

Recovery plan for the Nangur spiny skink (*Nangura spinosa*)



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Prepared by: Department of Environment and Resource Management

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Summary

Species and status

The Nangur spiny skink or Nangur skink *Nangura spinosa* is a medium-sized spinose lizard, belonging to the family Scincidae. It is listed as 'Critically Endangered' under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*, 'Endangered' under the Queensland *Nature Conservation Act 1992* and it is ranked as a medium priority under the Department of Environment and Resource Management 'Back on Track' species prioritisation framework.

Habitat and distribution summary

N. spinosa was first discovered by Europeans in 1992 (Covacevich et al. 1993) with the second population found approximately 38 km away in 1997 (Hannah et al. 1997). The skink is restricted to these two locations in south-east Queensland. Current estimates suggest a total population size of 183 adults with an extent of occurrence of approximately 45 km² (Borsboom et al. 2005). Targeted surveys are underway to assess whether the skink occurs in other areas of suitable habitat.

The species has been recorded on gentle sloping banks in semi-evergreen vine thicket on black basaltic soils (Covacevich et al. 1993). It has also been found on clay slopes in araucarian notophyll/microphyll vine forest and hoop pine (*Araucaria cunninghamii*) plantations (Hannah et al. 1997; Borsboom et al. 2005). At one site, the skinks showed a preference for road embankments, where more burrows were observed than on open ground (Borsboom et al. 2005). The skinks generally occur at altitudes of 315–600 m (Department of the Environment, Water, Heritage and the Arts 2009).

Threats summary

Habitat clearing and the establishment of hoop pine plantations were probably significant historical threats to *N. spinosa*. A number of potential current threatening processes have been identified. These include inappropriate fire regimes, weed invasion, introduced predators (cane toads, foxes, pigs and cats), hoop pine harvesting and re-establishment, and illegal collecting. Management options aimed at ameliorating these threats are discussed.

Recovery objective

The objective of this recovery plan is to improve the status of *N. spinosa* populations in the wild by implementing informed management decisions based on a thorough understanding of the species' biology and habitat requirements.

Summary of actions

The key actions required to promote the recovery of *N. spinosa* populations include:

- conduct surveys to determine the full extent and area of occupancy of the skink;
- undertake genetic comparison of the two known populations;
- monitor weed impact and where feasible initiate, continue and/or expand appropriate weed control (e.g. lantana) measures;
- monitor feral animal impact and where feasible initiate, continue and/or expand appropriate feral animal control measures;
- monitor illegal collection and disturbance activities;
- continue and expand *N. spinosa* population monitoring programs; and
- monitor ecological and biological parameters considered important for the survival of the wild populations and for implementing effective management practices.

1. General information

Conservation status

The Nangur spiny skink or Nangur skink (*Nangura spinosa*) is listed as 'Critically Endangered' under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*, 'Endangered' under the Queensland *Nature Conservation Act 1992* and it is ranked as a medium priority under the Department of Environment and Resource Management 'Back on Track' species prioritisation framework.

International obligations

The actions stated in this recovery plan are consistent with Australia's international obligations for listed threatened species.

Affected interests

Implementation of the recovery plan for *N. spinosa* may affect and/or require involvement from the stakeholders listed below:

- Department of Environment and Resource Management (DERM)
- Queensland Museum (QM)
- Department of Transport and Main Roads (DTMR)
- Department of Employment, Economic Development and Innovation (DEEDI)
- Australian Quarantine Inspection Service (AQIS)
- Hancock Queensland Plantations (HQP), managed by Hancock Timber Resource Group
- Burnett Mary Regional Group for NRM (BMRG)
- Gympie Regional Council (GRC)
- Indigenous groups
- independent researchers
- research institutions.

Consultation with Indigenous people

Consultation with Indigenous people has been undertaken with advice from, and through, the SEQTOA (South East Queensland Traditional Owner Alliance) and the Aboriginal Land Management Facilitators (ALMF) for Burnett Mary Regional Group (BMRG). The SEQTOA and ALMF were provided with the draft recovery plan for comment and for dissemination to representatives of local Indigenous groups and traditional owners. Implementation of the plan will take into account the Indigenous values, rights and interests concerning the Nangur spiny skink.

Benefits to other species or communities

Implementation of the recovery plan for *N. spinosa* will assist with the ongoing protection of the Nangur spiny skink and its habitat, through the promotion of improved land management practices to enhance conservation values. Any actions taken are likely to have flow-on benefits for other threatened species such as the 'Vulnerable' black-breasted button-quail *Turnix melanogaster* and the 'Endangered' leaf-tailed gecko *Phyllurus kabikabi* sp. nov.

Important habitat for *N. spinosa* may also benefit from implementation of the recovery plan. In particular, it may benefit regional ecosystems 12.12.17 and 12.8.21, which are listed as 'Endangered' under the Queensland *Vegetation Management Act 1999*, and 'Of concern' regional ecosystems 12.8.13.

Social and economic impacts

The implementation of this recovery plan will have some economic impacts as a consequence of the undertaking of management actions necessary for the maintenance of *N. spinosa* and its habitat. The majority of impacts are concerned with those activities of the current land managers. These activities include hoop pine plantation management and harvesting, weed control and fire management. There may be some impact on neighbouring land holders in relation to weed and fire management.

2. Biological information

Species description

The Nangur spiny skink was first discovered by Europeans in 1992 and formally described in 1993 (Covacevich et al. 1993). It belongs to the family Scincidae, which contains more than 370 species in Australia (Wilson et al. 2008). The skink is morphologically similar to the prickly forest skink (*Gnypetoscinus queenslandiae*), from north Queensland (Covacevich et al. 1993). Both species have unusual keeled body scales and are rainforest specialists (O'Connor & Moritz 2003).

N. spinosa has a robust build and grows to approximately 19 cm in length (9.5 cm snout–vent). It is readily distinguished by the spiny scales along its back, tail and flanks. The limbs are well developed and the tail tapers to a point. It is dark brown in colour with irregular cross-bands on the body. The labial scales are edged with black, there are dark flecks on the flanks and the underside is cream (Covacevich et al. 1993).

The mid body scales are in 28 rows and strongly keeled, forming longitudinal ridges. There are four pre-anal scales with the middle pair enlarged and the males have a bifurcate hemi-penis (Covacevich et al. 1993). The lower eyelid is moveable and scaly; the eye has a dark iris and a black pupil (Covacevich et al. 1993). The ear opening is large and lacks lobules (Covacevich et al. 1993; Wilson & Swan 2008).



Figure 1: Nangur spiny skink (photo: Steve K Wilson).

