Australian Government
Department of Sustainability, Environment, Water, Population and Communities

Biodiversity

Species Profile and Threats Database

Rhinonicteris aurantia (Pilbara form)— Pilbara Leaf-nosed Bat

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Biodiversity

Species Profile and Threats Database

Glossary

Rhinonicteris aurantia (Pilbara form)— Pilbara Leaf-nosed Bat

SPRAT Profile

For information to assist proponents in referral, environmental assessments and compliance issues, refer to the Policy Statements and Guidelines (where available), the Conservation Advice (where available) or the Listing Advice (where available).

In addition, proponents and land managers should refer to the Recovery Plan (where available) or the Conservation Advice (where available) for recovery, mitigation and conservation information.

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Legal Status and Documents

EPBC Act Listing Status	**Listed as Vulnerable** as *Rhinonicteris aurantia (Pilbara form)*
Listing and Conservation Advices	*Commonwealth Listing Advice on ten species of Bats* (Threatened Species Scientific Committee, 2001a) [Listing Advice]. *Commonwealth Conservation Advice on* Rhinonicteris aurantius (Pilbara form) (Threatened Species Scientific Committee, 2008xu) [Conservation Advice].
Policy Statements and Guidelines	*Survey Guidelines for Australia's Threatened Bats. EPBC Act survey guidelines 6.1* (Department of the Environment, Water, Heritage and the Arts (DEWHA), 2010m) [Admin Guideline].
Federal Register of Legislative Instruments	*Inclusion of species in the list of threatened species under section 178 of the Environment Protection and Biodiversity Conservation Act 1999 (29/03/2001)* (Commonwealth of Australia, 2001h) [Legislative Instrument] as *Rhinonicteris aurantius (Pilbara form)*. *Amendment to the list of threatened species under section 178 of the Environment Protection and Biodiversity Conservation Act 1999 (87) (23/09/2009)* (Commonwealth of Australia, 2009i) [Legislative Instrument] as *Rhinonicteris aurantia (Pilbara form)*.

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Naming

Scientific name	*Rhinonicteris aurantia (Pilbara form)* [82790]

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Family	Hipposideridae:Chiroptera:Mammalia:Chordata:Animalia
Species author	(J.E. Gray, 1845)
Infraspecies author	
Reference	
Other names	*Rhinonicteris aurantius (Pilbara form)* [66887]

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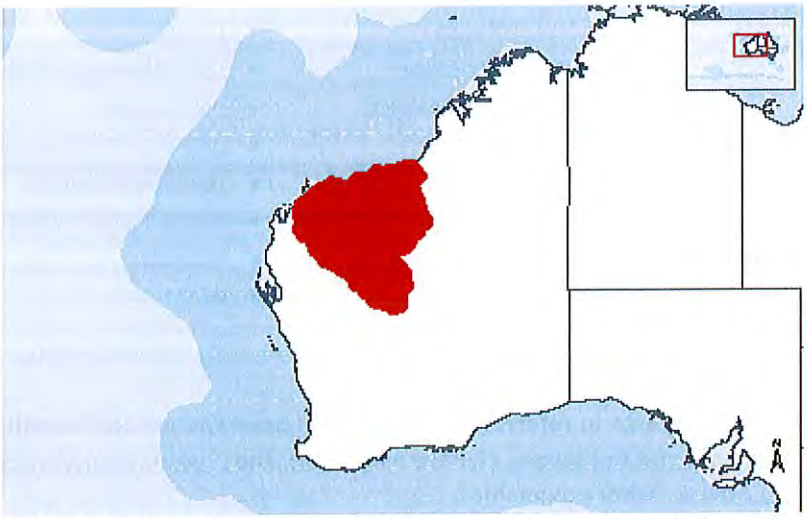
Distribution Map

Distribution map



This is an indicative distribution map of the present distribution of the species based on best available knowledge. See map caveatfor more information.

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Illustrations

Illustrations Google Images

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Australian and State/Territory Government Legal Status

The current conservation status of the Pilbara Leaf-nosed Bat, *Rhinonicteris aurantia* (Pilbara form), under Australian and State Government legislation, is as follows:

National: Listed as Vulnerable under the *Environment Protection and Biodiversity Conservation Act 1999*. *Rhinonicteris aurantia* (Pilbara form) is considered a species for the purpose of listing. The general form - *Rhinonicteris aurantia* - is not listed at the species level.

Western Australia: *Rhinonicteris aurantia* (including both Kimberley and Pilbara forms) is listed under the *Wildlife Conservation Act 1950*; Listed as rare or likely to become extinct under the *Wildlife Conservation (Specially Protected Fauna) Notice 2008*; and Listed as Vulnerable on the Western Australian Department of Environment and Conservation *Priority Fauna List*.

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Taxonomy

Scientific name: *Rhinonicteris aurantia* (Pilbara form)

Common name: Pilbara Leaf-nosed Bat, Orange Leaf-nosed Bat

While the Pilbara Leaf-nosed Bat is listed as *Rhinonicteris aurantius* (Pilbara form) under the EPBC Act and as *Rhinonicteris aurantius* under the Western Australian legislation, the correct scientific name for this species is *Rhinonicteris aurantia* (Armstrong 2006a). In this profile, the common name 'Orange Leaf-nosed Bat' is used to refer to *Rhinonicteris aurantia* - the taxon at the species level. *Rhinonicteris aurantia* (Pilbara form) will be referred to as the 'Pilbara Leaf-nosed Bat'. Further detailed information on nomenclature can be found in Armstrong (2006a).

The species as a whole is conventionally accepted. The genus contains one species only (though there is at least one fossil species, *Rhinonicteris tedfordi*, (Hand 1997)) and its closest relatives are morphologically distinct and not distributed in Australia (Hill 1982).

The Pilbara Leaf-nosed Bat population was first suggested to be distinct from the Orange Leaf-nosed Bat on the the basis of preliminary observations by Duncan and colleagues (1999). Isolation of the Pilbara and the more northern Orange Leaf-nosed Bat was thought to have occurred many thousands of years ago (Armstrong 2006b).

Armstrong (2003) found further evidence for the divergence of this population in skull morphology, echolocation call frequency and DNA (Armstrong 2002, 2006b; Armstrong & Coles 2007). However, the limited number of samples available to these studies have delayed a final taxonomic decision. Further genetic work aims to confirm their genetic isolation and provide an estimate of the approximate time since their separation (K.N. Armstrong, unpublished data).

Comparisons of skeletal museum specimens from the Pilbara, Kimberley and Northern Territory found that *Rhinonicteris aurantia* was morphologically similar throughout its entire range, except for subtle differences in the size of the nasal inflations (the Pilbara form had smaller nasal capsules; Armstrong 2002, 2003, 2005). This corresponded with a consistent pattern of echolocation call frequency difference, with the Pilbara population characterised by a higher mean call frequency (approximately 121 kHz compared with 114 kHz in the Kimberley and Northern Territory; Armstrong & Coles 2007). A third dataset demonstrated genetic divergence of the Pilbara population using population-level DNA markers (Armstrong 2006b). Morphological, echolocation and genetic data suggested divergence and local adaptation but further samples and nuclear DNA markers are needed for a more confident assessment of the taxonomic status of population isolates (Armstrong 2006b; Armstrong & Coles 2007).

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Description

The Pilbara Leaf-nosed Bat is a moderate-sized bat with short fur, relatively small ears and a fleshy noseleaf structure surrounding the nostrils. It weighs from 8.7–9.3 g and has a forearm length of 45.2–47.8 mm (Armstrong 2001, 2002). Sexes are mostly similar in size, especially in external features though subtle differences were reported in some skull characters (Armstrong 2002).

The Pilbara Leaf-nosed Bat has bright orange fur, especially on the front of the body. The back appears darker because of brownish tips to the fur. Paler orange bats are likely to be older. Several other colour variations can occur: pale/silver, lemon/yellow and fawn (Armstrong 2001). It may be identified in flight from its orange fur colour in a spotlight beam. However, such observations should be confirmed with the use of ultrasonic bat detectors, since other similar-sized species can sometimes appear pale (K.N. Armstrong unpubl. obs.). The Orange Leaf-nosed Bat in the Northern Territory also has colour variations, with some animals more commonly displaying colours other than orange (Churchill et al. 1988; Jolly 1988).

