Conservation Assessment of the Lord Howe Earthworm *Pericryptodrilus nanus* Jamieson, 1977 (Megascolecidae)

Thomas Rowell – 15/09/2022
NSW Department of Planning and Environment

Lord Howe Earthworm *Pericryptodrilus nanus* Jamieson, 1977 (Megascolecidae)
Distribution: Endemic to Lord Howe Island, New South Wales (NSW)
Current EPBC Act Status: Not Listed
Current NSW BC Act Status: Endangered

Proposed listing on NSW BC Act and EPBC Act: Critically Endangered

Reason for Change: Genuine change in extinction threat – increasing threat of habitat decline as a consequence of climate change.
Review of status was required as the current Endangered status was assigned under previous NSW legislation (*NSW Threatened Species Conservation Act 1995*) where the highest threat category available at the time of listing (2001) was Endangered.

Summary of Conservation Assessment

The Lord Howe Earthworm, *Pericryptodrilus nanus,* was found to be eligible for listing as Critically Endangered under Criterion B1ab(iii) + B2ab(iii).
The main reasons for this species being eligible are 1) It has a very highly restricted geographic range *(*AOO is 4 km^2*);* 2) It is found at only a single location in a 27-hectare area of Gnarled Mossy Cloud Forest (which is itself listed as a Critically Endangered ecological community); 3) There is inferred continuing decline in habitat quality as a consequence of climate change, as well as ongoing threats from invasive species.

Description and Taxonomy

The Lord Howe earthworm *P. nanus* is endemic to Lord Howe Island, described with other Lord Howe earthworm species by Jamieson 1977. It is an exceptionally small (25-32 mm) earthworm for the Megascolecidae, a family commonly associated with giant species (potentially up to 3 m, such as *Megascolides australis* the giant Gippsland earthworm) (Jamieson, 1977; Van Praagh and Yen, 2010). Jamieson (1977) describes the species as: “Length 25-32 mm. Width (mid-clitellar) 1.0-1.5 mm. Segments 111-123. Prostomium broadly epilobous. First dorsal pore 6/7 or 10/11. Setae perichaetine, >30 per setiger. Nephridiopores 3 straight series on each side. Clitellum annular, in segments 1/2 XIII, XIV- XVI. Small slit-like combined male and prostatic pores a pair in XVIII approximately in b on prominent papillae. Accessory genital markings 2 midventral presetal circular glandular areas, with indistinct pore like centres, one in XX, the other in XXI. Female pore unpaired, midventral, anteriorly on XIV. Spermathecal pores 2 pairs, in 7/8 and 8/9, between the third and fourth setal rows. Dorsal blood vessel single. Hearts 3 pairs, in X-XII. A rudimentary gizzard in segment V; calciferous glands at least extramurally absent; intestine commencing in XVI. Three subspherical slightly bilobed nephridial bladders present on each side per segment, those in the tenth setal lines large, the others (above and below) small. The nephridia of the intermediate series each with a preseptal funnel near the nerve cord; no funnels demonstrable for the dorsal and ventral series. Pharyngeal, or other enteronephric nephridia, and tufted nephridia absent. Testes and funnels in X and XI;

seminal vesicles in IX and XII. Ovaries and oviducal funnels in XIII. Large multiloculate ovisacs in XIV. Prostates thickly tubular, in XVIII and extending into XIX; ducts median, slender; vas deferens joining each gland at its junction with the duct. Penial setae absent. Spermathecae in VIII and IX; each with a subspherical ampulla, conical, and a large clavate inseminated lateral diverticulum which joins the duct at mid length; the diverticulum with or without a subsidiary less well developed or knoblike diverticulum of similar width at its base or all simple. This earthworm can be easily distinguished from all other earthworms on the island by the presence of the median accessory genital markings and three rows of nephridiopores." (Jamieson 1977).

In summary, *Pericryptodrilus nanus* is a small earthworm reaching 25–32 mm in length and 1–1.5 mm wide. The species has between 111 and 123 body segments, each with a ring of more than 30 hair-like structures called setae and usually with a break dorsally and ventrally, which is characteristic of the common genus of earthworms *Perichaeta.* The clitellum (thickened, non-segmented and glandular part of the body wall) is annular in shape and located toward the anterior part of the body. This earthworm also has a median accessory genital marking which, combined with three rows of nephridiopores (excretory pores), distinguishes the species from other earthworms on Lord Howe Island.