Life history and ecology

This species lives in burrows with a single entrance that are normally occupied by a single skink. However there are reports of burrows containing as many as five individuals that include a combination of adults, sub-adults and/or young (Borsboom et al. 2005). No more than two adult-sized animals have been recorded in a single burrow (Covacevich et al. 1993; Hannah et al. 1997; Borsboom pers. comm. 2010). Covacevich et al. (1993) recorded a burrow of 60 cm in length that terminated in an oval chamber of approximately 5 cm. Burrow entrances measure approximately 8 cm wide by 3 cm high (Hannah et al. 1997; Borsboom et al. 2005). Burrow longevity and active use varies, with at least one burrow found to be still in use after 13 years of monitoring (Borsboom pers. comm. 2010). Whether this burrow has been occupied continuously by the same skink is unknown (Borsboom pers. comm. 2010). In other instances burrows were found to be no longer in use by the skink within three months of the occupied burrow being found (Borsboom pers. comm. 2010).

Burrows are generally well-concealed with entrances usually found at the base of rocks, open ground, beneath exposed tree roots (Covacevich et al. 1993; Hannah et al. 1997; Borsboom et al. 2005). Burrows associated with rocks, exposed tree roots and bases of trees probably provide protection from predators digging out burrows (Borsboom et al. 2005). Field studies suggest a higher density of burrows along road embankments than on open ground (Borsboom et al. 2005). Roadside burrows were found on roadways that had received little to no machinery maintenance over recent years (Borsboom et al. 2005).

Burrow entrances are located where there is significant plant density and forest structure with a variety of rainforest species evident (Borsboom et al. 2005). It appears that the majority of skinks prefer to establish burrows where there is vegetation cover above 1.8 m high, but little vegetation at ground level; even road side burrows normally have significant overhanging vegetation (Borsboom et al. 2005). There is often a smooth 'resting platform' measuring approximately 11 cm wide by 8.5 cm long in front of a burrow entrance (Hannah et al. 1997). Research to date indicates that burrow entrances tend to face north-easterly, on north-easterly slopes (Borsboom et al. 2005). Skinks have been observed basking in sunlight half emerged from their burrow entrance in warm months (Wilson & Swan 2008). Crepuscular activity has been recorded outside burrow entrances in April (Borsboom 2007b).



Figure 2a: Arrow indicates Nangur spiny skink burrow Figure 2b: Nangur spiny skink habitat (photos: DERM).

Faecal pellets collected from near *N. spinosa* burrows suggest that this species has a varied diet consisting of ground dwelling invertebrates, primarily beetles and spiders (Covacevich et al. 1993). Some of these invertebrates are primarily active at night (Covacevich et al. 1993), further suggesting crepuscular and nocturnal activity by the skink (Borsboom 2007b). It has also been observed waiting near its burrow to ambush passing invertebrates (Wilson & Swan 2008; Wilson 1994).

Little is known of growth, maturation and reproduction for *N. spinosa*. Adults can weigh in excess of 30 g (Borsboom pers. comm. 2010), with neonates (identified by the presence of an obvious umbilical scar) weighing 1.5 g (Hannah et al. 1997). There is indirect evidence suggesting the skink bears live young (Covacevich et al. 1993).

Distribution

N. spinosa is confined to remnant dry rainforest, including semi-evergreen vine thickets at two locations approximately 38 km apart in south-east Queensland. The first population was discovered in 1992, the second in 1997 (Covacevich et al. 1993; Hannah et al. 1997). Estimates suggest a total population size of 183 adults with extent of occurrence approximately 45 km² (Borsboom et al. 2005). The area of occupancy has been estimated at 120 ha (Borsboom et al. 2005).

In the interests of protecting this species the two known localities are not identified specifically and are referred to herein as site A and site B.

Site A was previously part of a single semi-evergreen vine thicket / forest block estimated at 16,861 ha. Regional ecosystem mapping shows that 89.1% of this original block has been cleared (Borsboom et al. 2005). What remains is highly fragmented with the skink only found in a limited area of the largest remaining remnant, which has an area of approximately 750 ha (Borsboom et al. 2005). The historical distribution of the skink is unknown due to its recent discovery, but may have once occupied large areas now cleared for agriculture and grazing (Borsboom et al. 2005). Today the skink has an estimated area of occupancy of 120 ha – 24 ha at site A and 96 ha at site B – with site B comprising 32 ha of hoop pine plantation (Borsboom et al. 2005).

Vertebrate surveys of 18 dry rainforest sites in 1992 (Murgon to Rockhampton, and as far west as Monto and Biloela) failed to find *N. spinosa* at any location other than where it was first discovered (Horsup et al. 1993).

In 2005, a thorough search was carried out at 10 locations considered likely habitat for *N. spinosa*, with no new populations discovered (Borsboom & Willis 2005). The total estimated number of mature *N. spinosa* in 2005 was 183 – 43 at site A and 140 at location site B (Borsboom et al. 2005). Monitoring of *N. spinosa* burrows along a 1 km transect at site B in late March 2007 recorded 32 individuals (Borsboom 2007a). Later in 2007 a further eight sites were surveyed. These sites were thought to have potentially suitable habitat for the skink and were in close proximity to the two known sites, but no new populations were discovered (Borsboom 2007a; Borsboom 2007b). (See survey site details Appendix 1.) Ongoing surveys have failed to find further populations at another 20 sites in general proximity to known sites and with similar vegetation and other habitat features (Borsboom pers. comm. 2010).

Further surveys are required to determine the full geographic distribution of this species.

Habitat

To date, all known *N. spinosa* have been recorded at between 315 m and 600 m altitude on black, hard basaltic soil in semi-evergreen vine thickets, hoop pine plantations and clay slopes in araucarian notophyll vine forest (Covacevich et al. 1993; Hannah et al. 1997; Borsboom et al. 2005). Regional ecosystem (RE) polygons identified in known *N. spinosa* locations include: 12.8.13, 12.8.21, 12.12.13, 12.12.16 and 12.12.17 (Borsboom et al. 2005). Of particular concern are the regional ecosystems 12.8.21 and 12.12.17, which are listed as 'Endangered' under the *Vegetation Management Act 1999* (Qld) and 12.8.13 which is listed as an 'Of concern' regional ecosystem (Table 1).

The most common tall tree species growing in *N. spinosa* habitat at site B are hoop pine (*Araucaria cunninghamii*) and red kamala (*Mallotus philippensis*). At site A, the only tall tree species found near burrows was the scrub poison tree (*Excoecaria dallachyana*) (Borsboom et al. 2005). However, forested areas at site A have been previously logged for species such as hoop pine (Borsboom pers. comm. 2010).

Most *N. spinosa* burrows are in well structured vegetation with a diversity of plant types and native species with a closed canopy and little vegetation at ground level (Borsboom et al. 2005). Soil composition is likely to play a role in habitat suitability for the skink. Soils need to be of a suitable composition to allow burrows to be constructed and maintained (Borsboom et al. 2005).