The noseleaf is distinctively diamond-shaped, in contrast to the square-ish or round shape of the noseleaf in other leaf-nosed bats (*Hipposideros* spp.) and horseshoe bats (*Rhinolophus* spp.) respectively (though neither of these genera are present in the Pilbara). Illustrations of the noseleaf are found in Wood Jones (1925), Ride (1970) and Hill (1982). Apart from some very subtle size differences, the noseleaf is similar in structure between the Pilbara and its more northern counterpart, the Orange Leaf-nosed Bat (Armstrong 2002).

When in the roost, Orange Leaf-nosed Bats form aggregation patterns typical of other leaf-nosed bat species, with clusters of individuals maintaining a small distance of 12–15 cm between themselves, and always on the ceiling rather than vertical surfaces (Churchill et al. 1988; Jolly 1988). The species tend to be sensitive to human intrusion and will often take flight before they are encountered, disappearing further into the structure (Armstrong 2008, Hall 1983; Jolly & Hand 1995).

The Pilbara Leaf-nosed Bat is a supremely acrobatic and high energy flier, intercepting insect prey whilst in flight and also able to fly slowly like the dusky leaf-nosed bat *Hipposideros ater* (Bullen & McKenzie 2001, 2002, 2004).

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Australian Distribution

R. aurantia is endemic to Australia and its range stretches from the Pilbara region of Western Australia to Camoweal in Queensland.

The Pilbara Leaf-nosed Bat, however, is restricted to the Pilbara region and field surveys suggest that it is divided into three discrete subpopulations (eastern Pilbara mines and granite, Hamersley Range, Upper Gascoyne), separated by relatively flat areas that impede gene flow such as the Fortescue and Ashburton valley (Armstrong 2001, 2003, in litt.a).

Colonies of the the Pilbara Leaf-nosed Bat are found in three distinct areas: in the mines of the eastern Pilbara; scattered throughout the Hamersley Range in smaller colonies; and in sandstone formations south of the Hamersley Range in a small number of significant colonies (Armstrong 2001). This includes the confirmed roosts of: Bamboo Creek mine, Copper Hills mine, Klondyke Queen mine, Lalla Rookh mine and one cave in Barlee Range; and 16 other likely permanent occurrences.

Locations are defined as sites that support a colony, such as a cave or mine. Determining the number of locations occupied by the Pilbara Leaf-nosed Bat is complicated by two factors: first, not all roosts may be used throughout the year; and second, many records of the species in the region are of bats in flight or roadkills. Several observations within an area may derive from a single nearby roost, such as is probably the case at Cattle Gorge and Callawa Gorge (Ecologia 2005a, 2005b, 2006b). The Pilbara Leaf-nosed Bat has been observed in the vicinity of workings such as the Trump, Bow Bells and Marble Bar copper mine but it is possible that all of these individuals may have roosted in the Klondyke Queen mine (Armstrong 2001).

Four major roosts in mines are currently known from the eastern Pilbara district (i.e. excluding the currently flooded Comet mine) and one from a cave in Barlee Range Nature Reserve (see Population Information section).

Bamboo Creek mine, Bamboo Creek Mining Centre. This area contains many old workings but the most significant is the Bamboo Creek mine itself. This contains a main decline of at least 1 km and many workings extending from this. It is interconnected with entrances or other workings such as the Perseverance, Kitchener and Bamboo Queen. The Pilbara Leaf-nosed Bat maintains a large colony throughout the year which is likely to be the largest in the region. Bats exit predominantly from the main decline. A horizontal adit entrance used previously by the Pilbara Leaf-nosed Bat that is present at base of the Bamboo Queen open cut is now flooded, but the colony still has access from the main entrance (K.N. Armstrong September 2006, unpubl. obs.).

Copper Hills mine, near Nullagine. This old copper mine is in poor condition but maintains a colony of the Pilbara Leaf-nosed Bat over a pool at the bottom of a large pit that connects to underground workings.

Klondyke Queen mine, near Marble Bar. The areas between Klondyke King and Kopckes Reward (east of the Klondyke Queen mine) have been surveyed and found not to contain roosts of the Pilbara Leaf-nosed Bat (Armstrong 2001; Armstrong in litt. b; Biota 2001a). The western lease (M45/668) part of the project area contains a colony of the Pilbara Leaf-nosed Bat in the old workings of the Klondyke Queen. The mine is in a poor state of repair and there is evidence of several collapses, both near the entrance and underground (Armstrong 2001).

Lalla Rookh mine, Panorama Station. This mine was only recently found to contain the Pilbara Leaf-nosed Bat (K.N. Armstrong April 2004, unpubl. obs.) and the existence of a significant colony of the Ghost Bat *Macroderma gigas* is also known. The stoped (vertically excavated), angled entrance appears relatively stable but is dangerous for human entry. Environmental impact assessments nearby at the proposed Sulphur Springs mine recorded significant numbers of the Pilbara Leaf-nosed Bat in flight in a watercourse (Armstrong 2007a). The origin of these is unknown but might be the Lalla Rookh mine.

Yarrie - Nimingarra operations, near Goldsworthy. The public submission for the Goldsworthy Extension Project cited recent observations of the Pilbara Leaf-nosed Bat by their environmental consultant in several areas adjacent to planned activities (Ecologia 2005a, b, 2006b). Captures of the Pilbara Leaf-nosed Bat made for tissue sampling did not confirm roosts at any of the caves where the Pilbara Leaf-nosed Bat were observed in the local area (Cattle Gorge, Callawa Gorge), despite their continued presence (K.N. Armstrong September 2006, unpubl. obs.).

Comet mine, Marble Bar. This mine appears to remain unsuitable for habitation in its current flooded and unmanaged state. It is currently used as a tourist attraction and also contains a significant colony of the Ghost Bat *Macroderma gigas* (Armstrong 2001; Hall et al. 1997). Until recently, the owner (Haoma Mining NL) conducted underground tours but recently ceased following safety recommendations. This also reduces disturbance to bat colonies. Haoma Mining undertakes no specific action for bat management. The mine is relatively stable, despite being flooded in the lower levels.

A total of 16 observations of bats in flight might indicate additional roost sites, but these require confirmation. There are five roadkill records and each of these may indicate a previously unknown roost. Other unknown roosts may exist in underground mines or natural caves, however, the larger depths of the underground mines in comparison with the shallow depth of the natural caves would mark them as preferred habitat (Armstrong 2001).

A series of targeted surveys was conducted in the Pilbara between 1996 and 1999 by Armstrong (2001, 2003) which identified five new roost sites and several other localities where bats were observed in flight. The largest colonies were observed at Bamboo Creek mine and in a small cave in Barlee Range Nature Reserve.

With the exception of a colony known from the Klondyke Queen mine (Marble Bar, Western Australia; Churchill et al. 1988), most records from the Pilbara prior to 1995 were from opportunistic captures and observations of single individuals (Armstrong 2001).

There is an unsubstantiated record of remains of a Pilbara Leaf-nosed Bat in owl pellets of unknown age at Kintyre (Hart, Simpson & Associates 1994). This location is outside the Pilbara, but is "in similar country of stony hills with small caves". It is unlikely that the Pilbara Leaf-nosed Bat disperses through the desert or occupies habitat there (Armstrong 2003, 2006b).

The extent of occurrence of the Pilbara Leaf-nosed Bat is 122 447 km², bounded by records from: Red Hill Station and Barlee Range Nature Reserve in the west; Cattle Gorge and surrounding areas in the north; Copper Hills mine near Nullagine in the east; and Mt Vernon Station and Paraburdoo (Geode Creek, and an unnamed gorge in the Eastern Ranges) in the south (Armstrong 2001, 2003, in litt. a). The recent Pilbara Biological Survey conducted by the Western Australian Department of Environment and Conservation produced several new records of the species and the details are currently being prepared for publication (March 2007). None of the records were of colonies; all were recordings of bats in flight, so colony size and location was not determined (N.L. McKenzie 2006, pers. comm.).

There is no suggestion that there has been a decline in extent of occurrence in the past 10 years (or three generations) but there has been no detailed study of population size in this period. No known major roosts have been lost (K.N. Armstrong unpubl. data; Armstrong 2001). The colony at the Red Hill mine is now absent but the species is assumed to be still present in the general area as suggested by a record from Fortescue Roadhouse in 1990 (Armstrong 2001) and a more recent capture near Pannawonica ('Mesa K' in the Robe River valley; Biota 2007).