Distribution and Abundance

Pericryptodrilus nanus is endemic to Lord Howe Island (Jamieson 1977). Lord Howe Island (31.54°S, 159.08°E) is the largest of a collection of small volcanic islands in the Tasman Sea, 760 km northeast of Sydney (Department of Environment and Climate Change (NSW) 2007). The main island is around 11 km long, and only 2.8 km at its widest point, with a total area of 1455 hectares and a maximum elevation of 875 m on its highest peak, Mt Gower (Department of Environment and Climate Change (NSW) 2007). There is a small town on the main island, however development and tourism are strictly controlled; 75% of the main island, and all other islands in the Lord Howe Island Group are conservation protected, and UNESCO world heritage listed (Department of Environment and Climate Change (NSW) 2007).

There have been no assessments of distribution, abundance, or taxonomy for *P. nanus* since the original 1970s surveys described in Jamieson (1977). While there have been surveys for other invertebrates across Lord Howe Island (including Mount Gower; C. Stehn pers. comms. Feb 2022), there have been no more recent surveys for earthworms, and no incidental collection of additional earthworm specimens. Identification of *P. nanus* requires a close examination of morphology that would be challenging in the field, and this may contribute to the lack of observations since the original intensive surveys in the 1970s. As a result, all descriptions of distribution, abundance, and taxonomy in this assessment rely on Jamieson (1977).

Taxonomy and distribution were determined from the collection of 10 specimens, as outlined by Jamieson (1977), now lodged in the Australian Museum. *Pericryptodrilus nanus* has a severely restricted range, with two individuals collected from two sites on a single ridge near the summit of Mount Gower. The other eight specimens were recorded only as "from a ridge near the summit of Mount Gower", or "without location" (Jamieson 1977). In its original Final Determination for *P. nanus*, the NSW Scientific Committee (2001) observed that: "*Pericryptodrilus nanus* is restricted to Mount Gower,

Lord Howe Island, New South Wales. Sampling at many other sites at Lord Howe Island specifically for earthworms, has failed to extend the range of this species. The species is known from 10 specimens, lodged in the Australian Museum. They were all collected from the ridge of Mount Gower in deep leaf litter in moist environments close to streams."

Pericryptodrilus nanus appears to be entirely confined to, and dependant on Gnarled Mossy Cloud Forest, a Critically Endangered Ecological Community under the NSW BC Act (Auld and Leishman 2015). Gnarled Mossy Cloud Forest occurs only on the summit and ridgelines of Lord Howe Island's two southern peaks, Mount Gower and Mount Lidgbird (Auld and Leishman 2015). *Pericryptodrilus nanus* has only been found on the peak of Mount Gower, where Gnarled Mossy Cloud Forest covers approximately 27 hectares, and has not been found on the small, remnant patch on Mount Lidgbird (Jamieson 1977). Gnarled Mossy Cloud Forest faces severe ongoing threats from climate change and introduced species. Therefore the earthworm is still considered at extreme risk of extinction.

Historic surveys provide no data as to the abundance of *P. nanus* at sites in which it was collected, or patterns of distribution across its range, which means it is not possible to make reliable estimates of population size. In some comparably sized earthworm species densities can be high in good habitat; in Egypt *Allolobophora caliginosa* have been measured at 394 individuals per m^2 (El-Duweini and Ghabbour 1965), while in Tasmania *Megascolex montisarthuri* have been measured at 106 per m^2 (Laffan and Kingston 1997). Alternatively, at the lower end of worm densities, studies in the related giant Australian earthworm, *M. australis,* have recorded mean densities as low as 2 per m^2. However, it is not known how specialised the habitat of *P. nanus* may be across the Mt. Gower summit, which itself varies from drier ridges to moist creeks (Harris *et al.* 2005). Consequently, no estimates of abundance can be reliably made.

Estimates of AOO and EOO

Co-ordinates were associated with the collection of two individuals reported in Jamieson (1977); however, these were either mis-recorded or misreported, or reported at a coarse sale. The remaining eight specimens were either unlabelled or recorded as collected from 'Mount Gower Ridge' (Jamieson 1977).

EOO and AOO were estimated in Geocat (Bachman *et al.* 2011) based on records recorded in Jamieson (1977). Area of occupancy (AOO) was calculated by overlaying 2 km x 2 km grid cells over the known occurrence and is the spatial scale of assessment recommended by IUCN (2019). Extent of occurrence (EOO) of *P. nanus* is based on a minimum convex polygon enclosing all known occurrences of the species described in Jamieson (1977), the method of assessment recommended by IUCN (2019).

Surveys across the island in the 1970s found *P. nanus* to be restricted entirely to the Mt Gower summit plateau (now included in the Critically Endangered Ecological Community 'Gnarled Mossy Cloud Forest on Lord Howe Island') an area of only 27 hectares (Jamieson 1977; Auld and Leishmand 2015). As a consequence, the entire known population of *P. nanus* occurs in an area that can be contained within a single 2 km x 2 km grid square, which is the smallest standard grid resolution recommended

for assessments of AOO under the IUCN Standards and Petitions Committee (2019). AOO is estimated to be 4 km^2.