Table1: Regional ecosystems

12.8.13	Araucarian complex microphyll vine forest on Cainozoic igneous rocks
12.8.21	Semi-evergreen vine thicket with <i>Brachychiton rupestris</i> on Cainozoic igneous rocks
12.12.13	Araucarian complex microphyll to notophyll vine forest on Mesozoic to Proterozoic igneous rocks
12.12.16	Notophyll vine forest on Mesozoic to Proterozoic igneous rocks
12.12.17	Semi-evergreen vine thicket on Mesozoic to Proterozoic igneous rocks

Source: Queensland Herbarium 2009. Regional Ecosystem description database Version 6.0b: Department of Environment and Resource Management.

Important populations

N. spinosa is confined to two small isolated areas in south-east Queensland, with an estimated population of 43 individuals at site A and 140 at site B (Borsboom et al. 2005). To ensure the long-term survival of the species in the wild, both known populations and essential habitat needs to be conserved.

3. Threats

Identification of threats

As *N. spinosa* has a restricted geographic distribution there is a strong possibility that threats may lead to a decline in numbers and a reduction to the area of occupancy. The population at site A warrants special concern as only an estimated 43 mature skinks were recorded in 2005 (Borsboom et al. 2005). Regular monitoring of known burrows at Site A since January 2001 has never recorded more than five individuals during any one census (Borsboom pers. comm. 2010). Any reduction in numbers may have a dramatic impact on population viability, as small populations are generally more vulnerable to stochastic events, such as fire or climate change. The maintenance of the very small population at site A may be regarded as of greater importance for management following genetic studies that show it to be significantly divergent from the population at site B.

Reasons for the small population of *N. spinosa* at site A is largely unknown, but may be attributed to a combination of factors including: habitat loss, feral animals (pigs, foxes, cats and cane toads), hoop pine harvesting and replanting. All of these are likely to have a negative impact on the species (Borsboom et al. 2005). Due to the recent discovery of the skink, knowledge of threatening processes to the skink's survival is limited. More research is necessary to improve our understanding of threats and how they impact on the Nangur spiny skink.

Dry rainforest comprising of semi-evergreen vine thickets are important refuges for a diverse range of species. Threats such as fire and weed invasion should be managed to preserve the floral and faunal integrity of these ecosystems (Horsup et al. 1993).

Known threats

Clearing of habitat:

Historical clearing of semi-evergreen vine thicket for agricultural purposes has resulted in most remaining remnants being less than 100 ha in area (Covacevich et al. 1993). According to Queensland regional ecosystem mapping (EPA 2005) over 80% of this original vegetation has been cleared (Borsboom et al. 2005). Although there is no historical data on *N. spinosa* prior to its discovery, it is thought that the skink may have once occupied a significant proportion of the land now cleared of semi-evergreen vine thicket (Borsboom et al. 2005).

As all current known sites for *N. spinosa* are in protected estate or within hoop pine plantations the threat of broad-scale clearing should be limited, as long as site B is protected from further forestry activities (Borsboom et al. 2005). Harvesting of existing hoop pine plantations where the skink occurs will reduce canopy cover, vegetation structure and native species diversity around its burrows. This could potentially alter the diversity and abundance of prey insects and coupled with competition for insects from cane toads, may greatly impact upon the skink's survival.

Hoop pine plantation harvesting and re-establishment:

N. spinosa occupies 32 ha of hoop pine plantation within two plantation compartments at site B. These blocks were established over 50 years ago without the use of heavy machinery (Borsboom et al. 2005). Today, large sophisticated machinery is used for harvesting and re-establishment of hoop pine plantations. This machinery may impact negatively on the skink's habitat. It is estimated that 27% of the skink's total area of occupancy could potentially be lost and approximately 17% of the population possibly killed if the harvesting and re-planting is carried out with heavy machinery (Borsboom et al. 2005).

Current access to the two plantation compartments at site B is via unsealed roads which in recent years have received minimal maintenance. Prior to harvesting, earthwork (road widening and resurfacing) will be required to allow access for large machinery and logging trucks. These activities are likely to be detrimental to *N. spinosa*, in particular populations that occupy burrows along the road edges. Surveys at site B show a higher density of burrows along two sections of forestry roadway compared to adjoining native and hoop pine forest (Borsboom et al. 2005). It is estimated that 25% of the skink's population at site B could be killed if inappropriate road maintenance is undertaken (Borsboom et al. 2005).

These compartments are scheduled to be harvested over the next 10 years. The re-establishment of the hoop pine plantation is not planned, with the long-term outcome being to restore, as much as possible, the structure and floristics of the original natural forest present on the site prior to plantation establishment. The majority of the restoration will be achieved through natural regeneration.

Recommendations for the protection of *N. spinosa* from forestry operations include either ceasing all logging operations and replanting at known *N. spinosa* locations, or conducting pre-harvest surveys and establishing adequate buffer zones around *N. spinosa* burrows to prevent destruction of burrows and killing of skinks.

Illegal collection:

Illegal collection has previously been identified as a major threat to this species due to its limited distribution and small population size. Borsboom et al. (2005) noted that the size and rarity of *N. spinosa*, coupled with increased public information on the skink, makes it a potential target for illegal collection. In 2009, two locked gates were installed along access roads at site B to reduce unmonitored access to the area and disturbance to the skink. This mitigation has reduced the impact of this threat on the skink but ongoing monitoring and compliance is essential to safeguard its survival.

Potential threats

Feral animals:

While the impact of feral animals on the Nangur spiny skink is not quantified, cane toads, feral cats, foxes, dingoes and pigs are known to occur in *N. spinosa* habitat. These species are known to prey on small reptiles (Borsboom et al. 2005), and compete with native species for resources. There is the possibility that these species have already impacted on *N. spinosa* and this may be part of the reason why numbers are low and known sites for the skink are limited.

The cane toad (*Rhinella marina*) is a potential threat to *N. spinosa* through competition for food and other resources. These toads have been sighted at site A as early as 1992 (Covacevich et al. 1993). Borsboom et al. (2005) have recorded cane toads resting inside *N. spinosa* burrows at site B, where they were observed in some instances completely blocking

the burrow entrances and thus preventing any skinks in the burrow from leaving. Cane toads are capable of consuming anything of a size that they can swallow including small reptiles, amphibians and large numbers of invertebrates (Covacevich & Archer 1975). Invertebrates that the skink relies upon for food are also likely to be a component of the cane toad's diet, indirectly impacting on food available for *N. spinosa* (Covacevich et al. 1993). There is also a possibility that smaller *N. spinosa* individuals fall within the prey range of large cane toads (Borsboom et al. 2005).

Feral cats (*Felis catus*) are opportunistic predators, feeding on small mammals, birds, reptiles, amphibians, arthropods and fish (Jones & Coman 1981). Studies on the diet of feral cats in New South Wales showed that individual cats can have significant numbers of reptiles in their gut, with 19 skinks found in one cat's stomach (Jones & Coman 1981). Read and Bowen (2001) found that reptiles were the most abundant non-rabbit food item in their study on the diet of feral cats and foxes in arid South Australia. Evidence from Risbey et al. (1999) at Heirisson Prong in Western Australia supported this finding, adding that reptiles were particularly threatened during summer and autumn.