There is currently no information that will suggest a future change in extent of occurrence. An unconfirmed record from a horizontal mine shaft near Jimblebar (north of Newman) might suggest a larger extent of occurrence in the south-eastern Pilbara (Ecologia 2006a).

It is difficult to calculate accurately the area of occupancy for bats because colonies in a cave or mine are essentially point sources and the nightly foraging range of the Pilbara Leaf-nosed Bat is unknown. However, the two estimates provided below are based on extensive field surveys and an understanding of habitat requirements in the region (Armstrong 2001).

The first was calculated using GIS by Armstrong (2003), and later revised (Armstrong in litt.a). The GIS model was an estimate of the area of *potential* occupancy and so included both areas where bats have been recorded and areas where bats might occur based on a suitable combination of rock type and topographical relief. It defined areas that were predicted to have caves with suitable microclimate conditions for the Pilbara Leaf-nosed Bat - in geological terrain that had an observed propensity to form caves and that had significant topographical relief. The total area of potential occupancy was 5783 km² (Armstrong in litt.a), significantly smaller than the area of extent, highlighting how little of the region is available to the species in the Pilbara. Furthermore, much of this area is unsurveyed, and natural roosts, especially in ironstone formations, are likely to be sparse within the predicted area of occupancy model.

The second estimate is based on point locations and foraging range. Only five roosts with significant numbers are currently confirmed and there are 16 observations of occurrence that are considered likely to have a roost nearby but which may support only small colonies (K.N. Armstrong unpublished data). If it is assumed that bats have a normal maximum nightly foraging range of 10 km from their roost (not unreasonable considering other estimates of microbat range), then a circular radius from each point occupies 314 km². In total, the area for 21 locations is 6594 km² (K.N. Armstrong unpubl. data).

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Further observations of the Pilbara Leaf-nosed Bat in other localities will obviously increase the known area of occupancy. The foraging area used by each colony could be much less than 314 km^2.

There is evidence for a small decline in area of occupancy. A large colony was observed in the Comet mine near Marble Bar but has not been observed since the lower levels became flooded in 1997 (Armstrong 2001). This effectively removed one major roost site. The Pilbara Leaf-nosed Bat was observed within 1 km of McKinnon's mine in 2001 but roosting was not confirmed; the structure is collapsing and it is unlikely to be able to support as many individuals as the much larger Comet mine (K.N. Armstrong 2001, unpubl. obs.). In addition, while the Red Hill mine colony is likely to have dispersed many years ago (Armstrong 2001), bats are still present nearby in the Robe River valley (Mesa K), though no roosts have been confirmed yet (Biota 2007).

All other new observations of the species since the surveys of Armstrong (2001) have added to the known area of occupancy (Cattle Gorge, Callawa Gorge, Lalla Rookh mine, Robe River valley, Sulphur Springs) but it is unlikely that these represent recent expansions. For example, the newly discovered colony at the Lalla Rookh mine was colonised sometime in the last 100 years and it is feasible that bats seen approximately 10 km away at Sulphur Springs derive from that roost. In addition, new records near Goldsworthy (Cattle Gorge, Callawa Gorge) and in the Robe River valley are likely to indicate occupancy of natural caves for many hundreds or thousands of years. Not all bats in the eastern Pilbara roost in mines - bats observed at Cattle Gorge, Callawa Gorge, Soansville and Hillside Station are likely to roost in natural caves, suggesting that the Pilbara Leaf-nosed Bat was present in this part of the region before underground mining began in the late 1800s (Armstrong 2001). Thus, while knowledge of their presence has grown, there is no evidence for an increase in area of occupancy in the last ten years. Very few, if any, underground structures have been excavated in the region in the last ten years, with most mining moving to open cut. There has been limited excavation east of the town of Nullagine over the last 30 years or so but the Pilbara Leaf-nosed Bat has not been recorded in this area (Armstrong 2001, 2006c).

Major roost sites in mines (i.e. all known colonies, with the exception of the group in Barlee Range Nature Reserve) and some of those in caves coincide with current or likely future mining interests. Concurrent destruction of habitat has the potential to cause declines within the next ten years. It is assumed from some observations near Marble Bar (Armstrong 2001; in litt. b) that the species has the propensity to move several kilometres in response to disturbances. If neighbouring roost sites are also the focus of disturbances, it must be assumed that the risk of mortality will increase.

There are no captive or re-introduced populations of the Pilbara Leaf-nosed Bat. Mining developments in the future may require consideration of translocation as an option (McKenzie et al. 1999).

There is evidence for both spatial and genetic fragmentation of the Pilbara Leaf-nosed Bat within the Pilbara region. The subpopulation occupying natural cave roosts in the Barlee Range Nature Reserve is separated spatially by the Ashburton valley from the subpopulation that occupies the Hamersley Range. However, this may not represent a major impediment to dispersal and gene flow. The largest spatial discontinuity occurs at the Fortescue valley and separates Barlee Range/Hamersley Range subpopulations from the colonies in the mines of the eastern Pilbara (Armstrong 2003, in litt. a). The genetic study of Armstrong (2006b) was limited somewhat by sample size, but demonstrated that the Barlee Range/Hamersley Range and eastern Pilbara groups were distinct and divergent, with a level of difference of 1.2%. The implication of spatial fragmentation is that losses in one area are unlikely to be replaced from colonies in other subpopulations in the short term. The implication of genetic fragmentation is that different parts of the Pilbara contain unique genetic diversity.

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Surveys Conducted

Numerous targeted surveys were undertaken between 1996 and 1999 by Armstrong (2001, 2003). Five new roost sites were identified and bats were observed in flight in several other localities. An important colony was also located in the Copper Hills mine, north of Nullagine. In addition, several other small mines in the Marble Bar area were thought to be used by a few individuals on at least a temporary basis, though roosting was not able to be confirmed. Bats were observed in flight in a diverse range of other Pilbara landscapes, including ironstone hills (Brockman Iron formations near Paraburdoo and Fortescue Iron formations at Soansville in the east Pilbara) and amongst granite boulder terrain on Hillside Station. While roosts could not be located despite intensive searching, they were assumed to be in relatively deep structures associated with groundwater seeps (Armstrong 2001, 2003).

Recent increases in mining activity have led to further observations of the Pilbara Leaf-nosed Bat by environmental consultants. Significant numbers were observed in the Lalla Rookh mine (K.N. Armstrong April 2004, unpubl. obs.), in flight in several locations near Goldsworthy (Cattle Gorge and Callawa Gorge) (K.N. Armstrong September 2006, unpubl. data), and most recently a capture was made in the Robe River valley near Mesa K (Biota 2007). The currently unpublished observations from the Pilbara Biological Survey will add further localities, although roost sites were apparently not located (N.L. McKenzie 2006, pers. comm.).

Knowledge of the species habitat and distribution has improved considerably in the period since the survey of Churchill and colleagues (1988), however some areas of the Pilbara have still not been surveyed adequately for the species (Armstrong 2001). Furthermore, the difficulty of locating actual roost sites, particularly those in natural caves, limits knowledge on colony size and number in the Hamersley Range.

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Population Information

Accurate estimates of numbers of Pilbara Leaf-nosed Bats are difficult to obtain as the species is rarely captured in any numbers. Recent capture activity allowed some estimation, though exhaustive counts were not possible because of the requirement to cease capture after 30–40 animals and the fact that the species repeatedly flies in and out of the roost structure after dusk, which makes passive counts impossible (K.N. Armstrong September 2006, unpubl. data).

It is currently not possible to estimate population size in the Hamersley Range. However, it is quite likely that colonies will be scattered, of small size and the total abundance smaller than that in the eastern Pilbara.

Estimates of Pilbara Leaf-nosed Bat abundance based on captures and observations of bats in flight, both past and present.