Pericryptodrilus nanus is restricted to one very small site, and as a result EOO is less than or equal to estimates of AOO. Where EOO is less than or equal to AOO then IUCN guidelines recommend EOO estimates be changed to be equal to AOO to ensure consistency with the definition of AOO as an area that fits within EOO IUCN Standards and Petitions Committee (2019). As such, the EOO is also ~4km^2. While *P. nanus* is known only from a small number of specimens, its dependence on Gnarled Mossy Cloud Forest, and a failure to detect the species elsewhere means these estimates of EOO and AOO are likely to be an accurate indication and are appropriate for assessment under the IUCN (2012) criteria.

Ecology

There has been no intensive study of behaviour, genetics, or population dynamics in *P. nanus.* Distribution and taxonomic descriptions are all drawn from museum specimens described by Jamieson (1977). All specimens were collected from a small number of sites in moist leaf litter and moss near streams at the summit of Mount Gower, Lord Howe Island (Jamieson 1977).

Members of the family Megascolecidae generally reproduce as bi-parental hermaphrodites, however there are also examples of parthenogenically reproducing species (Dyne and Jamieson 2004). Adults lay eggs, which are encased in a cocoon, hatching into precocial juveniles. The presence of sperm-producing male reproductive organs in *P. nanus* suggests that it reproduces bi-parentally, however some other species of worm reproduce both bi-parentally and parthenogenically, so it is possible that *P. nanus* may also do so (Dyne and Jamieson 2004).

Across taxa, earthworms are generally dependent on stable, moist environments for habitat, feeding on organic matter (Schmidt and Curry 2001; Eggleton *et al.* 2009; Uvarov *et al*. 2011). Abundance is often closely related to changes in temperature and moisture content, with populations dramatically reducing in dry conditions or in response to large fluctuations in temperature (Schmidt and Curry 2001; Eggleton *et al.* 2009; Uvarov *et al*. 2011). Given general similarities in habitat and ecology between earthworm species it is likely that *P. nanus* populations follow similar patterns.

Threats

There are 15 Key Threatening Processes considered relevant to biodiversity on Lord Howe Island (Department of Environment and Climate Change (NSW) 2007). Of these '*Anthropogenic Climate Change*', '*Infection of Native Plants by Phytophthora cinnamomi'*, and '*Predation by the Ship Rat on Lord Howe Island*' all affect *Pericryptodrilus nanus*, along with habitat loss caused by invasive weeds, predation by introduced predators, and suspected competition with introduced species.

Climate Change and Habitat Loss

Climate change poses the most severe ongoing risk to *Pericryptodrilus nanus*, threatening the Gnarled Mossy Cloud Forest ecosystem to which *P. nanus* appears to be entirely confined, and dependant on. Cloud forests depend on consistent and ongoing formation of cloud to provide the high humidity required by its constituent plant

species. Increase in sea temperatures is likely to increase the altitude at which clouds form, pushing cloud forests further towards the summit of mountains on which they occur, dubbed the 'lift-cloud-base hypothesis' (Auld and Leishman 2015). On Lord Howe Island, Gnarled Mossy Cloud Forest is already confined to the summit of the two southern mountains, and as such there is no higher altitude into which species that occur in cloud forest can move as the altitude of cloud formation increases (Auld and Leishman 2015).

While there is uncertainty in the projected range and severity of climate impacts in Lord Howe Island, data over the last 50 years shows there has been an ongoing decrease in rainfall and cloud cover, and an increase in overall temperature (Auld and Leishman 2015). In their 2015 ecosystem risk assessment of Gnarled Mossy Cloud Forest, Auld and Leishman (2015) determined that:
"…sea level temperatures around Lord Howe Island have risen by some 0.6°C since 1940… average annual air temperature on Lord Howe Island is expected to rise (compared with 1990 levels) by 1.3 ± 0.6°C by 2030, although there is much uncertainty around such estimates and attempting to apply global projections to Lord Howe Island…Cloud cover over the last 50 years declined an estimated 22% (95% Confidence Limit 4–38%) towards the threshold of collapse set at 50% cloudy days per year… For annual rainfall, we found over the last 50 years there had been a decline of 31% (95% CL 4–79%)… Both minimum and maximum temperatures at sea level increased in the last 50 years…"

The ongoing threat to this ecosystem has a direct impact on the potential for survival of *P. nanus*. Reduction in cloud formation and moisture availability is likely to result in a decline in quality and range of Gnarled Mossy Cloud Forest on Lord Howe Island, as available moisture decreases and species better suited to drier conditions replace resident species (Auld and Leishman 2015). In addition, drought on Lord Howe Island in the summers of 2017-2019 resulted in some loss of canopy cover (H. Bower pers. comm Jan 2022; International Union for Conservation of Nature and Natural Resources 2020). A warming climate increases the ongoing risk of loss of canopy species, reducing shade and contributing to changes in microclimate, and general drying due to lack of rainfall on the summit. Earthworms across taxa show dramatic declines when confronted with loss of soil moisture or fluctuations in temperature, and ongoing changes in temperature and moisture availability as a result of climate change on Lord Howe Island are likely to have a similar effect on populations of *P. nanus* (Eggleton et al. 2009; Schmidt and Curry 2001; Yvariv *et al.* 2011).