Feral pigs (*Sus scrofa*) are known to degrade and disturb habitat utilised by *N. spinosa*, especially at site A. Pig foraging can cause erosion, reduce water quality in streams and alter the composition and distribution of forest litter, thus impacting on soil seed and invertebrate populations (Mitchell et al. 2007). Pig predation is also claimed to affect small reptile populations. A report by the Queensland Murray Darling Committee states that feral pigs, foxes and cats directly impact five species of reptiles in southern Queensland through competition or predation (Marshall 2007).

Foxes (*Vulpes vulpes*) and wild dogs are also known to occur at both sites and can potentially impact *N. spinosa*. Foxes have a varied diet including mammals, birds, reptiles, amphibians, insects, fruit and human waste (Saunders et al. 1995). Molsher et al. (2000) found in their fox diet study that one fox stomach contained eight legless skinks, one blind snake and one dragon. While reptiles generally appear to be a minor food item for foxes (Saunders et al. 1995; Molsher et al. 2000), work needs to be undertaken to quantify the level of predation foxes have on reptiles. Current pest management for feral animals is limited to the use of regular 1080 baiting to control wild dogs.

Monitoring of the impact of feral animals on the Nangur spiny skink and evaluating current control measures needs to be undertaken. Consideration must be taken when implementing any pest management strategy, for control of a dominant predator may result in an increase in population size of another predator (i.e. mesopredator release).

Fire

Vine thickets are not normally susceptible to fire as their high moisture content limits vegetation drying (Ginsberg 1998). However, in extreme conditions, such as prolonged drought (which can cause heavy leaf fall) or disturbance, the forest is at risk of being burnt. The potential for hotter fires is increased by the spread and growth of lantana, partly through the build-up of forest floor fuel loads. Many skinks have the ability to flee fire or retreat to a well insulated site (Lindermayer et al. 2008). In the case of the Nangur skink, its burrow may offer a safe retreat from fire. It should be noted, however, that some burrows are quite shallow and may not provide sufficient insulation from high intensity burns. Fire has the potential to degrade core *N. spinosa* habitat, opening it up to further invasion of weeds, such as lantana (Fensham et al. 1993). Fire may also impact on the availability of insects preyed on by the skink.

While few preventative measures will successfully stop an intense fire, a combination of back burning, maintaining firebreaks, reducing fuel loads in adjacent habitats and controlling weeds (including lantana) will reduce spot fires from erupting in skink habitat.

At site B, forestry roads act as firebreaks. Currently these roads are not adequately maintained and pose a safety issue in regards to fire (Davies pers. comm. 2009). Firebreaks on the eastern, south-eastern and north-western side will be difficult to maintain due to the ruggedness of the terrain (Borsboom et al. 2005).

Minimal fire management has been undertaken in the past at site A as the vine thickets where the skink occurs were not considered susceptible to fire (Thompson pers. comm. 2009).

Weed invasion

Lantana (*Lantana camara*) is an invasive weed infesting areas where *N. spinosa* occur. It is especially prevalent along edges of vine scrubs adjacent to roads. While it is unknown exactly what impact lantana has on *N. spinosa*, it is suggested that lantana may change the diversity and biomass of arthropods, reduce natural light availability and/or change the characteristics of forest floor litter (Borsboom pers. comm., 2010). Dense patches of lantana can prevent native flora regeneration and alter natural processes in vine scrub. According to the National Lantana Management Group, *N. spinosa* and regional ecosystem 12.12.13 are at a high risk from lantana invasion. Lantana can reduce the resilience of regional ecosystem 12.12.13 species (National Lantana Management Group 2009). It can also increase the flammability of vine scrub resulting in hotter fires that open up the area to further lantana invasion (Fensham et al. 1993).

No active skink burrows have been discovered in areas infested by dense lantana (Borsboom et al. 2005). How lantana influences the status of a burrow is unclear. Ongoing survey work along road edges at site A have been hampered by lantana infestations (Borsboom et al. 2005). Lantana control is essential for maintaining access to *N. spinosa* survey sites. Control programs should be tailored to protecting *N. spinosa* and regional ecosystem 12.12.13. At site A, prior to 2006, a number of access roads were inaccessible due to lantana thickets (Borsboom et al. 2005). In 2006 DERM (formerly EPA) rangers undertook lantana control along a number of inaccessible roads in the vicinity of site A to allow vehicles access (Borsboom pers. comm., 2010).

Cat's claw creeper (*Macfadyena unguis-cati*) is a potentially serious threat to *N. spinosa* at site B. It is a rampant climber that smothers rainforest and riparian vegetation by choking native flora and forming a dense heavy mass of vegetation that has been known to fell trees (Biosecurity Queensland 2007). Currently cat's claw creeper appears to be low in abundance in areas adjacent to where the skink occurs (Davies pers. comm. 2009); however these infestations will almost certainly spread if control measures are not undertaken.

Cat's claw creeper has the potential to smother burrows and reduce light reaching the forest floor. It may also have an impact on the arthropod biomass. The extensive root system and persistent underground tubers may damage burrows and affect the skink's ability to forage. Control of cat's claw creeper is difficult due to its thick extensive root system; however, it is recommended that action be implemented to ensure this weed does not spread into known *N. spinosa* habitat.

Other weeds that should be monitored for their impact on *N. spinosa* include weedy *Sporobolus* grasses (such as rat's tail grasses *S. pyramidalis* and *S. natalensis*). These weed species have the potential to form thick roadside swards and may impact on the skink by smothering preferred burrow sites (Borsboom et al. 2005).

4. Recovery objectives, performance criteria and actions

Overall objective

To improved the status of *N. spinosa* in the wild through implementing informed management decisions based on a thorough understanding of the species' biology and habitat requirements.

Specific objective 1: To assess the distribution of *N. spinosa* and ensure 'essential habitat' for this species is considered in planning processes.

Action 1.1: Clarify essential habitat required for the survival of *N. spinosa*.

Performance criterion: Surveys to clarify essential habitat for *N. spinosa* completed.

Rationale: To date all known *N. spinosa* have been recorded on black, hard basaltic soil in semi-evergreen vine thickets, hoop pine plantations and clay slopes in araucarian notophyll vine forest (Covacevich et al. 1993; Hannah et al. 1997; Borsboom et al. 2005).

Further surveys and research is required to clarify that this is essential habitat for the survival of *N. spinosa*.

Potential contributors: DERM.

Action 1.2: Conduct surveys to assess *N. spinosa* presence/absence in areas of suitable habitat and to clarify the extent of the species distribution.

Performance criterion: Surveys to assess the species distribution completed.

