due to safety concerns through a number of existing fire management plans and fire response plans, by BHP Billiton Iron Ore and others. 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. Naturally-occurring fires, especially those associated with lightning strike, are unlikely to be exacerbated by the Proposal. Fires in close proximity to mining infrastructure may be controlled to protect safety and assets.

Further, the effect of fire on each species is complex and can be positive or negative in different situations. Extensive and intense fires may contribute to the decline of each species through mortality, loss of important habitat, increased predation from feral and native animals due to removal of ground cover, and decreased availability of food/prey resources; however, the effects of other fires are more uncertain. Woinarski et al. (2004) found that in tropical forests, annual, low intensity fire regimes are likely to increase favourable conditions for the Northern Quoll in terms of food availability.

The effect of altered fire regimes on the Greater Bilby is particularly complex, with periodic burning of arid vegetation communities an important factor in improving Greater Bilby habitat. Seeds that are liberated following fire are a significant part of the Greater Bilby's diet, and occurrence of the Greater Bilby has been closely associated with recently burnt (less than one year) habitat in the Tanami Desert (Southgate et al. 2007). In some areas, fire is necessary for thinning vegetation and encouraging growth of favoured seeding grass, which may promote breeding success of the Greater Bilby over the medium- to long-term; however, fire may contribute to species decline from habitat destruction in the short-term, as the Greater Bilby requires a mosaic of successional changes to meet its habitat requirements and to encourage its dispersal and colonisation into unoccupied areas (DoE 2013b).

Finally, 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 environment; however, this was not considered in the application of the potential impacts of grazing.

NOISE

The Proposal will result in emission of noise; however, the extent to which the Greater Bilby, Northern Quoll, Pilbara Leaf-nosed Bat and Pilbara Olive Python may be affected by noise from mining or other human activities is not well understood. It is possible that noise may initially displace individuals, or result in mortality if young are abandoned, or if increases in predation occur, but that individuals may become habituated to noise over time (Fortescue Metals Group 2009). However, for the MNES considered, little has been documented about habituation to noise, or what effects the physiological stress leading up to habituation may cause (Saleh 2007). Assessing the potential impact of noise may be complicated by the presence or absence of other impacts (an individual will often become habituated to noise if no other stimuli are present; Larkin et al. 1996) and the frequency or intensity of the noise emission (an individual may respond differently to rare or short-term noise emissions than to ongoing noise disturbance).

Most studies of noise impacts on fauna have been undertaken in Europe or America in relation to military operations, which may differ somewhat to impacts from mining operations. Noise may interfere with communication (Hill 2001) or elicit behavioural responses that lower foraging, breeding or brooding efficiency (Larkin et al. 1996). While the effect of noise on animal communication is reasonably well documented, little has been documented about the effect on more complex ecosystem processes such as predator-prey interactions (Siemers and Schaub 2011). There is some evidence that an individual animal's fitness may be affected by anthropogenic noise by decreasing foraging efficiency, which in turn may lower survival and reproductive rates (Larkin et al. 1996); however, individuals may quickly become accustomed to noise if other sensory systems, such as sight or smell, are not affected (Fortescue Metals Group 2009).

LIGHT

The Proposal will result in emission of light; however, the extent to which the Greater Bilby, Northern Quoll, Pilbara Leaf-nosed Bat and Pilbara Olive Python may be affected by light from mining or other human activities is not well understood. It is possible that light may initially displace individuals, or result in mortality if young are abandoned, or if increases in predation occur, but that individuals may become habituated light over time (Fortescue Metals Group 2009). However, for the MNES under consideration, little has been documented about habituation to light, or what effects the physiological stress leading up to habituation may cause (Saleh 2007). Assessing the potential impact of light may be complicated by the presence or absence of other impacts (an individual will often become habituated to light if no other stimuli are present; Larkin et al. 1996) and the frequency or intensity of the light emission (an individual may respond differently to rare or short-term light emissions than to ongoing light disturbance).

Light impacts could alter movements and behaviour, as individuals could become disoriented by artificial light, resulting in changes in foraging success and reduced fitness, and increase the likelihood of predation. Lighting could also potentially disrupt circadian rhythms and melatonin production, or reduce the time individuals have to source food, shelter, or mates (Beier 2006). In some instances, artificial light may increase foraging activity through increased abundance of food resources (e.g. lights attracting insects; Larkin et al. 1996).