Increased threat of severe storms as a result of climate change

Climate change may increase the likelihood and severity of sub-tropical storms on and around Lord Howe Island, posing an additional severe threat to Gnarled Mossy Cloud Forest (Auld and Leishman 2015). These storms damage standing trees, reducing canopy cover and affecting the microclimate of the surrounding area, posing a threat to the entire ecological community (Auld and Leishman 2015). Any damage to the ecological community is likely to reduce the quality or extent of the already severely restricted habitat available to *Pericryptodrilus nanus*.

Introduced earthworms

In 2007, the Lord Howe Island biodiversity management plan identified competition with introduced invertebrates as an ongoing threat to Lord Howe Island endemic species, and in particular highlighted an unidentified introduced earthworm suspected to directly compete with *P. nanus* (Department of Environment and Climate Change (NSW) 2007). Additionally, the NSW Scientific Committee (2001) identified two other introduced earthworm species of concern, observing that: 'Exotic species are already present on Lord Howe Island around the settlement including *Allobophora caliginosa*, and *Amynthas diffringens* (later synonymized with *A. corticis*) (Jamieson, 1977 and Australian Museum collections), and the spread of these species or introductions of others could have deleterious impacts on *Pericryptodrilus nanus*.'

There has not been a formal examination of the interaction between *P. nanus* and introduced earthworms, however displacement of native earthworms by introduced species has been observed in a broad diversity of species and ecosystems across the world (Winsome *et al.* 2006; Sánchez-De León and Johnson-Maynard 2009). The mechanisms by which exotic earthworms displace native species are still unclear (*i.e.* competition for food, exotic disease, ecosystem change through different patterns of habitat use etc.), however, across studies, introduced earthworms have been shown to pose a consistent threat to native species (Sánchez-De León and Johnson-Maynard, 2009; Winsome *et al*. 2006).

To date no program has been developed to assess the threat posed by introduced earthworms, and they remain a likely ongoing threat to *P. nanus*.

Introduced and Native Flatworms

Since 2017, invertebrate surveys conducted by Department of Planning and Environment staff under the Saving our Species program (SoS) and the Australian Museum have noted an increase in at least three endemic and two introduced planarian flatworm species at the summit of Mount Gower (C. Stehn pers. comms. Feb 2022). Flatworms are often generalist predators, and many species commonly prey on earthworms (Boag and Yeates 2001; Sugiura 2010). As probable predators of *P. nanus*, any increase in flatworms on Mount Gower is likely to affect survivorship in *P. nanus.*

There have been no systematic surveys for flatworms on Mount Gower, and further studies are required to determine the extent and severity of their impact on *P. nanus* and the broader Mount Gower ecosystem (C. Stehn pers. comms. Feb 2022).

Rodents

Introduced rodents, in particular the ship rat *Rattus rattus* and house mouse *Mus musculus*, have had a devastating effect on the native fauna of Lord Howe Island. Since their introduction following a shipwreck in 1918, ship rats have been a driving factor in the extinction of many Lord Howe Island plant and animal species (Department of Environment and Climate Change (NSW) 2007). Introduced rodents are a suspected predator of *P. nanus*, but no formal study has been conducted to assess their impact on the population.

Rats have also severely impacted plant communities on Lord Howe, including Gnarled Mossy Cloud Forest. Rats eat seeds and seedlings of many key structural species, clearing young standing plants, and reducing the seedbank and future generations of key species. This affects the health and distribution of the Gnarled Mossy Cloud Forest on which *P. nanus* depends (Auld and Leishman 2015).

An extensive program of rodent eradication on the main island began in 2019 (Harper *et al.* 2020). This program appears to have been successful and rodents (rats and mice) have been eradicated from the island. As a result, it is likely that there will be increases in some invertebrate species previously severely impacted by rodent predations (T. Auld pers. comm. December 2021; International Union for Conservation of Nature and Natural Resources 2020). However, the program has not yet been officially declared successful and ongoing monitoring is in place, both for rodents and to quantify the benefits and/or ecosystem changes resulting from the pest eradication.