Rationale: To date *N. spinosa* has been found at only two disjunct locations approximately 38 km apart in southeast Queensland. In 2005 evidence suggested that the total number of skinks at both these sites was 183 individuals, with a total estimated area of occupancy of 120 ha and an extent of occurrence of 45 km² (Borsboom et al. 2005).

Surveys at a further 18 sites in close proximity to known skink locations, have so far been unsuccessful in finding additional skink populations (Borsboom et al. 2005; Borsboom & Willis 2005; Borsboom 2007a; Borsboom 2007b). There are a number of sites with similar vegetation, soil composition and altitude that could potentially contain populations of *N. spinosa*. It is recommended that surveys be undertaken in suitable remnant vegetation on both State managed land and private property, in particular areas to the north, north-west and west of current known sites.

It is recommended that contact be made with landholders and neighbours adjacent to known *N. spinosa* sites and in areas where it could potentially occur. The aim of such contact would be to discuss sightings of the skink. Discovery of additional populations would improve the species status and management options could then be explored to ensure the protection of new populations. If *N. spinosa* is discovered on private land, negotiations with the landholder should be undertaken to implement appropriate land management practices to protect the skink and its habitat.

Potential contributors: DERM, Gympie Regional Council, landholders/managers, neighbours, Hancock Queensland Plantations, Traditional Owners.

Action 1.3: Encourage landholders to protect and manage key habitat for *N. spinosa*.

Performance criterion: Agreements for managing known *N. spinosa* habitat (in relation to identified threats) are negotiated and implemented.

Rationale: Maintaining existing wild *N. spinosa* populations and key habitat is important for the species recovery. It is essential to develop and implement strategies that mitigate identified threats to *N. spinosa* and its habitat.

Working with landholders and land managers on activities that will reduce the loss of important habitat for *N. spinosa* is a key step towards the species' survival. Providing knowledge on the skink and how it uses its habitat will aid in maintaining any populations outside the protected estate.

Land management activities may take the form of implementing an appropriate fire regime, feral animal control, reducing land clearing and weed control.

Potential contributors: DERM, Hancock Queensland Plantations, Gympie Regional Council, landholders/managers, Traditional Owners.

Specific objective 2: To reduce the impact of threatening processes on *N. spinosa* populations by maintaining and/or implementing effective threat abatement programs.

Action 2.1: Continue and expand weed control programs to protect *N. spinosa* habitat.

Performance criterion: Weed control programs maintained and expanded at known *N. spinosa* locations.

Rationale: Lantana (*Lantana camara*) is a weed of national significance and landholders are required by law to control this species. In August 2009, a lantana control program was implemented to reduce infestations of lantana near burrow monitoring transects and to maintain access to site B (Borsboom 2009).

Cat's claw creeper (*Macfadyena unguis-cati*) is a major weed of native forests and forestry plantation areas in Queensland (Biosecurity Queensland 2007). It is a declared Class 3 plant under the Queensland *Land Protection (Pest and Stock Route Management) Act 2002* that may require removal from near environmentally significant areas.

To maintain and/or restore known *N. spinosa* habitat, existing control programs at known sites should be expanded to include potential habitat in surrounding areas. Control of lantana and cat's claw creeper will allow continued access to skink monitoring sites.

Control methods may include physical removal (where erosion does not pose a threat to burrows) or the cutting of weeds near ground level with a follow-up poisoning of stumps and regrowth. Weed control during the cooler months when the skink is less active above ground is preferred.

A biological control for cat's claw creeper and lantana should be investigated and communication established with DEEDI Biosecurity Queensland in regards to the latest advances in provision and availability.

Potential contributors: DERM, DEEDI Biosecurity Queensland, Gympie Regional Council, landholders/managers, Traditional Owners.

Action 2.2: Continue and expand feral cat, fox, pig and wild dog/dingo control programs to protect known populations of *N. spinosa*.

Performance criterion: Feral animal control programs continued and expanded at known *N. spinosa* locations.

Rationale: Feral cats, foxes, wild dogs/dingoes and pigs occur at known *N. spinosa* locations. While not quantified, it is suspected that these species have the potential to impact on *N. spinosa*.

Feral foxes, cats, pigs and wild dogs are known to prey on small reptiles (Borsboom *et al.* 2005), and pigs can degrade and disturb habitat utilised by *N. spinosa*. Monitoring the impact of feral animals on the skink and evaluating current control methods needs to be undertaken concurrently. Current pest management for wild dogs at site A and B involving the use of 1080 baiting should be continued and expanded where and when required.

The most appropriate and effective methods for controlling feral cats, foxes and pigs needs to be assessed to ensure that they are compatible with the management objectives. An integrated pest management strategy to control feral animals will need to be created in partnership with relevant stakeholders. Managing bodies need to consider that control of a dominant predator may result in an increase in population of another predator when implementing any pest management strategy.

Potential contributors: DERM, DEEDI Biosecurity Queensland, Gympie Regional Council, landholders/mangers, Traditional Owners.

Action 2.3: Implement cane toad control measures to protect known populations of *N. spinosa*.

Performance criterion: Cane toad control programs implemented at known *N. spinosa* locations.

Rationale: Cane toads are a potential threat to *N. spinosa* through competition for food and shelter (Borsboom *et al.* 2005). There is also a concern that smaller skinks may be at risk from being eaten by large cane toads (Covacevich & Archer 1975).

While difficult to eliminate cane toads, it may be possible to limit cane toad breeding opportunities at site A and B, leading to a decrease in numbers. Two man-made stock dams exist close to known *N. spinosa* locations and are potentially important breeding sites for cane toads. Constructing a fence around each dam may prevent toads accessing the water and breeding in large numbers. Fencing would allow water to enter and exit the dam and be sturdy enough to prevent damage from other animals, while also allowing operational staff access to the water for fire management.

Other cane toad control measures worth investigating include cane toad traps and hand removal. These methods may provide a temporary control measure if deemed necessary during any critical life periods for the skink.

Potential contributors: DERM, DEEDI Biosecurity Queensland, landholders/mangers, Traditional Owners.

Action 2.4: Modify hoop pine plantation harvesting and re-establishment at sites where *N. spinosa* occur.

Performance criterion: Hoop pine plantation harvesting and re-establishment to be modified in sites where *N. spinosa* occur.

Rationale: Reports suggest that an estimated 27% of *N. spinosa*'s total area of occupancy will be lost and approximately 17% of the population killed if hoop pine plantation harvesting and re-planting is undertaken with heavy machinery (Borsboom et al. 2005). Two hoop pine plantation compartments where the skink is known to occur at site B are scheduled for harvest in the next ten years (Borsboom et al. 2005).

Based on the skink's distribution in the native forest around the two compartments (Borsboom et al. 2005), it has been suggested that the two compartments may have been prime habitat for the skink prior to plantation establishment. The establishment clearing of the two compartments was undertaken without the use of heavy machinery (Borsboom et al. 2005). This may be one reason the skink is currently found within the two compartments and why the understorey and mid-storey still contains a significant number of vine forest tree species (Borsboom et al. 2005).