CLIMATE CHANGE

Climate projections for the Pilbara have been studied in detail by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) (Loechel et al. 2011; Charles et al. 2013; Watterson et al. 2015). The CSIRO ôInterim report on the hydroclimate of the Pilbara: Past, present and futureô(Charles et al. 2013) described the fundamental scientific tool used to evaluate how the future climate will evolve in response to enhanced concentrations of atmospheric greenhouse gases: the Global Climate Model (GCM). Charles et al. (2013) used GCM projections from 13 GCMs for two different emissions scenarios. A scaling approach was then applied to modify historical daily rainfall and potential evaporation data to produce datasets of how the historical data would have looked under future atmospheric conditions. The baseline period was 1961 to 2011 and the climate was based on 2030 and 2050 atmospheric conditions for both low and high emissions scenarios.

With regard to projected annual rainfall, the models produced a large range of results; some indicated a decrease in rainfall and others an increase. In general, the high emissions scenario resulted in a drier climate in comparison to existing and lower emissions scenarios. The median results showed that future climate rainfall projections do not vary by more than five per cent from current levels.

The report by Charles et al. (2013) also suggested that the global frequency of tropical cyclones will either decrease or remain essentially unchanged due to greenhouse warming. Modelling carried out on Australian tropical cyclones indicated an approximate 100 kilometre southward shift in genesis and decay regions of cyclones, as well as an increase in wind speed, rainfall intensity and integrated kinetic energy. These indications suggest that the intensity of cyclonic rainfall in the Pilbara is likely to increase. An increase in tropical cyclone intensity not only increases the degree of destruction at the centre of the cyclone but also the geographic area over which the cyclonic winds and flooding rains impact. Thunderstorm intensity, which is important for regular runoff events, was not modelled by Charles et al. (2013).

The CSIRO projections suggest that both mining companies and the local communities will need to adapt their practices to improve water use efficiency and cope in the hotter extremes. Dunlop et al. (2012) suggested that one probable impact of climate change is alteration to vegetation structure in response to a reduction in the availability of water.

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.

8.1.3 Key information gaps related to methods

Key information gaps for the methods relate to the estimated levels of potential impact. Uncertainty exists with regard to the distance or area thresholds specified for each potential impact and the magnitude/value of the potential impact applied for each distance or area category. Further uncertainty exists in relation to the potential synergistic or interactive effects of different impacts, whereby the resultant effect may be different in nature to the sum of the individual effects. Of key relevance with regard to uncertainty are the potential impacts applied for which there was an associated low level of confidence; however, uncertainty applies to all potential impacts.

More broadly, with regard to the method used to apply potential impact to MNES in this CIA, a literature review is provided in **Appendix B**, which includes analysis of CIA theories and principles and the approaches used in real world examples of CIA in Australia, North America and Europe. **Appendix B** includes analysis of numerous CIA case studies and examination of the tasks common to most studies, along with analysis of practice guides for conducting CIA, each of which offers a recommended approach for CIA.

A key difference in the studies was the modelling technique applied. The various approaches reviewed each customised a modelling technique to suit their specific goals. This included purchasing specialised software, creating a tailored probability model, using correlation and regression analyses, and building software that incorporates a GIS component and relies on impact matrices, where required. The spatial approach used in this CIA to apply potential impacts to the Greater Bilby, Hamersley Lepidium, Northern Quoll, Pilbara Leaf-nosed Bat and Pilbara Olive Python is consistent with the recommended approach. One of the main advantages of the approach is identification of the spatial distribution of potential impacts and the likely interaction (through multiplication and spatial overlay). This is suitable for large scale assessments such as for the Proposal. The main limitations of the approach relate to the distance or area thresholds specified for each potential impact and the magnitude/value of the potential impact applied for each distance or area category, not to the approach per se.