Common Blackbirds (*Turdus merula*)

As a predator of earthworms, the common blackbird *Turdus merula* is a suspected predator of *P. nanus* on Lord Howe Island, however no formal study has been conducted to assess their impact. *T. merula* were likely introduced to Lord Howe Island in the early 1940s in an attempt to control weevils that were feeding on palms (Department of Environment and Climate Change (NSW) 2007). The species is now common on the main island where they are predators of native invertebrates (Department of Environment and Climate Change (NSW) 2007; State of Queensland 2016). There is currently no program to remove blackbirds from Lord Howe Island, and they remain an ongoing threat to invertebrates (Department of Environment and Climate Change (NSW) 2007; State of Queensland 2016).

Invasive fungal plant pathogens

There are two key fungal pathogens that threaten plant communities on Lord Howe Island; root-rot, *Phytophthora cinnamomi,* and Myrtle Rust, *Austropuccinia psidii*. The reliance of *P. nanus* on Gnarled Mossy Cloud Forest means the threat these pathogens pose to this ecosystem also threatens the ongoing stability of *P. nanus.*

Phytophthora cinnamomi is an introduced pathogen that has had a devastating effect on plant communities world-wide, causing catastrophic dieback in many species (Türkölmez *et al.* 2019; Weste 1974; Weste et al. 1973), and is listed as the key threatening process 'Dieback caused by the root-rot fungus (*Phytophthora cinnamomi)'* under the EPBC Act. *Phytophthora cinnamomi* affects a huge variety of plants, including *Dracophyllum spp.* that are commonly dominant in Gnarled Mossy Cloud Forest (T. Auld pers. comm. December2021). *Phytophthora cinnamomi* was detected in a small orchard on Lord Howe Island in 2003 and is now considered a threat on the island (Auld and Hutton 2004). It has so far been contained, however the movement of residents and tourists across the island risk its spread in the future.

Myrtle rust, *Austropuccinia psidii,* is an exotic fungus that affects Myrtaceae, destroying tissue, limiting reproductive success, and ultimately leading to plant death (Makinson 2018). Myrtle rust may affect *Metrosideros* sp. and *Leptospermum* sp., which are some of the dominant tree covers in some areas of Gnarled Mossy Cloud Forest (T. Auld pers. comm. December 2021). While *A. psidii* is not currently detected on Lord Howe, spores may blow over from the mainland or be brought in on boats,

visitors, or supplies. There have been outbreaks on the island in the past that have been effectively controlled, however it remains an ongoing threat (Auld and Leishman 2015; T. Auld pers. comms. December 2021).

Invasive Weeds

Invasive weeds pose a threat to Gnarled Mossy Cloud Forest. Cherry Guava (*Psidium cattleyanum var. cattleyanum*) and Ground Asparagus (*Asparagus aethiopicus*) have both been observed in proximity to, and at similar altitude to Gnarled Mossy Cloud Forest (Lord Howe Island Board 2016). These species are the two most common and invasive weed species on Lord Howe Island, and have been severely detrimental to other ecological communities on the island (Lord Howe Island Board 2016). Invasion of these species into Gnarled Mossy Cloud Forest would affect the vegetation structure and may reduce the amount of suitable habitat available to *P. nanus*, however studies into the ecology and habitat use in *P. nanus* would be necessary to estimate the scale of this threat. There is currently an intensive weed management program underway across the Lord Howe Island group, and this may reduce the risk of weed invasion in the future (Lord Howe Island Board 2016).

Assessment against IUCN Red List criteria

Further survey work is needed to clarify the distribution of *P. nanus*, but it is considered that the available evidence is strong enough to support the listing assessment given below.

Criterion A *Population Size reduction*

Assessment Outcome: Data Deficient

Justification: The species is known only from 10 museum held specimens, and there is no available data to determine if there has been a reduction in the population size of *P. nanus* (Jamieson 1977).

Criterion B *Geographic range*

Assessment Outcome: Critically Endangered under Criterion B1ab(iii)+B2ab(iii)

Justification: *Pericryptodrilus nanus* has a very restricted range, being known only from specimens collected in a single 27-hectare area of Gnarled Mossy Cloud Forest at the summit of Mount Gower, Lord Howe Island (Jamieson 1977). The small size of this location results in *P. nanus* having an AOO and EOO of 4km^2, with all occurrences falling within a single 2 km x 2 km grid. This puts both EOO and AOO for this species below the thresholds for Critically Endangered listing for criterion B (EOO <100km^2, AOO <10km^2).

In addition to these thresholds, at least two of three other conditions must be met. These conditions are:

a) The population or habitat is observed or inferred to be severely fragmented **OR** there is 1 (CR), ≤5 (EN) or ≤10 (VU) locations.

    Assessment Outcome: Sub-criterion met - 1 Location (CR). There is only one location, which meets the threat category of Critically Endangered. The species is not currently considered to be severely fragmented.