Location	Past observations	Captures (Sept. 2006)	Comment and likely numbers	Sources
Bamboo Creek mine, Bamboo Creek Mining Centre	Many individuals exiting main drive, no counts attempted.	43	Large colony, feasibly 100–200 individuals.	Armstrong 2001; K.N. Armstrong unpublished data.
Cave BR1, Barlee Range Nature Reserve	Capture of 57 individuals in flight, 1999.	11	Night roost, individuals roost elsewhere and forage in this area regularly. Feasibly 100 individuals in Barlee Range Nature Reserve based on previous capture record.	Armstrong 2001; K.N. Armstrong unpublished data.
Cave BR2, Barlee Range Nature Reserve	Approx. 10 in May 1997	-	Major roost site, numbers observed likely an underestimate, but cave becomes unavailable in the driest periods, other roost is likely nearby.	Armstrong 2001
Comet mine, Marble Bar	Large colony observed by J.N. Dunlop	-	Large colony absent since 1997, but small numbers may actually roost on occasions.	Armstrong 2001
Copper Hills mine, north of Nullagine	Up to 3 individuals observed in flight.	2	At least 10–20 individuals likely to be present based on emergence observations.	Armstrong 2001; K.N. Armstrong unpublished data.
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Klondyke Queen mine, Marble Bar	72 captures in 1981, estimated 350 individuals, all subsequent counts have estimated 20 or less.		All were captured in Sept. 2006. Typical colony size is likely to be 20 individuals or less.	Churchill et al. 1988; Armstrong 2001; K.N. Armstrong unpublished data.
Lalla Rookh mine, Panorama Station	Not evaluated.	32	Colony size likely to be 50-100 individuals.	K.N. Armstrong unpublished.
Red Hill mine, Red Hill Station	Unknown, one specimen in WA Museum	-	Mine collapsed, not currently used.	Armstrong 2001
Bow Bells mine, Marble Bar	2	-	Possible roosting habitat but not confirmed.	Armstrong & Coles 1997
Callawa Gorge, Goldsworthy	Not previously trapped.	11	Roost likely nearby. Number 20+?	K.N. Armstrong unpublished data.
Cattle Gorge, Goldsworthy	Not previously trapped.	7	Roost likely nearby. Number 20+?	K.N. Armstrong unpublished data.
Geode Creek, near Paraburdoo - Channar	2 captured.	1 observed	Roost likely nearby. Number 10+?	Armstrong 2006b
Sulphur Springs, Panorama Station	Several individuals captured in harps set in a watercourse, 2006.	-	Roost at Lalla Rookh or nearby?	Armstrong 2007a

The Pilbara population should be considered as comprising two subpopulations based on available data from genetic markers (Armstrong 2006b). The first includes colonies in the eastern Pilbara district. The second includes all colonies in the Hamersley Range and the Upper Gasgoyne region. The mean genetic difference between these two groups was 1.2% and no genetic types were present in both subpopulations.

Pilbara
There is no data to suggest a recent past population decline. The following population counts are based on data from observations in the three largest mines in the area - Klondyke Queen mine, Comet mine and Bamboo Creek mine:

- The colony in the Klondyke Queen was estimated to be 350 individuals (72 actually being captured in 1981 [Churchill et al. 1988]). The most recent observations provided counts of less than 10 since 1996 (Armstrong 2001) and the most recent captures were of only 12 individuals (K.N. Armstrong September 2006, unpubl. data), however, numbers may fluctuate within days (Armstrong in litt. b; Biota 2001a).

- The Comet mine was observed to contain a large colony prior to 1992 but is unlikely to currently support similar numbers because of its flooded status (Armstrong 2001). Local prospectors reported a large colony of the Pilbara Leaf-nosed Bat in the Comet mine prior to 1981 but a later survey did not observe it because of flooding (S.K. Churchill pers. comm. 2006).

- The Bamboo Creek mine ceased operations in 1996 and was only surveyed for the Pilbara Leaf-nosed Bat after this time. It is most reasonable that declines at the Klondyke Queen and Comet may actually reflect dispersal to the Bamboo Creek mine rather than mortality but there is no evidence to resolve this.

Perceived declines, therefore, may actually be fluctuations in occupancy and numbers as a result of disturbance and subsequent relocation (Armstrong 2001). There is also no evidence to suggest population size has increased in the last 10 years, though current numbers were unlikely to be present in the district 100 years prior, before underground workings became available to bats (Armstrong 2001).

Extreme natural fluctuations in population numbers are unlikely, since females produce only one young per year (Churchill 1995). There is evidence that some roosts might not be occupied in drier parts of the year, however, this is unlikely to change extent of occurrence. Area of occupancy might decrease during these periods, if bats aggregate in fewer roosts. Seasonal movements are still not well understood but some roosts are known to be permanent, some seasonal (based on observations of bats in flight) and others may only be night roosts (Armstrong 2001; Churchill 1995). There is no evidence to suggest extreme fluctuations in numbers or their distribution.

The genetic difference between the eastern and western Pilbara suggests that both subpopulations are required to maintain genetic diversity (Armstrong 2006b) as well as for their contribution to overall numbers in the region (Armstrong 2001). Some sites are particularly important because of the size of the colony they can support (e.g. Bamboo Creek, Lalla Rookh, Klondyke Queen and Copper Hills). In addition, each roost represents a connection for movement in a region that does not provide many roosting opportunities for the species (Armstrong 2001). Thus, the Pilbara population can ill afford to lose any colony, either the individuals or the roost structure itself. Some roosts that coincide with plans for development, such as the Klondyke Queen mine, might benefit from translocation if a suitable alternative can be found.

The largest group that roosts in natural structures is known from Barlee Range Nature Reserve, maintains unique genetic diversity (Armstrong 2006b) and can be considered secure.

A small group exists in natural caves near Paraburdoo (Geode Creek; exact locations still unknown despite several surveys; Armstrong 2001) despite the increase in mining activities nearby at Channar and the Eastern Ranges. This group is important as it represents the only known regular and permanent occurrence of the Pilbara Leaf-nosed Bat in the entire Hamersley Range (K.N. Armstrong September 2006, unpubl. obs.).

More recently, several occurrences of the Pilbara Leaf-nosed Bat have been recorded near Goldsworthy, though roosts have not yet been confirmed in any of the caves that they have been observed near (Ecologia 2005a, b, 2006b). Along with observations of one to two individuals at Soansville and in the granite terrain of Hillside station, they represent the only known utilisation of natural caves north of the Fortescue valley (Armstrong 2001). Lack of information on roost sites and colony size limits an assessment of the relative importance of these colonies compared to those in mines, however, they are at least important as alternative roosts for mine colonies that suffer disturbance and might be involved in aiding long distance dispersal between roosts, serving as stopovers.

The Orange Leaf-nosed Bat is more widely distributed than the Pilbara Leaf-nosed Bat, occuring from the southern Kimberley, through the Northern Territory and into Queensland.

No cross-breeding has been observed, either with other species, or between Pilbara and the more northern Kimberley populations. Cross-breeding is very unlikely as the Pilbara Leaf-nosed Bat is the only representative in the genus and populations are isolated by the 500 km expanse of the Great Sandy Desert. It appears unlikely that the Pilbara Leaf-nosed Bat crosses the Great Sandy Desert (Armstrong 2003) as the sandy desert landscape does not provide caves with suitable roost microclimates (Armstrong 2003).

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Land Tenure of Populations

A major component of the Pilbara Leaf-nosed Bat population, from both a demographic and genetic perspective, occurs in Barlee Range Nature Reserve. No roost has been confirmed in any other reserve system in the region. The remainder of known roosts and observations of bats in flight or specimens collected occur on mining and pastoral leases. Apart from being protected in Barlee Range Nature Reserve, there is no active management of the species.

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Habitat

The Pilbara Leaf-nosed Bat is restricted to caves and mine adits (horizontal shafts) with stable, warm and humid microclimates because of its poor ability to thermoregulate and retain water (Armstrong 2001; Baudinette et al. 2000; Churchill et al. 1988; Churchill 1991b; Jolly 1988; Kulzer et al. 1970). The roost is usually over pools of water in deeper mines, or deep within the mine or cave structure in an area that maintains elevated temperature and humidity. Thus, the roosting site is often at depth in mines; in small crevices within caves, usually those ascending between sedimentary rock layers; and with associated groundwater seeps (e.g. at Barlee Range; Armstrong 2001). In the Pilbara few actual roost clusters have been observed, perhaps the only one being that in the Comet mine prior to 1992 (Armstrong 2001). Simple vertical shafts are not used and shallow caves beneath mesa bluffs are also unlikely roost sites (Armstrong 2001).