For example, the level of potential impact for predation was set at 20 per cent for the Greater Bilby, Northern Quoll and Pilbara Olive Python within two kilometres of human settlements (such as towns and mine camps), roads and power lines. Uncertainty exists for both the value of 20 per cent and the distance of two kilometres. These values were based on a review of available scientific and other literature, along with specialist expertise and knowledge; however, the actual effect of feral predators on the three MNES in question may be more or less (both in terms of magnitude and extent) than that determined in the CIA.

Levels of potential impact were also standardised across all impacts (e.g. predation and low grazing pressure were both rated as Low [20 per cent impact] for the Greater Bilby; **Table 11** and **Table 13**) and all species (e.g. a Medium level impact for the Greater Bilby was applied as a 50 per cent impact, as were Medium level impacts for all other species). This was a deliberate and measured decision made in the development of the CIA methodology, in large part to minimise conjecture given the high level of uncertainty for some threats and lack of species-specific data. This approach was considered fit for purpose to assess the potential cumulative impacts of the Full Development Scenario in the context of the objectives of this study. It is considered unlikely that greater precision (for example application of a variable Low level impact of 20, 25 or 30 per cent on a case by case basis according to species and type of impact) is defensible based on scientific literature and publicly available data. Further, it is considered likely that, if such a change were made, the effect on the key outcomes of the CIA would be inconsequential. This is particularly likely to be the case in the context of the Proposal, which was determined to be a non-significant contributor to the potential cumulative impacts to MNES (Section 9).

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**).

Levels of potential impact were set based on the best available literature, data and specialist expertise and knowledge. This 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. For example, application of potential impacts of fragmentation was based on patch size (Section 3.3.5), but did not consider distance between patches. The CIA could be refined through information gained from studies specifically targeting the species and potential impacts considered.

The CIA methodology has been subject to extensive review by a specialist peer review panel (Section 2.7) and was generally accepted by peer reviewers as robust and technically sound, with some reservations. With respect to each MNES:

- For the Greater Bilby, ñthe cumulative impact likely to occur with the expansion of mining has been difficult to access based on the assessment conducted. This will remain the case until a more robust indication of distribution and extent of habitat suitability can be defined and the description of the threat layer is better resolvedò (Southgate, R., pers. comm., 2015). ñThere are a number of minor errors or interpretive problems in the Species synopsis but none drastically affect the impact assessment modelling. A coherent a priori conceptual model of habitat and conditions where one might expect to find a bilby in the Pilbara is still lackingò (Southgate, R., pers. comm., 2015). ñThe key threats identified appear reasonable except for the omission of fire. Weeds are likely to be a sleeper problem. Most of the assumptions regarding risk of impact and the ranking of potential impacts look reasonable given our current state of knowledge for the region. However, there is considerable parameter uncertainty regarding the potential impact of key threats because there is lack of clarity regarding the inclusion/exclusion of spatial data of assets used to develop threat layersò (Southgate, R., pers. comm., 2015).
- For Hamersley Lepidium, the ñGIS coverages of disturbance footprints, which are overlaid with the species distribution predictions to assess levels of impacts, are mostly based on reasonable data and acceptable assumptionsò (van Etten, E., pers. comm., 2015). The specific impact levels applied for Hamersley Lepidium ñseem appropriate and reasonable in the case of this species given clearing completely removes the species, whilst even high levels of weed infestation would not necessarily eliminate the species at the local scaleò (van Etten, E., pers. comm., 2015).
- For the Northern Quoll, there is ñsome concern with presentation of methodology and assumptions madeé For example, the risk posed by Foxes and feral Cats is strongly linked to distance from settlement, but the general observation of the impact of these species suggests this link is overstated. Both species are widespread away from settlement and have had massive impacts upon significant mammals away from settlement. It remains a concern that the Cane Toad is not included in the analysesé ò (Bamford, M., pers. comm., 2015).
- For the Pilbara Leaf-nosed Bat, the reviewer ñdid not highlight any major issue with the methods and analyses thaté limited the usefulness of outputs or the opportunity to make sound conclusions, except for the issue with species occurrence dataò (Armstrong, K., pers. comm.,

2015). ñMy understanding of the CIA analysis process as it is presented is that it is appropriate. But I do also think there are problems with certain datasets that have probably influenced the results, and therefore the usefulness of the modelsò (Armstrong, K., pers. comm., 2015).