Justification: *Pericryptodrilus nanus* is only found at one location, being restricted to and reliant on a very small (27 hectares) extant area of Gnarled Mossy Cloud Forest (Jamieson 1977; Auld and Leishman 2015). Climate change, plant pathogens, or species invasions are highly likely to affect the entire extent of Gnarled Mossy Cloud Forest, and as a result cause decline in habitat extent or quality for the entire population of *P. nanus.*

There is no data on population structure or distribution available for *P. nanus* on which to determine if populations are fragmented across its range.

b) Continuing decline observed, estimated, inferred or projected in any of: (i) extent of occurrence; (ii) area of occupancy; (iii) area, extent and/or quality of habitat; (iv) number of locations or subpopulations; (v) number of mature individuals.

Assessment Outcome: Sub-criterion met – Continuing decline is inferred in (iii) area, extent and quality of habitat.

Justification: *Pericryptodrilus nanus* is completely restricted to Gnarled Mossy Cloud Forest on the peak of Mount Gower, Lord Howe Island (Jamieson 1977). Observed and projected reduction in rainfall and moisture availability driven by climate change is likely to reduce the area, extent, and quality of Gnarled Mossy Cloud Forest as it becomes drier, reducing the availability of the moist leaf litter on which *P. nanus* depends (Auld and Leishman 2015).

c) Extreme fluctuations.

Assessment Outcome: Data Deficient

Justification: The species in known only from 10 museum held specimens, and no formal assessment of population dynamics or fluctuations has been conducted (Jamieson 1977).

Criterion C Small population size and decline

Assessment Outcome: Data Deficient

Justification: Size and stability of the population is unknown. The species is known only from 10 museum held specimens, and no assessment of population size or decline has been conducted (Jamieson 1977).

Criterion D Very small or restricted population

Assessment Outcome: Not met

Justification: The population is only known from a single location, at the peak of Mount Gower, with a total AOO of only 4 km^2, the smallest standard grid resolution recommended for assessments under IUCN (2019). However, the population size is unknown, and there is no clear future threat to *P. nanus* that would contribute to the extinction of the species in a very short time frame, and as a result *P. nanus* does not meet the thresholds for listing under Criterion D.

To be listed as Vulnerable under D, a species must meet at least one of the two following conditions:

D1. Population size estimated to number fewer than 1,000 mature individuals

Assessment Outcome: Data Deficient

Justification: Population size is unknown. The species in known only from 10 museum held specimens, and no formal assessment of population size has been conducted (Jamieson 1977). While it is unlikely that the population of *P. nanus* is less than 1,000, the lack of population surveys means it is not possible to clearly estimate population size in *P. nanus.*

D2. Restricted area of occupancy (typically <20 km^2) or number of locations (typically <5) with a plausible future threat that could drive the taxon to CR or EX in a very short time.

Assessment Outcome: Not met

Justification: While the population is only known from a single location with a small total AOO (4 km^2), there is no clear future threat to *P. nanus* that would contribute to the extinction of the species in a very short time frame.

Criterion E Quantitative Analysis

Assessment Outcome: Data Deficient

Justification: No population viability analysis available.

Conservation and Management Actions

This species is currently listed on the NSW Biodiversity Conservation Act 2016 and a conservation project has been developed by the NSW Department of Planning and Environment under the Saving our Species program. The conservation project identifies priority locations, critical threats and required management actions to ensure the species is extant in the wild in 100 years. *Pericryptodrilus nanus* sits within the Data-deficient species management stream of the SoS program and the conservation project can be viewed here

https://www.environment.nsw.gov.au/savingourspeciesapp/project.aspx?ProfileID=10888

References:

Auld TD, Hutton I (2004) "Conservation issues for the vascular flora of Lord Howe Island" *Cunninghamia* **8**, 490–500.

Auld TD, Leishman MR (2015) "Ecosystem risk assessment for Gnarled Mossy Cloud Forest, Lord Howe Island, Australia" *Austral Ecology* **40**, 364–372. doi:10.1111/aec.12202

Bachman S, Moat J, Hill AW, de laTorre J, Scott B (2011) "Supporting red list threat assessments with GeoCAT: Geospatial conservation assessment tool" *ZooKeys* **150**, 117–126. doi:10.3897/zookeys.150.2109

Boag B, Yeates GW (2001) “The potential impact of the New Zealand flatworm, a predator of earthworms, in western Europe” *Ecological Applications* **11**, 1276–1286. doi:10.1890/1051-0761(2001)011[1276:TPIOTN]2.0.CO;2

Department of Environment and Climate Change (NSW) (2007) Lord Howe Island Biodiversity Managment Plan. Sydney. doi:10.2307/4118055

Dyne GR, Jamieson BGM (2004) “Native Earthworms of Australia II (Megascolecidae, Acanthodrilinae)” 200.