Recommendations for the protection of *N. spinosa* from forestry operations include conducting pre-harvest surveys and establishing adequate buffer zones around *N. spinosa* burrows to prevent destruction of burrows and killing of skinks. This may effectively exclude harvesting and re-harvesting for different compartments.

It is strongly recommended that extensive pre-harvest surveys be undertaken in the two hoop pine plantation compartments, extending out to 25 m from the plantation boundary by personnel experienced in surveying for the skink. A minimum of two years prior to any planned harvesting operations including associated roadway upgrades. Surveys should be carried out to determine the number and locations of *N. spinosa*, home range, movement patterns and breeding biology and ecology. Surveys should be conducted between October and March, with results providing a base line data for further negotiations on excluding harvesting operations or to install buffer zones around known skink sites.

Should limited harvesting occur in the two compartments with protective buffer zones for the skink, then post-harvest monitoring of the effectiveness of the buffers should be undertaken. It is strongly recommended that areas harvested are not re-planted with hoop pine and are allowed to regenerate naturally.

Potential contributors: DERM, Hancock Queensland Plantations, Traditional Owners.

Action 2.5: Strategic road maintenance to be undertaken in known *N. spinosa* habitat.

Performance criterion: Strategic road maintenance undertaken, monitored and assessed.

Rationale: Current access to hoop pine plantation blocks at site B is via unsealed roads, which in recent years have received minimal maintenance (Borsboom et al. 2005). Road maintenance has the potential to impact significantly upon the skink, in particular on populations that occupy burrows along road embankments. Surveys at site B show a higher density of burrows along two sections of roadway compared to adjoining native forest and hoop pine plantation (Borsboom et al. 2005). It is estimated that 25% of the skink's population at site B could be killed if inappropriate road maintenance is undertaken (Borsboom et al. 2005).

As a result of minimal maintenance to roads around known skink locations, many are now overgrown with lantana making access difficult and posing a risk to operational personnel requiring safe access for fire control (Borsboom *et al.* 2005).

While some road maintenance activities may be detrimental to *N. spinosa*, there is a need to implement some form of maintenance from a safety perspective. Appropriate maintenance should be negotiated following the determination of an appropriate buffer around known *N. spinosa* burrows (Action 2.4). Signage along roads in the park should be installed, directing any road maintenance issues to the land manager prior to works being undertaken.

Potential contributors: DERM, Hancock Queensland Plantations, Gympie Regional Council.

Action 2.6: Implement a fuel management program to minimise the risk of fire damage to *N. spinosa* habitat.

Performance criterion: A fuel management program to be implemented, monitored and assessed in known *N. spinosa* habitat

Rationale: Fire can cause the degradation of the skinks habitat, opening it up to further invasion of weeds (Fensham *et al.* 1993), and altering plant litter biomass on the forest floor. To date, very little fire management in terms of controlled burns has been conducted. Infestations of lantana coupled with prolonged dry periods, has created the fuel load that now poses a threat of intense fire around some burrows.

Some roads that act as firebreaks are currently not adequately maintained and have become blocked by infestations of lantana. Firebreaks on the eastern, south-eastern and north-western sides of site B will be difficult to maintain due to the ruggedness of the terrain (Borsboom *et al.* 2005).

To prevent fire from degrading *N. spinosa* habitat, a fire management program is required at both site A and B. Firebreaks should be maintained and lantana controlled along roadways to allow easy access. More frequent burning in the open forest areas surrounding the vine thickets/forests may be considered together with requirements for buffer burning. Options to reduce fuel load near burrows should be investigated to minimise the likelihood and risk of spot fires in skink habitat.

Potential contributors: DERM, Hancock Queensland Plantations, neighbours landholders/managers, Gympie Regional Council.

Action 2.7: Monitor *N. spinosa* populations and habitat for evidence of illegal collection and disturbance.

Performance criterion: *N. spinosa* populations monitored to assess the level of illegal collection and disturbance.

Rationale: The rarity, size, taxonomic uniqueness and increasing availability of information on *N. spinosa*, make it a potential target for illegal collection by reptile enthusiasts both within Australia and overseas (Borsboom *et al.* 2005).

Prior to the installation of locked gates at site B in 2009, evidence of illegal disturbance of burrows had been suspected. The option of installing gates at site A to reduce the opportunity of collectors accessing *N. spinosa* burrows will be assessed. Ongoing monitoring

and compliance will assist in assessing the vulnerability of this species to illegal collection and disturbance.

Occupied burrows are currently being regularly monitored along a number of transects at site A and B. The monitoring program includes looking for signs of illegal collecting or disturbance (Borsboom pers. comm. 2010). If there is evidence of illegal collecting (by field observation or by other means) then consideration will be given to upgrade to more sophisticated monitoring techniques such as electronic surveillance along burrow transects.

Maintaining relationships with neighbouring landholders will assist in the identification of activities that warrant further investigation. Relevant DERM and Australian Quarantine Inspection Service (AQIS) staff will be advised if evidence of illegal collecting is uncovered.

Potential contributors: DERM, Hancock Queensland Plantations, Gympie Regional Council landholders/managers, AQIS.

Specific objective 3: To increase knowledge of *N. spinosa* biology, population dynamics and ecology to guide future management.

Action 3.1: Monitor *N. spinosa* populations to assess the efficiency of threat abatement actions.

Performance criterion: Monitoring programs conducted, maintained and regularly assessed at *N. spinosa* sites.

Rationale: Monitoring programs are essential for determining *N. spinosa* population size, dynamics and structure, and for assessing the efficacy of threat abatement actions. Ongoing monitoring of *N. spinosa* populations will help ensure that habitat supporting this species is managed to benefit the skink.

Although some *N. spinosa* can be observed in their burrows in winter (Borsboom pers. comm., 2010), monitoring is recommended during the warmer months when the skink is most active. Initially burrows already being monitored (action 3.3, 3.4 and 2.7) should be used to determine if threat abatement activities are proving successful. If additional populations are located, monitoring programs could be established at these sites to determine the efficacy of threat abatement programs if undertaken.

Potential contributors: DERM, land holders/managers, Queensland Museum, Traditional Owners.

Action 3.2: Conduct genetic comparison of the two populations of *N. spinosa*.

Performance criterion: Genetic comparison of the two populations completed and where applicable results applied to on-ground management.

Rationale: To date there are only two known populations of *N. spinosa* in locations separated by 38 km of habitat which surveys suggest does not contain the skink (Borsboom et al. 2005). The habitat separating the two sites is mainly sclerophyll forest types (Borsboom et al. 2005). It has been suggested that the two skink populations may have been separated for an evolutionarily significant time frame. Genetic studies of rainforest frog and reptile species often show significant divergence between populations (Couper pers. comm. 2009). The results of a genetic comparison of populations may affect recovery actions for the skink.