- The methods and analyses used for the Pilbara Olive Python CIA were considered ñtechnically sound considering the purpose of the assessment and the limited availability and considerable variability of available dataò (Fitzgerald, M., pers. comm., 2015).

9 Key outcomes and significance assessment

9.1 KEY OVERALL OUTCOMES

The key overall outcomes of the CIA are summarised in **Table 49**, which presents the modelled potential impact to Habitat Rank 4 for each MNES that was attributable to each of the impacts considered in the CIA, and the potential cumulative effect attributable to all impacts combined, as a percentage of the modelled extent of Habitat Rank 4 in the base case.

Of note:

- The overall potential cumulative impact to the Greater Bilby, Northern Quoll and Pilbara Olive Python was high (and above the indicators of potentially significant effects; Section 2.6.1).
- The overall potential cumulative impact to Hamersley Lepidium and the Pilbara Leaf-nosed Bat was low (and well below the indicators of potentially significant effects; Section 2.6.1).
- Existing impacts were the main contributor to the modelled potential cumulative impacts for all MNES, although the magnitude of contribution was significantly greater for the Greater Bilby, Northern Quoll and Pilbara Olive Python.
- The contribution of reasonably foreseeable future third party mines to the modelled potential cumulative impact to all MNES was negligible as a percentage of the total area of the Pilbara bioregion and in comparison to the effect of existing impacts.
- The contribution of the Full Development Scenario to the modelled potential cumulative impact to all MNES was negligible as a percentage of the total area of the Pilbara bioregion and in comparison to the effect of existing impacts.

Table 49: Cumulative Effects Assessment matrix for potential cumulative impacts to MNES

MNES	Existing impacts	Future third party mines	Full Development Scenario	Potential cumulative impact
Greater Bilby	94%	0%	<1%	94%
Hamersley Lepidium	3%	<1%	4%	7%
Northern Quoll	91%	<1%	<-1%	91%
Pilbara Leaf-nosed Bat	2%	<1%	<1%	2%
Pilbara Olive Python	74%	<1%	<1%	75%

* Minor discrepancies between some values may be present due to rounding. Percentages were determined using the Pilbara bioregion; however, it is noted that the distributions of 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.

9.2 EVALUATION OF OBJECTIVES

This CIA was undertaken to achieve the following objectives:

- present a base case of habitat suitability in the Pilbara bioregion for each of 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 outcomes in achieving the first three objectives are summarised in the following sections:

- Present a base case of habitat suitability in the Pilbara bioregion for each of five relevant MNES, from which potential cumulative impact increases could be measured ï this is reported on in detail in **Appendix A** and summarised for each species 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).
- 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 ï this is reported on for each species in Section 3.5, **Table 14** and **Table 15** (Greater Bilby); Section 4.5, **Table 19** and **Table 20** (Hamersley Lepidium); Section 5.5, **Table 28** and **Table 29** (Northern Quoll); Section 6.5, **Table 36** and **Table 37** (Pilbara Leaf-nosed Bat); and Section 7.5, **Table 47** and **Table 48** (Pilbara Olive Python).
- Determine the proportion of potential cumulative impact attributable to the Proposal ï this is reported on for each species in Section 3.5, **Table 14** and **Table 15** (Greater Bilby); Section 4.5, **Table 19** and **Table 20** (Hamersley Lepidium); Section 5.5, **Table 28** and **Table 29** (Northern Quoll); Section 6.5, **Table 36** and **Table 37** (Pilbara Leaf-nosed Bat); and Section 7.5, **Table 47** and **Table 48** (Pilbara Olive Python).

The fourth objective is addressed in Section 9.2 (Greater Bilby), Section 9.4 (Hamersley Lepidium), Section 9.5 (Northern Quoll), Section 9.6 (Pilbara Leaf-nosed Bar) and Section 9.7 (Pilbara Olive Python). The CIA outcomes have been subject to extensive review by a specialist peer review panel (Section 2.7). Key comments from each of the species matter experts on the panel are included in Sections 9.2 to 9.7 and a summary of the species matter expertsôassessment of the cumulative impact of the Proposal to the viability of the five relevant MNES considered in the CIA is provided in **Appendix D**.