Eggleton P, Inward K, Smith J, Jones DT, Sherlock E (2009) “A six year study of earthworm (Lumbricidae) populations in pasture woodland in southern England shows their responses to soil temperature and soil moisture” *Soil Biology and Biochemistry* **41**, 1857–1865. doi:10.1016/j.soilbio.2009.06.007

El-Duweini AKhalaf, Ghabbour SamirI (1965) “Population Density and Biomass of Earthworms in Different Types of Egyptian Soils” *British Ecological Society* **2**, 271–287.

Harper GA, Pahor S, Birch D (2020) “The Lord Howe Island Rodent Eradication: Lessons Learnt from an Inhabited Island” *Proceedings, 29th Vertebrate Pest Conference* 1–11.

Harris R, Cassis G, Auld T, Hutton I (2005) “Floristics and structure of the mossy cloud forest of Mt Gower summit, Lord Howe Island” *Pacific Conservation Biology* **11**, 246–256. doi:10.1071/PC050246

International Union for Conservation of Nature and Natural Resources (2020) Lord Howe Island Group 2020 Conservation Outlook Assessment.

IUCN (2012). IUCN Red List Categories and Criteria: Version 3.1. Second edition. Gland, Switzerland and Cambridge, UK: IUCN. iv + 32pp.

IUCN Standards and Petitions Committee (2019) “Guidelines for Using the IUCN Red List Categories and Criteria. Version 14. IUCN Standards and Petitions Committee” *IUCN Red List* **14**, 1–60. Available at http://www.iucnredlist.org/documents/RedListGuidelines.pdf.%0ATHE

Jamieson BGM (1977) “The indigenous earthworms (Megascolecidae: Oligochaeta) of Lord Howe Island” *Records of the Australian Museum* **30**, 272–308. doi:10.3853/j.0067-1975.30.1977.390

Laffan MD, Kingston T (1997) “Earthworms in some Tasmanian forest soils in relation to bioturbation and soil texture profile” *Australian Journal of Soil Research* **35**, 1231–43.

Lord Howe Island Board (2016) Lord Howe Island Weed Management Strategy 2016–2025. Lord Howe Island, NSW.

Makinson RO (2018) Myrtle Rust reviewed: the impacts of the invasive pathogen Austropuccinia psidii on the Australian environment. Canberra.

NSW Threatened Species Scientific Committee (2001) Pericryptodrilus nanus (an earthworm) - Endangered Species Listing NSW Scientific Committee - Final Determination. Available at https://www.environment.nsw.gov.au/topics/animals-and-plants/threatened-species/nsw-threatened-species-scientific-committee/determinations/final-determinations/2000-2003/pericryptodrilus-nanus-an-earthworm-endangered-species-listing

van Praagh BD, Yen AL (2010) "National Recovery Plan for the Giant Gippsland Earthworm Megascolides australis" 31.

Sánchez-De León Y, Johnson-Maynard J (2009) "Dominance of an invasive earthworm in native and non-native grassland ecosystems" *Biological Invasions* **11**, 1393–1401. doi:10.1007/s10530-008-9347-6

Schmidt O, Curry JP (2001) "Population dynamics of earthworms (Lumbricidae) and their role in nitrogen turnover in wheat and wheat-clover cropping systems" *Pedobiologia* **45**, 174–187. doi:10.1078/0031-4056-00078

State of Queensland (2016) Invasive animal risk assessment: Blackbird (Turdus merula). Brisbane.

Sugiura S (2010) "Prey preference and gregarious attacks by the invasive flatworm Platydemus manokwari" *Biological Invasions* **12**, 1499–1507. doi:10.1007/s10530-009-9562-9

Türkölmez S, Derviş S, Çiftçi O, Serçe U (2019) "First report of Phytophthora cinnamomi causing root and crown rot of Ficus carica in Turkey" *Plant Disease* **103**, 776. doi:10.1094/PDIS-08-18-1294-PDN

Uvarov A v., Tiunov A v., Scheu S (2011) "Effects of seasonal and diurnal temperature fluctuations on population dynamics of two epigeic earthworm species in forest soil" *Soil Biology and Biochemistry* **43**, 559–570. doi:10.1016/j.soilbio.2010.11.023

Weste G (1974) "Phytophthora cinnamomi - The cause of severe disease in certain native communities in Victoria" *Australian Journal of Botany* **22**, 1–8. doi:10.1071/BT9740001

Weste G, Cooke D, Taylor P (1973) "The invasion of native forest by Phytophthora Cinnamomi. II.* Post-infection vegetation patterns, regeneration, decline in inoculum and attempted control" *Australian Journal of Botany* **21**, 13–29. doi:10.1071/BT9730013

Winsome T, Epstein L, Hendrix PF, Horwath WR (2006) "Competitive interactions between native and exotic earthworm species as influenced by habitat quality in a California grassland" *Applied Soil Ecology* **32**, 38–53. doi:10.1016/j.apsoil.2005.01.008

Expert Communications

Tony Auld – New South Wales Government, Department of Planning and Environment (retired)
Hank Bower – Lord Howe Island Board
Nicholas Carlile – New South Wales Government, Department of Planning and Environment
Chris Reid – The Australian Museum
Craig Stehn – New South Wales Government, Department of Planning and Environment

APPENDIX 1

Assessment against *Biodiversity Conservation Regulation 2017* criteria
The Clauses used for assessment are listed below for reference.