A sample of tail tips for genetic analysis was completed in 2010 from both *N. spinosa* sites and genetic testing undertaken to determine if there is significant genetic divergence (Borsboom pers. comm. 2010). Results show that the two populations are genetically different. An intensified effort will be required to preserve the smaller population at site A.

Potential contributors: DERM, Queensland Museum, research institutions.

Action 3.3: Continue to monitor burrow transects.

Performance criterion: Burrow transect monitoring program reviewed, amended where required and continued.

Rationale: Burrow monitoring transects were established in January 2005 at both sites and for the most part have been surveyed at least annually for signs of use by the skinks and disturbance (Borsboom pers. comm. 2010). To date, 121 known burrows have been tagged and are being actively monitored. Data obtained from surveys provides information on preferred burrow sites, the sizes and numbers of *N. spinosa* using a burrow and how long an individual burrow is occupied.

With the discovery of additional *N. spinosa* burrows, a review of existing monitoring is required to assess methodology including timing and frequency of monitoring and the number, coverage and adequacy of current monitoring transects. Any new locations for the skink will need to be incorporated into the burrow monitoring program.

Potential contributors: DERM, Hancock Queensland Plantations, Queensland Museum, landholders/managers.

Action 3.4: Determine *N. spinosa* home range and movement patterns.

Performance criterion: Home range and movement patterns determined and relevant results incorporated into on-ground management.

Rationale: Ecological information on *N. spinosa* is limited. There is no information on the daily or seasonal movements of individuals, home range sizes or dispersal of young.

The skinks are usually encountered sitting in their burrow entrance but individuals have been seen up to one metre from their burrow (Couper pers. comm. 2009; Borsboom et al. 2005). Most burrows are occupied by a single adult (Covacevich et al. 1993; Hannah et al. 1997; Borsboom pers. comm. 2010), so movement between burrows must occur for mating to take place.

Juveniles have been found sharing a burrow with an adult, possibly their mother (Covacevich et al. 1993; Wilson 1994; Hannah et al. 1997). Obtaining data on home range sizes and movements is crucial for determining effective buffer zones around burrows should forestry activities continue in and around the skinks habitat (Actions 2.4, 2.5). Currently 33% of the estimated area of occupancy at site B is in hoop pine plantation.

Potential contributors: DERM, Hancock Queensland Plantations, Queensland Museum, research institutions.

5. Summary table

Table 2: Summary of objectives, performance criteria, recovery actions and potential contributors

Priority ratings for each recovery action: **1** = high priority; **2** = medium priority; **3** = low priority.

Specific objectives	Performance criteria	Actions	Potential Contributors	Priority
1: To assess the distribution of <i>N. spinosa</i> and ensure 'essential habitat' for this species is considered in planning processes.	Surveys to clarify essential habitat for <i>N. spinosa</i> completed.	1.1: Clarify essential habitat required for the survival of <i>N. spinosa</i> .	DERM	1
	Surveys to assess the species distribution completed.	1.2: Conduct surveys to assess <i>N. spinosa</i> presence/absence in areas of suitable habitat and to clarify the extent of the species distribution.	DERM, GRC, landholders, neighbours, HQP, Traditional Owners	1
	Agreements for managing known <i>N. spinosa</i> habitat (in relation to identified threats) are negotiated and implemented.	1.3: Encourage landholders to protect and manage key habitat for <i>N. spinosa</i> .	DERM, HQP, GRC, Landholders, Traditional Owners	1
2: To reduce the impact of threatening processes on <i>N. spinosa</i> populations by maintaining and /or implementing effective threat abatement programs.	Weed control programs maintained and expanded at known <i>N. spinosa</i> locations.	2.1: Continue and expand weed control programs to protect <i>N. spinosa</i> habitat.	DERM, DEEDI, GRC, landholders, Traditional Owners	1
	Feral animal control programs continued and expanded at known <i>N. spinosa</i> locations.	2.2: Continue and expand feral cat, fox, pig and wild dog/dingo control programs to protect known populations of <i>N. spinosa</i> .	DERM, DEEDI, GRC, landholders, Traditional Owners	2
	Cane toad control programs implemented at known <i>N. spinosa</i> locations.	2.3: Implement cane toad control measures to protect known populations of <i>N. spinosa</i> .	DERM, DEEDI, landholders, Traditional Owners	3
	Hoop pine plantation harvesting and re-establishment to be modified in sites where <i>N. spinosa</i> occur.	2.4: Modify hoop pine plantation harvesting and re-establishment at sites where <i>N. spinosa</i> occur.	DERM, HQP, GRC, landholders, Traditional Owners	2

Specific objectives	Performance criteria	Actions	Potential Contributors	Priority
	Strategic road maintenance to be undertaken monitored and assessed.	2.5: Strategic road maintenance to be undertaken in known <i>N. spinosa</i> habitat.	DERM, HQP, DTMR, GRC	2
	A fuel management program to be implemented, monitored and assessed in known <i>N. spinosa</i> habitat.	2.6: Implement a fuel management program to minimise the risk of fire damage to <i>N. spinosa</i> habitat.	DERM, HQP, landholders, GRC	3
	<i>N. spinosa</i> populations monitored to assess the level of illegal collection and disturbance.	2.7: Monitor <i>N. spinosa</i> populations and habitat for evidence of illegal collection and disturbance.	DERM, HQP, GRC, landholders, AQIS	2
3: To increase knowledge of <i>N. spinosa</i> biology, population dynamics and ecology to guide future management.	Monitoring programs conducted, maintained and regularly assessed at <i>N. spinosa</i> sites.	3.1: Monitor <i>N. spinosa</i> populations to assess the efficiency of threat abatement actions.	DERM, land holders, QM, Traditional Owners	1
	Genetic comparison of the two populations completed and where applicable results applied to on-ground management.	3.2: Conduct genetic comparison of the two populations of <i>N. spinosa</i> .	DERM, QM, research institutions	1
	Burrow transect monitoring program reviewed, amended where required and continued.	3.3: Continue to monitor burrow transects.	DERM, HQP, QM, landholders	1
	Home range and movement patterns determined and relevant results incorporated into on-ground management.	3.4: Determine <i>N. spinosa</i> home range and movement patterns.	DERM, HQP, QM, research institutions	2

Priority ratings for each recovery action: **1** = high priority; **2** = medium priority; **3** = low priority