9.3 GREATER BILBY

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. 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**).

After modelled existing impacts were accounted for, the remaining extent of Habitat Rank 4 was 112,291 hectares (**Table 14**). Of this, the modelled potential impacts of future third party mines and the Full Development Scenario were zero per cent and approximately 0.1 per cent respectively. These modelled potential impacts are considered negligible and unlikely to place substantial additional pressure on the species such that the chance of its persistence in the region is affected.

Comments from Dr. Rick Southgate, the Greater Bilby subject matter expert on the peer review panel (Section 2.7), aligned with this conclusion. Dr. Southgate stated that the direct cumulative effects of BHP Billiton Iron Ore’s mining operations on the viability of the Greater Bilby population in the Pilbara bioregion are likely to be minor relative to the indirect cumulative effects (Southgate, R., pers. comm., 2015). Dr. Southgate’s assessment of the cumulative impact of the Proposal to the viability of the Greater Bilby is summarised in **Appendix D**.

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 Proposal will not affect the Greater Bilby’s chance of persistence in these parts of its range.

Other relevant threats that were not modelled in the CIA for the Greater Bilby included inappropriate fire regimes, weeds, the Cane Toad, noise, light and climate change (Section 3.3.2). Of these, the potential future effects of fire and climate change on the Greater Bilby in the Pilbara bioregion may be substantial; however, any such impacts would occur largely independent of, and would not be exacerbated by, the Proposal. Some, such as fire, are also likely to be influenced primarily by assumptions of fire management and fire response.

A separate IAR for the Proposal has been prepared and considers the outputs of this report in the context of the management frameworks that BHP Billiton Iron Ore has proposed to manage potential cumulative impacts identified in this CIA report. The IAR also discusses in further detail the potential for the Proposal to affect the Greater Bilby’s persistence and viability in the Pilbara bioregion.

9.4 HAMERSLEY LEPIDIUM

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; **Table 19**). This modelled potential impact is relatively minor in the context of the total modelled extent of Habitat Rank 4 in the Pilbara bioregion and would not be likely to affect the species’ chance of persistence in the bioregion.

After modelled existing impacts were accounted for, the remaining extent of Habitat Rank 4 was 844,783 hectares (**Table 19**). Of this, the modelled potential impacts of future third party mines and the Full Development Scenario were approximately 0.4 per cent and four per cent respectively. These modelled potential impacts are considered minor and unlikely to place substantial additional pressure on the species such that the chance of its persistence in the region is affected.

Comments from Dr. Eddie van Etten, the Hamersley Lepidium subject matter expert on the peer review panel (Section 2.7), supported the outcomes of the modelling and aligned with this conclusion. Dr. van Etten stated that the modelled existing and future impacts to Hamersley Lepidium are considered to be realistic and based on reasonable assumptions and, while the cumulative loss of Habitat Rank 4 is large in absolute terms, it is considered to be relatively small in the context of the speciesô likely widespread distribution (van Etten, E., pers. comm., 2015). Dr. van Etten further stated that it is unlikely that the modelled impacts of the CIA to Hamersley Lepidium habitat suitability will further threatened the species ñgiven there will still likely be many large and widespread populations throughout the Pilbara outside future disturbance footprints which will remain viable over the long-termò (van Etten, E., pers. comm., 2015). Dr. van Ettenõs assessment of the cumulative impact of the Proposal to the viability of Hamersley Lepidium is summarised in **Appendix D**.

It is noted that, while large populations of Hamersley Lepidium occur on mining tenements and therefore that mining poses a potential key threat to the species, disturbance events such as mining can also result in mass germination of Hamersley Lepidium as the species is a disturbance opportunist (Onshore Environmental 2012). Therefore, there is a possible mechanism for the Proposal to result in a positive impact to Hamersley Lepidium, although this is speculative and was not modelled in the CIA on this basis.

Other relevant threats that were not modelled in the CIA for Hamersley Lepidium included inappropriate fire regimes and climate change (Section 4.3.2). The potential effects of these on Hamersley Lepidium may be substantial; however, any such impacts would occur largely independently of, and would not be exacerbated by, the Proposal.