Overall Assessment Outcome:
Pericryptodrilus nanus was found to be Critically Endangered under Clause 4.3 (a)(d)(e, iii)

Clause 4.2 – Reduction in population size of species
(Equivalent to IUCN criterion A)
Assessment Outcome: Data Deficient

(1) - The species has undergone or is likely to undergo within a time frame appropriate to the life cycle and habitat characteristics of the taxon:			
	(a)	for critically endangered species	a very large reduction in population size, or
	(b)	for endangered species	a large reduction in population size, or
	(c)	for vulnerable species	a moderate reduction in population size.
(2) - The determination of that criteria is to be based on any of the following:			
	(a)	direct observation,	
	(b)	an index of abundance appropriate to the taxon,	
	(c)	a decline in the geographic distribution or habitat quality,	
	(d)	the actual or potential levels of exploitation of the species,	
	(e)	the effects of introduced taxa, hybridisation, pathogens, pollutants, competitors or parasites.	

Clause 4.3 - Restricted geographic distribution of species and other conditions (Equivalent to IUCN criterion B)
Assessment Outcome: Critically Endangered under Clause 4.3 (a)(d)(e, iii)

The geographic distribution of the species is:				
	(a)	for critically endangered species	very highly restricted, or	
	(b)	for endangered species	highly restricted, or	
	(c)	for vulnerable species	moderately restricted,	
and at least 2 of the following 3 conditions apply:				
	(d)	the population or habitat of the species is severely fragmented or nearly all the mature individuals of the species occur within a small number of locations,		
	(e)	there is a projected or continuing decline in any of the following:		
		(i)	an index of abundance appropriate to the taxon,	
		(ii)	the geographic distribution of the species,	
		(iii)	habitat area, extent or quality,	
		(iv)	the number of locations in which the species occurs or of populations of the species,	
	(f)	extreme fluctuations occur in any of the following:		
		(i)	an index of abundance appropriate to the taxon,	
		(ii)	the geographic distribution of the species,	
		(iii)	the number of locations in which the species occur or of populations of the species.	

Clause 4.4 - Low numbers of mature individuals of species and other conditions
(Equivalent to IUCN criterion C)
Assessment Outcome: Data Deficient

The estimated total number of mature individuals of the species is:				
	(a)	for critically endangered species	very low, or	
	(b)	for endangered species	low, or	
	(c)	for vulnerable species	moderately low,	
and either of the following 2 conditions apply:				
	(d)	a continuing decline in the number of mature individuals that is (according to an index of abundance appropriate to the species):		
		(i)	for critically endangered species	very large, or
		(ii)	for endangered species	large, or
		(iii)	for vulnerable species	moderate,
	(e)	both of the following apply:		
		(i)	a continuing decline in the number of mature individuals (according to an index of abundance appropriate to the species), and	
		(ii)	at least one of the following applies:	

			(A)	the number of individuals in each population of the species is:		
				(I)	for critically endangered species	extremely low, or
				(II)	for endangered species	very low, or
				(III)	for vulnerable species	low,
			(B)	all or nearly all mature individuals of the species occur within one population,		
			(C)	extreme fluctuations occur in an index of abundance appropriate to the species.		

Clause 4.5 - Low total numbers of mature individuals of species
(Equivalent to IUCN criterion D)
Assessment Outcome: Data Deficient

The total number of mature individuals of the species is:			
	(a)	for critically endangered species	extremely low, or
	(b)	for endangered species	very low, or
	(c)	for vulnerable species	low.

Clause 4.6 - Quantitative analysis of extinction probability
(Equivalent to IUCN criterion E)
Assessment Outcome: Data Deficient

The probability of extinction of the species is estimated to be:			
	(a)	for critically endangered species	extremely high, or
	(b)	for endangered species	very high, or
	(c)	for vulnerable species	high.

Clause 4.7 - Very highly restricted geographic distribution of species– vulnerable species
(Equivalent to IUCN criterion D2)
Assessment Outcome: Not met

For vulnerable species,	the geographic distribution of the species or the number of locations of the species is very highly restricted such that the species is prone to the effects of human activities or stochastic events within a very short time period.