As with all cave-roosting bats, the Pilbara Leaf-nosed Bat has separate diurnal and nocturnal habitats - the roost and foraging sites.

In the eastern Pilbara, roosting habitat includes underground mines in the greenstone terrain. Most of these mines are old gold or copper workings that have been abandoned, although improvement in mining techniques has resulted in renewed mining interest at some sites. The Pilbara Leaf-nosed Bat prefers those with a horizontal adit type entrance, especially the deepest and most complex structures that intersect the watertable (e.g. Klondyke Queen, Comet, Bamboo Creek mines, possibly the Bow Bells mine). Simple shafts are not inhabited but structures with wide vertical stopes (linear vertical excavations that usually follow a vein deposit) can be used if the lower levels of the mine include cross cuts and access the watertable (e.g. Lalla Rookh, Copper Hills; possibly the Trump mine). Simple adits without cross cuts (or with short cross cuts at the same level) might be used as night roosts occasionally (Armstrong 2001).

Observations of bats in flight in the eastern Pilbara also suggest the presence of roosts in relatively deep crevices amongst granite boulder koppies (rockpiles) and caves in mesa formations of the Cleaverville Formation (part of the Gorge Creek Group of ironstone remnants; e.g. at Soansville; Armstrong 2001). Caves use by the Pilbara Leaf-nosed Bat in the Hamersley Range has not been determined, however, the species has been observed in flight in the gorges formed in dip faces of relief (the face of a hill opposite to that where the inclined layered sedimentary sequences are exposed - strike face) composed of Brockman Iron Formation. Side gorges with inclined layered ironstone sequences have the greatest potential to support relatively warm humid microclimates. Caves in gorge settings, rather than caves beneath bluffs on the strike faces of mesas, are most likely to be the only natural subterranean formations preferred by the species in upland country in this type of ironstone unit. Deeper caves in Mara Mamba Iron Formation might be used, but no such occurrences have yet been recorded. The species also inhabits caves in the massive siliceous Kiangi Creek Formation of Barlee Range. Caves used by the Pilbara Leaf-nosed Bat were formed in zones of weakness between heavily folded sandstone bedding layers that extended up inclined bedding layers. The species might also be found in this formation further east (e.g. near Mt Vernon) (Armstrong 2001, 2003, in litt. a).

The daytime occupation of trees expounded by Gould (1863) has never been corroborated (Calaby & Keith 1974; Dixon 1978; Parker 1973), despite a suggestion that bats become "forest dwellers" in the Northern Territory during the wet season. There have been several accounts of roosting in man-made structures (review in Armstrong 2003, p. 13; Churchill et al. 1988), but never in the Pilbara. The Pilbara is considered too dry to support the Pilbara Leaf-nosed Bat in such temporary structures with suboptimal microclimates.

Foraging habitat is diverse owing to the wide distribution of the Pilbara Leaf-nosed Bat (Churchill et al.1988), however in the Pilbara it has been observed in the following habitats: *Triodia* hummock grasslands covering low rolling hills and shallow gullies, with scattered *Eucalyptus camaldulensis* along the creeks (e.g. near Marble Bar, Bamboo Creek, Lalla Rookh and Copper Hills; Armstrong 2001; K.N. Armstrong unpubl. obs.; Churchill et al. 1988); over small watercourses amongst granite boulder terrain and around nearby koppies; over pools and low shrubs in ironstone gorges; and above low shrubs and around pools in gravelly watercourses with *Melaleuca leucodendron*, such as in Barlee Range Nature Reserve (Armstrong 2001).

Typically, the Pilbara Leaf-nosed Bat flies low in the open spaces in watercourses and gorges, and over *Triodia* grassland, sometimes within centimetres of the ground, but up to 2–3 m in height (K.N. Armstrong unpubl. obs.). Flight behaviour was described by Churchill and colleagues (1988) as a "sinuous pattern of turns; zigzagging up and down ...".

It often shares roosts with the Ghost Bat, *Macroderma gigas,* Finlayson's Cave Bat, *Vespadelus finlaysoni,* Common Sheath-tailed Bat, *Taphzous georgianus,* and possibly Hill's Sheath-tailed Bat, *Taphozous hilli,* in some parts of its range. Any management strategy that benefits the Pilbara Leaf-nosed Bat is also likely to benefit these species. Daytime refuges are in natural caves or underground mines. Some are used on a permanent basis, such as the Bamboo Creek mine, others rely on seasonal or sporadic inputs of groundwater to maintain groundwater seeps and elevated roost humidity, such as in Barlee Range (Armstrong 2001). The effects of fire and flooding are unknown.

The Pilbara Leaf-nosed Bat is not known to occur in any Threatened Ecological Community in the Pilbara. It shares roosts in some instances with the Ghost Bat (Armstrong 2001; Hall et al. 1997) which is included on the Western Australian Department of Environment and Conservation's Priority Fauna List.

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Life Cycle

Females reach sexual maturity after about seven months, and males at about 16 months (Churchill 1995). Life expectancy is unknown but is likely to be around 10 years, similar to other medium sized bats in the families Hipposideridae and Rhinolophidae (Wilkinson & South 2002).

Little information is available on reproduction in the Pilbara Leaf-nosed Bat though there is some information on the Orange Leaf-nosed Bat. A comprehensive study of the seasonal life history and reproductive status of the Northern Territory population of the Orange Leaf-nosed Bat, based on morphology, was provided by Churchill (1995). Mating occurred in July, followed by a prolonged gestation of 150 days, and parturition began in December. Young were weaned and independent by late February. This was assumed to be similar in the Pilbara form. Armstrong (2001) captured pregnant females in December at Barlee Range and Bamboo Creek. In March, observations suggested that young had recently been weaned and were independent.

Churchill (1995) found that most bats dispersed from the largest colonies in the wet season (1991) and that late pregnancy, parturition and weaning take place away from these roosts (Churchill 1995). Thus, they apparently do not form maternity colonies as is seen in species such as the Ghost Bat. In the Pilbara, it was suggested that bats might occupy some locations throughout the year if sufficient water was present to maintain humidity in roosts. In other roosts, they might move elsewhere when conditions dry out, as was observed in Barlee Range cave BR2 (Armstrong 2001). Some colonies appear to be permanent.

Generation length is unknown but is likely to be around five years. Churchill (1995) found that females attain sexual maturity at seven months of age, though in males it occurs in their second year, at about 16 months. Longevity of this species is unknown but is likely to be similar to other bats of equivalent size in the families Hipposideridae and Rhinolophidae. While a very small proportion of bats in these families may live up to 30 years (Caubere et al. 1984; Wilkinson & South 2002), most will live around 10 years, especially if they are obligate cave roosting and do not hibernate (Tuttie & Stevenson 1982; Wilkinson & South 2002).

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Feeding

Diet has not been studied in the Pilbara Leaf-nosed Bat but information is available from Orange Leaf-nosed Bats in the Northern Territory (Churchill 1994). The Orange Leaf-nosed Bat is partially selective, preferring moths and beetles, but also feeding opportunistically on short term emergences of groups such as termites. Lower frequencies of other insect types were also found in faecal samples (see also Vestjens & Hall 1977). It is assumed that Pilbara form also feed selectively for the most part on moths and beetles (Armstrong 2002). The significant differences in call frequency between population isolates (Armstrong & Coles 2007) may have very little influence on prey type (Armstrong & Kerry, in litt.).
Bats emerge from their daytime roosts after dusk and usually after species such as Finlayson's Cave Bat and Common Sheath-tailed Bat, with whom they sometimes share roosts, have left (Churchill et al. 1988). At least some individuals remain near the entrance of the roost and continually enter and re-emerge for around two hours after initial emergence (K.N. Armstrong unpubl. obs.). Such swarming behaviour might have a social function, since bats are sometimes observed following each other. They are also thought to rest in 'night roosts' (including the main roost), which provide suitably warm, humid conditions. This may explain the habit of re-entering roosts during the night, but some subterranean structures may function only as night roosts (e.g. cave BR-1 at Barlee Range; Armstrong 2001; K.N. Armstrong 2007, unpubl. obs.).

Pilbara Leaf-nosed Bats forage in the open against vegetation (Bullen & McKenzie 2002). In addition to the entrance of underground mines, they are most often observed in flight in gorge environments or along watercourses in granite boulder country, flying low over vegetation, sometimes within centimetres of the ground, but usually within approximately 3 m (Armstrong 2001; K.N. Armstrong unpubl. obs.). This feeding behaviour can contribute to the mortality of a small proportion of individuals.