A separate IAR for the Proposal has been prepared and considers the outputs of this report in the context of the management frameworks that BHP Billiton Iron Ore has proposed to manage potential cumulative impacts identified in this CIA report. The IAR also discusses in further detail the potential for the Proposal to affect Hamersley Lepidiumõs persistence and viability in the Pilbara bioregion.

9.5 NORTHERN QUOLL

The potential cumulative impact to Northern Quoll habitat suitability was a decrease in the extent of the most suitable habitat (Habitat Rank 4) of approximately 1.4 million hectares (91 per cent of the modelled extent in the base case). Existing impacts were the main contributor to this potential impact. 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 (**Table 28** and **Table 29**).

After modelled existing impacts were accounted for, the remaining extent of Habitat Rank 4 was 140,516 hectares (**Table 28**). Of this, the modelled potential impacts of future third party mines and the Full Development Scenario were zero per cent and approximately 0.4 per cent respectively. These modelled potential impacts are considered negligible and unlikely to place substantial additional pressure on the species such that the chance of its persistence in the region is affected.

Comments from Dr. Mike Bamford, the Northern Quoll subject matter expert on the peer review panel (Section 2.7), aligned with this conclusion. Dr. Bamford stated that ñgreatest risk to viability remains the Cane Toad, with feral predators and fire also of concern. Grazing and weeds may have an effect. Cumulative impacts associated with BHP operations are thought unlikely to have the landscape scale impacts that drive population viabilityò (Bamford, M., pers. comm., 2015). Dr. Bamfordõs assessment of the cumulative impact of the Proposal to the viability of the Northern Quoll is summarised in **Appendix D**.

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 Proposal will not affect the Northern Quollõs chance of persistence in these parts of its range.

Other relevant threats that were not modelled in the CIA for the Northern Quoll included the Cane Toad, inappropriate fire regimes, parasitism and disease, hunting and persecution, climate change, noise and light (Section 5.3.2). Of these, the potential future effects of the Cane Toad, fire and climate change on the Northern Quoll in the Pilbara bioregion may be substantial; however, any such impacts would occur largely independently of, and would not be exacerbated by, the Proposal. Some, such as fire, are also likely to be influenced primarily by assumptions of fire management and fire response Mining may facilitate establishment of the Cane Toad in the Pilbara bioregion through provision of artificial water sources; however, this would be addressed through risk assessment and management.

A separate IAR for the Proposal has been prepared and considers the outputs of this report in the context of the management frameworks that BHP Billiton Iron Ore has proposed to manage potential cumulative impacts identified in this CIA report. The IAR also discusses in further detail the potential for the Proposal to affect the Northern Quollõs persistence and viability in the Pilbara bioregion.

9.6 PILBARA LEAF-NOSED BAT

The potential cumulative impact to Pilbara Leaf-nosed Bat habitat suitability was a decrease in the extent of the most suitable habitat (Habitat Rank 4) of approximately 39,000 hectares (two per cent of the modelled extent in the base case; **Table 36**). This modelled potential impact is relatively minor in the context of the total modelled extent of Habitat Rank 4 in the Pilbara bioregion and would not be likely to affect the speciesô chance of persistence in the bioregion.

Comments from Dr. Kyle Armstrong, the Pilbara Leaf-nosed Bat subject matter expert on the peer review panel (Section 2.7), generally aligned with this conclusion. Dr. Armstrong stated that the "viability of the (Pilbara Leaf-nosed Bat) attributable to the cumulative BHPBIO operations probably represents a small proportion of the overall threat allocation for this taxon in the Pilbara, but significant local losses contributing to an overall level of decline sufficient for IUCN threatened status listing could still occur without exploratory survey, mitigation and management" (Armstrong, K., pers. comm., 2015). Dr. Armstrong further stated that the effects of mining ñmight not necessarily be negligible. If even a small number of known roosts containing a significant proportion of the known regional population are destroyed, this could have a major effect on area of occupancy as well as the viability of the population. Loss of roosts is a very local effect, but even the loss of one important focal roost can have a large implication for area of occupancy and the regional population. The location of important roosts needs to be considered explicitly; otherwise, this will not be reflected accurately in the degree of change of area of occupancyò (Armstrong, K., pers. comm., 2015). Dr. Armstrongõs assessment of the cumulative impact of the Proposal to the viability of the Pilbara Leaf-nosed Bat is summarised in **Appendix D**.