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Movement Patterns

Nightly and seasonal movements have not been studied to date. Churchill (1991b,1995) observed seasonal reductions in numbers in the largest colonies of the Orange Leaf-nosed Bat in the Northern Territory and concluded that most individuals dispersed to other roosts during the wet season.

Armstrong (2001) suggested that the species maintains gene flow within the Pilbara region by dispersing among underground roosts. If nearby roosts are within the nightly flight range of individuals, which is still unknown, then contact between particular areas can be maintained. If the supply of groundwater to underground structures was reduced either seasonally or otherwise intermittently because of unpredictable rainfall, and roost humidity dropped, it is thought that some roosts would become temporarily unavailable. If some roosts become unavailable during part of the year, the 'intervening areas' between suitable roosts become wider. If these are too wide to allow movement between suitable roosts then gene flow would be reduced. Some preliminary information from genetic markers suggests that seasonal movements do not occur (Armstrong 2006b) but the extent of gene flow in the region is being tested using microsatellite DNA markers (K.N. Armstrong 2007, unpubl. data).

In the Pilbara, there does not appear to be a seasonal exodus during summer months, as is seen in the Orange Leaf -nosed Bat during the wet season of the Northern Territory. Aggregations of the Pilbara Leaf-nosed Bat are thought to form because of the seasonal availability of some roosts and also for mating (Armstrong 2001). Rainfall in the Pilbara is low and locally unpredictable, with most rain derived from localised thunderstorms and cyclones (Beard 1975; Gentilli 1972; Tinley 1991). Therefore, the availability of groundwater, that controls seepage for elevating the humidity of roosts, is dependent on these unpredictable falls. Seasonal absences at some roosts may be dependent on the amount of rainfall and corresponding groundwater seepage. Aggregations in the winter months are likely to be for mating; those in the summer are most likely to be controlled by the availability of suitable roost microclimates (Armstrong 2001).
It is assumed that bats can move distances of up to 60 km easily between mines (Armstrong 2001) though not necessarily overnight. Nightly foraging range and area is unknown. Night roosts have been observed in Barlee Range Nature Reserve (Armstrong 2001; K.N. Armstrong September 2006, unpubl. obs.), so bats do not stay in flight continuously for the whole night. Whether this occurs because of energy constraints is unknown but it would limit the range of the species, especially during cooler periods, given their physiological constraints (Baudinette et al. 2000; Kulzer et al. 1970).

Within the roost, individuals maintain a small distance of 12–15 cm amongst themselves (Churchill et al. 1988; Jolly 1988), suggesting territoriality as has been observed in other bats in the family Hipposideridae (e.g. Schneider's Leaf-nosed Bat, *Hipposideros speoris*,: Selvanayagam & Marimutha 1984; Commerson's Leaf-nosed Bat, *H. commersoni*, Giant Leaf-nosed Bat, *H. gigas*,: Fenton 1985). In these species, territoriality is manifested as antagonistic behaviour such as wing-flicking or 'nattering' towards neighbours, and marking of the roost surface with urine. The species is difficult to observe in the roost, especially in the Pilbara, because they are generally found in narrow parts of caves or unsafe areas of mines. Whether roost territoriality has implications for upper limits on colony size (assuming that limited numbers can share space in one of the few suitable roosts available) is also unknown.

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Survey Guidelines

The Pilbara Leaf-nosed Bat is relatively easy to detect if it is present in an area, in part because it flies low to the ground. In addition, it has a curiosity for light sources, which means that traversing areas at night wearing a headtorch will likely attract nearby individuals (K.N. Armstrong unpubl. obs).

The Pilbara Leaf-nosed Bat is unmistakable in appearance when captured. Externally, individuals from the Pilbara population are indistinguishable from their northern counterparts, except by call frequency. The Pilbara Leaf-nosed Bat produces reference (when hand-held) frequencies over approximately 120 kHz (Armstrong & Coles 2007). Photographs can be found in Jolly and Hand (1995), Churchill (1998) and Armstrong (2007).

Echolocation calls are distinctive, having a CF-FM (constant frequency - frequency modulated) structure. The constant frequency component is of relatively short duration (approximately 8 ms), and with a peak frequency of 117 kHz and above (but usually above 120 kHz). The CF component is followed by a brief frequency-modulated sweep of approximately 20 kHz. No other bat emits CF-FM calls in the Pilbara, and none emit calls of such high frequency. These calls are easily identified on heterodyne electronic detectors set to 120 kHz. Anabat detectors have less detection range than some other detector models, but can still detect calls of sufficient amplitude. An experienced observer can identify a heterodyned call in real time but confirmation should be made by recording the call onto tape or by other digital means for later analysis and presentation.

The Australian Museum Business Services (AMBS 2004a) has previously prepared guidelines for efficient and effective survey of bats, summarised below.

Recommended survey approach

1. Pre-survey considerations. Prospective areas can be identified prior to the field survey using geological and topographical maps, aerial photography, and searches of databases such as Minedex at the Western Australian Department of Resources and Industry to locate underground workings and tenement details. The area for surveys can be narrowed down prior to site visitation to those with steep gorges or bluffs, or mining centres with underground workings (Armstrong 2003, in litt.a).

2. Determining presence in a locality. Presence in a general area can be determined with a reasonable degree of reliability by traversing suitable habitat (gorges, breakaway scarps, creeks, mine entrances) with hand-held electronic call detectors. Hand held heterodyne call detectors can be set to 120 kHz to exclude other bat calls and background noise and give real-time feedback of presence. Echolocation call detection (with frequency division, time expansion or heterodyne detectors) should be the primary means by which the presence of this species is determined. Relative or approximate abundance data should be an adequate substitute for absolute abundance in most situations. The Pilbara Leaf-nosed Bat produces constant frequency (CF; a stable tone at one frequency) type calls, which do not change significantly when in a confined space. Thus, recordings taken with electronic detectors inside the cave should allow identification of the species.Other bat calls are sometimes audible on the detector at 120 kHz, however the calls of the Pilbara Leaf-nosed Bat are distinctive to an experienced observer. It is strongly recommended that calls are also recorded for later confirmation and peer verification in reports. Traverses should begin at dusk. Unattended detectors that record automatically can also be set for later analysis of call data.

3. Determining roost occupancy. The simplest method of confirming or determining occupancy in a cave or mine is by completely sealing the entrance with a cloth sheet (which is preferable to plastic sheeting and tarpaulins). The sheet should be installed in the late afternoon. Bats will normally exit adits rather than shafts, and all entrances should be monitored or sealed. The objective is to identify the origin of any Pilbara Leaf-nosed Bat (either from inside or outside of the cloth barrier) by monitoring each side of the sheet at the time of their emergence at dusk. Observers are placed on either side of the sheet, each with a heterodyne detector set to approximately 120 kHz. Alternatively, remote units such as an Anabat system can be placed on either side of the cloth, pointing away from the barrier to minimise the chance of recording calls from the opposite side. All calls should be recorded and analysed and those from which a positive identification is made should be presented for peer verification.

The sheet should be removed as soon as presence within the structure has been confirmed. An approximate indication of abundance can be determined by counting passes in 15 minute time intervals (for example) over an unattended detector positioned at the entrance, in conjunction with brief bouts of spotlighting.

4. Cave searches. It may still be useful to conduct underground surveys to narrow down the potential roosts to the deepest and most complex structures. Thus, many caves could be searched briefly during the day and the most prospective then monitored for emergence at dusk. If cave searches are performed, care must be taken not to disturb bats, including non-target species such as the Ghost Bat, which may exit into daylight. Prior to entry, a cloth sheet should be installed over the entrance to prevent bat exits. If Pilbara Leaf-nosed Bats are observed, they should not be disturbed and the observer should retreat outside immediately. Appropriate safety precautions should be taken when searching caves to avoid hazards such as dust, asbestos and microbe inhalation, and eye and head injury (Armstrong & Higgs 2002).

5. Determination of a roost site in an area. If roosts must be confirmed in an area where only bats in flight have been detected, comprehensive surveys of caves and mines should be undertaken by combining various approaches. If roosts still cannot be found, it might be necessary to capture bats in flight and radiotrack them back to a roost. Capture of this species is extremely difficult but can sometimes be successful with harp traps set in watercourses. Lengths of cloth should be hung to block flyways and direct bats to the trap. Another novel method involves construction of a large tent-like structure over the water surface and trapping them inside when they fly beneath (K.N. Armstrong unpubl. data).

6. Survey effort. Several hours per day may be required to conduct ground-based surveys for caves and mines. For large project areas in gorge country, ground-based searching could be expected to take several days. The survey to confirm absence in a particular roost, for situations where the species has been observed in flight nearby, may need to be repeated after six months.

Underground surveys

Roost searches in caves might prove successful, however, in Pilbara caves or mines, a colony is most likely to be present in a small horizontal fissure inaccessible to humans. In caves and relatively large underground mines, the species is unlikely to be encountered or will be in an area unsafe for human entry. The entry of underground mines is not recommended for safety reasons. If entry to mines is absolutely necessary, permission should be sought firstly from the leaseholder and a mines inspector from the Western Australian Department of Resources and Industry should be consulted and may be required on-site.

Roost occupancy and approximate numbers are best assessed without underground surveys by monitoring bat emergence at the largest horizontal exits at dusk. The Pilbara Leaf-nosed Bat has a peculiar habit of 'appearing' near the entrances of caves or adits after dusk. Individuals do not necessarily roost in some structures so an assessment of occupancy in a particular structure must exclude the possibility of casual night visitation or 'fly ins' (K.N. Armstrong, unpubl. obs.).

Other Approaches

For environmental assessments, the species can be surveyed adequately without the need for capture. Bat (harp) traps and mistnets should be avoided to lessen the possibility that leaf-nosed bats will be prompted to vacate the roost (it must be assumed that they would perish in the less suitable microclimate of an alternative roost). The use of trapping equipment is also discouraged in order to avoid by-catch of other typically abundant species such as *Taphozous* and *Vespadelus* species.

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Threats

Heat and water loss

Attributes that make this species particularly vulnerable to a threatening process include their poor ability to limit heat and water loss in unsuitable roost microclimates and the limited availability of suitable roosts in the region (Armstrong 2001; Baudinette et al. 2000; Churchill et al. 1988; Churchill 1991b; Kulzer et al. 1970). Impact assessments should take into account that proposed works might interrupt mating around July, females will be heavily pregnant from November and with young until around March (Armstrong 2001).

The most important intrinsic factor that affects survival in the Pilbara Leaf-nosed Bat is their poor ability to maintain heat and water balance (Baudinette et al. 2000; Kulzer et al. 1970). In all cases where disturbance to a roost appears likely, it is assumed, based on the precautionary principle, that this will result in bats leaving the structure, with the consequence that they are exposed to an increased risk or rate of mortality due to relocation to a suboptimal roost. The species might move among roosts as part of their normal nightly foraging activity and it is likely that this would only include roosts with suitable atmospheric and roost conditions. Two issues are relevant when considering the outcomes of an artificial departure of the Pilbara Leaf-nosed Bat:

- The timing of the departure might coincide with a period where there are relatively few roosts providing suitable (and seasonally available) microclimates sufficient to maintain the same rate of survival .

- The distance of the next nearest suitable roosts might be greater than that of nearer, less suitable roosts, and thus risk of mortality is greater if bats choose nearer sites (K.N Armstrong 2007 pers. comm.).

Mine collapse

Some parts of the Klondyke Queen mine are unstable and there may have been collapses within, which might have contributed to the decline since the survey of Churchill and colleagues (1988). The stability of mines such as McKinnons, Trump, Lalla Rookh and Copper Hills appears reasonable but not as good as the Comet and Bamboo Creek mines (K.N. Armstrong unpubl. obs.).

Apart from intentional destruction of an old mine adit, including as part of planned mining activities, collapse of a mine structure is the most likely catastrophic threat. Many of the historical workings in the eastern Pilbara are around 100 years old. Some are angled stopes (vertical excavations; e.g. Lalla Rookh, Trump), and others are in relatively soft fuchsite schist or other crumbly or powdery igneous greenstone rocks (Klondyke Queen, Comet, McKinnons, Copper Hills). Following heavy rains, a large section of wall in the stope of the Klondyke Queen was observed to have fallen, and some of the roof comprises loose cobbles held up by old timber (K.N. Armstrong 2001, unpublished obs.). The compounding effect of heavy rains, fluctuating underground waterlevels and aging of timber supports is likely to gradually weaken most of the mines that are occupied by the Pilbara Leaf-nosed Bat. With some careful management, and liaison among leaseholders, the largest and most stable workings, not subject to renewed mining interest, could be preserved and strengthened for bats (Armstrong & Anstee 2000; McKenzie et al.

1999).

Flooding
Flooding has caused evacuation of the Pilbara Leaf-nosed Bat from the Comet mine (Armstrong 2001). The lower levels of the Bamboo Creek mine are also flooded (K.N. Armstrong Sept. 1997, unpubl. obs.), but the underground area of this mine is greater and contains numerous side workings. In other mines containing water (Copper Hills, perhaps others near Marble Bar), flooding is not an issue because mines do not penetrate as deep as the Comet and Bamboo and were not required to be dewatered.

Natural Predators
While little information is available regarding natural predators of the Pilbara Leaf-nosed Bat, the Orange Leaf-nosed Bat has several natural predators in the Northern Territory. Predation occurs either inside roosts or at cave entrances during the nightly emergence of bats. Predators include various species of snake such as the Olive Python, *Liasis olivaceus,*, Brown Tree Snake, *Boiga irregularis,* and King Brown Snake, *Pseudechis australis* (Churchill et al. 1988; Jolly 1988). Roosts are often cohabited by the carnivorous Ghost Bat, which is an efficient predator with excellent eyesight (Pettigrew et al. 1988) and hearing (Guppy & Coles 1988). Wings of the Pilbara Leaf-nosed Bat were recorded from the accumulation of food remains beneath a roost of the Ghost Bat in the Klondyke Queen Mine (Churchill et al. 1988). In Northern Territory caves, the Orange Leaf-nosed Bat may avoid the Ghost Bat by roosting in small, inaccessible parts of the cave (Jolly 1988).

Mine development
Both open cutting of underground works and exploration drilling present a potential threat to the Pilbara Leaf-nosed Bat. Drilling occurred at the Comet in 1991–1993 and at the Klondyke Queen mine in 1994–1996 and also in 2004 (Armstrong 2001; Biota 2001a). Drilling up to 50 m of the Klondyke Queen adit entrance did not appear to have an impact on bat occupancy (Armstrong in litt.b; Biota 2001a). Exploration drilling in the Nullagine district has involved extensive earthworks within 10 m of historical workings (Armstrong 2006c). Similar such operations at workings occupied by the Pilbara Leaf-nosed Bat are likely to have an adverse effect.

There are, however, several roost sites of the Pilbara Leaf-nosed Bat in the eastern Pilbara that are the current or likely future focus of open cut mining developments. Some projects introduce a greater level of disturbance than others, and at least one is likely to result in the loss of a roost site (Klondyke Queen). The scarcity of roost sites means that the loss of even one will result in a reduction in area of occupancy. This might also result in a reduction of actual numbers even if there is no direct cause of mortality. Concurrent impacts at nearby major roost sites may limit the options of a disturbed colony for relocation, and any relocation to other nearby roosts with suboptimal microclimates carries an elevated risk of mortality.

Blasting in adjacent workings
Blasting and excavation of a new adit was undertaken in the 1980s immediately adjacent the Klondyke Queen mine. It is not known if this contributed to the decline in numbers since the survey of Churchill and colleagues (1988). Blasting in any structure is likely to cause evacuation of the Pilbara Leaf-nosed Bat. Blasting in an iron ore open cut mine occurs up to 400 m of the Cattle Gorge and Nimingarra open cut iron ore mines near Goldsworthy (BHP Billiton 2005) but visitation of nearby foraging habitat by Pilbara Leaf-nosed Bats still occurs. The maintenance of a buffer zone therefore appears to have had some level of success, and monitoring is ongoing (Ecologia 2005a, b, 2006b).