With regard to potential impacts to Pilbara Leaf-nosed Bat roosts, Dr. Armstrong noted that ñwe know of relatively few roosts in or near BHPBIO leases that have colonies of significant size, or caves that are considered to be important long term resources for the (Pilbara Leaf-nosed Batò (Armstrong, K., pers. comm., 2015). Of the eight confirmed diurnal roost locations within the Pilbara bioregion provided by Dr. Armstrong, none were located near the existing BHP Billiton Iron Ore and third party mines considered in the CIA, nor the Proposal mining operations (**Figure 58** and **Figure 60**). Only the Koodaideri roost is located near one of the proposed future third party iron ore mines considered in the CIA (**Figure 59**). Identification and management of the potential impacts to this roost are reported on in detail in the Public Environmental Review document and Response to Submissions document for the

Koodaideri Iron Ore Mine and Infrastructure Project (State Assessment Number 1933; EPBC Act Reference Number 2012/6422).

Other relevant threats that were not modelled in the CIA for Pilbara Leaf-nosed Bat included loss of suitable roosts due to flooding of dis-used mines, loss (evacuation) of suitable roosts due to human entry of roosts and capture of bats, loss of suitable roost habitat due to sealing/destroying of old mine shafts and horizontal adits during site rehabilitation, natural predators, climate change, the Cane Toad, noise, light and vibration (Section 6.3.2). The potential effects of climate change on the Pilbara Leaf-nosed Bat may be substantial; however, any such impacts would occur largely independently of, and would not be exacerbated by, the Proposal. Of the other threats, some may have a substantial effect on the Pilbara Leaf-nosed Bat and may be influenced by the Proposal, particularly at a local scale if a significant roosting site is affected; however, in such cases, there exists considerable potential to minimise the risk to the roosting site and resident bats through site-specific design and management measure.

A separate IAR for the Proposal has been prepared and considers the outputs of this report in the context of the management frameworks that BHP Billiton Iron Ore has proposed to manage potential cumulative impacts identified in this CIA report. The IAR also discusses in further detail the potential for the Proposal to affect the Pilbara Leaf-nosed Batõs persistence and viability in the Pilbara bioregion.

9.7 PILBARA OLIVE PYTHON

The potential cumulative impact to Pilbara Olive Python habitat suitability was a decrease in the extent of the most suitable habitat (Habitat Rank 4) 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 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 (**Table 47** and **Table 48**).

After modelled existing impacts were accounted for, the remaining extent of Habitat Rank 4 was 289,086 hectares (**Table 47**). Of this, the modelled potential impacts of future third party mines and the Full Development Scenario were 0.8 per cent and 0.5 per cent respectively. These modelled potential impacts are considered negligible and unlikely to place substantial additional pressure on the species such that the chance of its persistence in the region is affected.

Comments from Dr. Mark Fitzgerald, the Pilbara Olive Python subject matter expert on the peer review panel (Section 2.7), generally aligned with this conclusion, but noted the ñsubstantial and probably unavoidable uncertainty concerning the ñviabilityò of Pilbara Olive Python attributable to BHP Billiton Iron Ore operationsò and that ñpredictions about viability of the species are unavoidably speculativeò (Fitzgerald, M., pers. comm., 2015). Dr. Fitzgerald stated that, ñwhile persistence of the Pilbara Olive python within the Pilbara Bioregion is considered likely, the viability of the species within the BHPBIO (Proposal) lands will likely depend upon timely implementation of effective threat managementò (Fitzgerald, M., pers. comm., 2015). Dr. Fitzgeraldõs assessment of the cumulative impact of the Proposal to the viability of the Pilbara Olive Python is summarised in **Appendix D**.

Other relevant threats that were not modelled in the CIA for the Pilbara Olive Python included mortality from false human identification, inappropriate fire regimes, climate change, the Cane Toad, noise and light (Section 7.3.2). Of these, the potential future effects of fire, climate change and the Cane Toad on the Pilbara Olive Python in the Pilbara bioregion may be substantial; however, any such impacts would