Human entry of roosts
Human entry of roosts is unlikely to be a major disturbance unless bats are captured. Most underground mine workings are in a poor state of repair and are dangerous to enter. Furthermore, the Pilbara Leaf-nosed Bat usually roosts deep in underground structures and is likely to be in spaces inaccessible to people and might therefore be difficult to observe in the roost. This is also true for caves (e.g. cave BR-2 at Barlee Range) (Armstrong 2001). Entry and capture for scientific research or environmental monitoring programs might cause a colony to vacate. The species is known to relocate to other roosts following trapping (K.N Armstrong 2007, pers. comm.; Hall 1983; Jolly & Hand 1995).

Roadkills
Five records of the species in the Pilbara, and a similar number from the Kimberley region, are from roadkills, or specimens found in carparks (Armstrong 2001). The species tends to fly relatively low and displays a curiosity for light sources. Such roadkill records have helped with information on distribution and contributed specimens for taxonomic analyses (Armstrong 2002). Sporadic occurrences of roadkill are unlikely to have a significant impact on the population size. However, if a busy haul or access road is to be located close to a known roost or foraging site,

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it might contribute to a local decline.

Site rehabilitation
Backfilling of old shafts and horizontal adits by mining companies for safety reasons has the potential to deprive the Pilbara Leaf-nosed Bat and other species such as the Ghost Bat of roost habitat. This may also result in direct mortality if bats are present when the structure is sealed or destroyed (Biota 2001b).

Almost half of the specimens from the Pilbara in the Western Australian Museum are from individuals that have been collected following collision with a vehicle (Fortescue Roadhouse, 1990; near Tom Price, 1995; near Yarrie, 2005), or that were found in carparks, presumably after falling off the vehicle (Millstream, no date; Karratha, 1985) (Armstrong 2001). This results from their low-flying habit and possibly their curiosity for light sources which brings them into contact with vehicles.

Genetic diversity appears well maintained in the region (Armstrong 2006b), but further work is required into genetic diversity and degree of inbreeding in subpopulations with new genetic markers and larger sample size (K.N. Armstrong 2007, unpubl. data).

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Threat Abatement and Recovery

Recovery objectives and management and research actions for the Pilbara Leaf-nosed Bat were outlined in the *Action Plan for Australian Bats* (McKenzie et al. 1999) with the primary recovery objectives being:

- Protect known Pilbara colonies and/or translocate them if necessary.
- Ascertain if colonies in natural roosts in the Barlee Range Nature Reserve are declining.
- Locate and protect natural breeding roost sites in the Pilbara region.

Several new observations of bats in flight have been made in the region, mainly through environmental impact assessments and also through the Pilbara Biological Survey, but no roosts have yet been confirmed in natural caves other than at Barlee Range. It is very likely that several occur near Goldsworthy but also several other localities where they have been observed in flight. No efforts by environmental consultants have yet been successful in locating a roost site (e.g. at the Eastern Ranges development near Paraburdoo - Armstrong 2001; near Mesa K - Biota 2007; several localities near Goldsworthy; Ecologia 2005a, b, 2006b).

New Recommendations
Armstrong (pers. comm. 2007) suggests several new strategies to replace those in McKenzie and colleagues (1999) given the current state of knowledge of this species.

- Complete genetic comparisons between Pilbara and Kimberley populations to provide resolution of subspecific population status.
- Complete population genetic work in the region to determine degree of substructuring, rates of migration between subpopulations, and levels of heterozygosity and inbreeding.
- Develop a regional plan that addresses both short term threats and long term preservation. Key components should include:
    - Prioritise mine roost importance considering all identified threats and mining interests;
    - Liaison with leaseholders in the district to avoid concurrent impacts;
    - Consideration of a reserve system for the species, and others such as the Ghost Bat, which occupies many of the same sites. This would involve acquisition of vesting over suitable sites;
    - Refurbish mines that will be set aside for bat habitat, where feasible. The type of refurbishment will be dependent on site characteristics but could involve ground stabilisation with culverts or other equipment, control of flooding, or construction of a suitably-shaped side passage within a larger flooded structure.
    - Consideration of the construction of replacement roosts if mining industry liaisons reveal an insufficient number are likely to be left for habitation following mining. Rather than simply excavating new tunnels, novel, lower budget strategies could be considered, such as building specially designed culvert/concrete bunkers or tunnels, perhaps partly associated with mine voids that would later fill with water. Designs could incorporate strategies to avoid safety issues, and be installed as part of rehabilitation

responsibilities and commitments. If designs are relatively simple and cheap, they could be installed as standard, or in other sites with mine voids as environmental offsets.

  - Ensure that any translocation or exclusion programs are conducted scientifically following careful consideration of alternate sites, and avoidance of concurrent impacts in the district. Maintaining area of occupancy should take precedence over simple population augmentation at an existing colony.
  - Consider the Ghost Bat simultaneously in all strategies concerning the Pilbara Leaf-nosed Bat, to simplify strategies and reduce costs.

- Ensure that surveys and regular monitoring programs conducted by environmental consultants and others follow a standard recommended protocol for avoiding disturbance to the species, and providing unambiguous confirmation that bats observed near a cave or mine entrance are actually roosting within.
- Locate natural roost sites in areas where bats have been observed or recorded in flight, following the standard protocol above. Protect them from disturbance with suitably sized buffer zones and controlled access to the area.
- Ensure drilling programs conducted in close proximity will not intersect bat habitat and are monitored. The degree of monitoring and the approach for management of the site during drilling should be designed according to the characteristics of the program.

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Major Studies

The first field observations from across most of the range, including roost structure, abundance estimates, roost microclimates, cohabiting species, predation, pelage (fur) colouration and foraging habitat were provided by Churchill and colleagues (1988) and Jolly (1988).

The first comprehensive ecological studies were undertaken in the Northern Territory (Churchill 1991a, Churchill 1991b, Churchill 1994, Churchill 1995). Following this was a more comprehensive study of physiology that built upon the study of Kulzer and colleagues (1970) and highlighted the extremely high rates of water loss (Baudinette et al. 2000).

Armstrong (2001, 2003, in litt.a) conducted field surveys culminating in a GIS analysis of spatial population structure and preferred habitat distribution based on geological and topographical features. This found genetic sub-structuring (population fragmentation) in the region, between Barlee Range and the eastern Pilbara (Armstrong 2006b).

Pilbara and Kimberley Orange Leaf-nosed Bats were included in studies that investigated foraging habitat, aerodynamic capability and foraging strategy of a range of Western Australian bats (Bullen & McKenzie 2002; McKenzie & Rolfe 1986).

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Management Documentation

Specific recovery and research actions for the Pilbara Leaf-nosed Bat are are detailed in the Action Plan for Australian Bats, prepared by Duncan and colleagues (1999).

The Australian handbook for the conservation of bats in mines and artificial cave-bat habitats (Thomson 2002) provides management guidelines for cave-dwelling species that may inhabit disused mine sites.

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Threat Class Summary

The following table lists known and perceived threats to this species. Threats are based on the International Union for Conservation of Nature and Natural Resources (IUCN) threat classification version 1.1.

Threat Class	Threatening Species	References
Climate Change and Severe Weather:Habitat Shifting and Alteration:Habitat loss, modification and/or degradation		*Commonwealth Conservation Advice on Rhinonicteris aurantius (Pilbara form)* (Threatened Species Scientific Committee, 2008xu) [Conservation Advice].

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Threat Class	Threatening Species	References
Ecosystem/Community Stresses:Indirect Ecosystem Effects:Restricted geographical distribution (area of occupancy and extent of occurrence)		*Commonwealth Listing Advice on ten species of Bats* (Threatened Species Scientific Committee, 2001a) [Listing Advice].
Energy Production and Mining:Mining and Quarrying:Habitat destruction, disturbance and/or modification due to mining activities		*Commonwealth Conservation Advice on* Rhinonicteris aurantius (Pilbara form) (Threatened Species Scientific Committee, 2008xu) [Conservation Advice].
Human Intrusions and Disturbance:Human Intrusions and Disturbance:Human induced disturbance due to unspecified activities		*Commonwealth Conservation Advice on* Rhinonicteris aurantius (Pilbara form) (Threatened Species Scientific Committee, 2008xu) [Conservation Advice].
Species Stresses:Indirect Species Effects:Low numbers of individuals		*Commonwealth Listing Advice on ten species of Bats* (Threatened Species Scientific Committee, 2001a) [Listing Advice].

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Caveat

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