6. Total estimated costs

Table 3: Summary of objectives, recovery actions, and costs

Objective	Action if implemented	2010(\$)	2011(\$)	2012(\$)	2013(\$)	2014(\$)	Total(\$)
1: To assess the distribution of <i>N. spinosa</i> and ensure 'essential habitat' for this species is considered in planning processes.	1.1: Clarify essential habitat required for the survival of <i>N. spinosa</i> .	5,000	5,000	5,000	0	0	15,000
	1.2: Conduct surveys to assess <i>N. spinosa</i> presence/absence in areas of suitable habitat and to clarify the extent of the species distribution.	13,250	13,750	14,000	8,000	8,250	57,250
	1.3: Encourage landholders to protect and manage key habitat for <i>N. spinosa</i> .	2,000	2,000	2,000	2,000	2,000	10,000
2: To reduce the impact of threatening processes on <i>N. spinosa</i> populations by maintaining and /or implementing effective threat abatement programs.	2.1: Continue and expand weed control programs to protect <i>N. spinosa</i> habitat.	12,000	6,250	6,500	6,750	7,000	38,500
	2.2: Continue and expand feral cat, fox, pig and wild dog/dingo control programs to protect known populations of <i>N. spinosa</i> .	5,000	5,250	5,500	5,750	6,000	27,500
	2.3: Implement cane toad control measures to protect known populations of <i>N. spinosa</i> .	6,500	2,500	2,500	2,750	2,750	17,000
	2.4: Modify hoop pine plantation harvesting and re-establishment at sites where <i>N. spinosa</i> occur.	0	24,000	0	0	0	24,000
	2.5: Strategic road maintenance to be undertaken in known <i>N. spinosa</i> habitat.	2,000	2,000	2,000	2,250	2,250	10,500
	2.6: Implement a fuel management program to minimise the risk of fire damage to <i>N. spinosa</i> habitat.	2,500	10,000	2,500	2,750	2,750	20,500
	2.7: Monitor <i>N. spinosa</i> populations and habitat for evidence of illegal collection and disturbance.	5,000	5,000	5,000	5,000	5,000	25,000
3: To increase knowledge of <i>N. spinosa</i> biology, population dynamics and ecology to guide future management.	3.1: Monitor <i>N. spinosa</i> populations to assess the efficiency of threat abatement actions.	3,000	5,000	3,250	3,250	3,500	18,000
	3.2: Conduct genetic comparison of the two populations of <i>N. spinosa</i> .	6,250	0	0	0	0	6,250
	3.3: Continue to monitor burrow transects.	12,000	6,250	6,500	6,750	7,000	38,500
	3.4: Determine <i>N. spinosa</i> home range and movement patterns.	18,500	6,000	47,500	6,500	6,750	85,250
	Estimated total cost per year (\$)	93,000	93,000	102,250	51,750	53,250	393,250

7. Management practices

The management practices prescribed below are based on current understanding of threats to *N. spinosa* populations and existing conservation measures known to be effective in addressing these. These practices are necessary for the protection of *N. spinosa* and its habitat and therefore, the long-term persistence of this species in the wild.

- Conduct field study to better understand the ecology (e.g. movement patterns, population structure, reproduction, etc) of *N. spinosa*;
- Maintain a coordinated predator control program targeting cane toads, feral cats, feral pigs and foxes that involves relevant State and Local government agencies, with a focus on known locations for the skink;
- Restore/maintain *N. spinosa* habitat by maintaining and/or implementing control programs to address the impacts of environmental weeds;
- Restrict disturbance from logging operations and associated activities and infrastructure by applying an appropriate buffer zone in areas where the skink can be potentially impacted on by these activities;
- Continue to secure the long-term protection of suitable habitat and populations by establishing management plans that favour the persistence of viable populations in the wild.
- Update signage along roadways where *N. spinosa* burrows occur to alert road maintenance staff of the need to consult land managers prior to undertaking road maintenance.

8. Evaluation of recovery plan

Completion of actions within this plan may require reporting by DERM or other contributors to Department of Sustainability, Environment, Water, Population and Communities. These reports may be published and will be submitted to the A/Assistant Director General of Sustainable Communities and Landscapes, DERM. Reports will be available through DERM's Recovery Action Database (an interactive web-based information system).

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Appendix 1: *N. spinosa* survey site details including broad habitat characteristics

Site	Location	Survey date	Survey altitude range (altitude skink present) [m]	Geological rock name (dominant rock)*	Regional ecosystem#	Digital Soil Atlas soil map unit (soil type)*	Skink present
1	Areas in site A	2001–Nov 2009	275–440 (315–350)	Neara Volcanics/cg (mafites)	12.12.13/12.12.17/12.8.1 3/12.8.21 12.12.7/12.12.8 Non-remnant (=cleared)	Me6 (Gn3.11) Me6 (Gn3.11)	Yes/No No No
				Neara Volcanics (mafites)	12.12.13/12.12.17/12.8.1 3/12.8.21	Me6 (Gn3.11)	No
				Main Range Volcanics (basalt)	12.12.13/12.12.17/12.8.1 3/12.8.21 Non-remnant (= cleared)	Me6 (Gn3.11)	Yes/No No
				Aranbanga Volcanics Group/r (felsites)	12.12.13/12.12.17/12.8.1 3/12.8.21 12.12.24	Me6 (Gn3.11)	No No No
				Ri/s SEQ (felsites)	12.12.13/12.12.17/12.8.1 3/12.8.21 12.12.13/12.8.21/12.8.13 12.12.7/12.12.8	Me6 (Gn3.11) Me6 (Gn3.11)	No
				Qa-SEQ (alluvium)	12.12.13/12.12.17/12.8.1 3/12.8.21	Me6 (Gn3.11) Me6 (Gn3.11)	No No
						Me6 (Gn3.11)	
						Me6 (Gn3.11)	
						Me6 (Gn3.11)	
						Me6 (Gn3.11)	
2	Site B	Jan 2001-Aug 2009	140–600 (440–600)	North Arm Volcanic Group (mixed mafites & felsites)	12.12.13/12.12.16/12.12.17 Hoop Pine plantation 12.12.15 ecotone with 12.12.13/12.12.16/12.12.17 12.12.15	Mm5 (Gn3.42) Mm5 (Gn3.42) Mm5 (Gn3.42)	Yes/No Yes/No Yes No
				Neara Volcanics (mafites)	12.12.13/12.12.16/12.12.17 Hoop Pine plantation	Mm5 (Gn3.42) Mm5	Yes/No No No

Site	Location	Survey date	Survey altitude range (altitude skink present) [m]	Geological rock name (dominant rock)*	Regional ecosystem#	Digital Soil Atlas soil map unit (soil type)*	Skink present
				Karandah Granodiorite/a (granitoid)	12.12.13/12.12.16/12.12.17 Hoop Pine plantation	(Gn3.42) Mm5 (Gn3.42)	No No No No
				Wide Bay Creek Gneiss metamorphic rock	12.12.13/12.12.16/12.12.17 Hoop Pine plantation	(Gn3.42) Mm5 (Gn3.42)	No No No No
				Manumbar Metamorphics/a (mafites)	12.12.13/12.12.16/12.12.17 Hoop Pine plantation	Mm5 (Gn3.42) Fu5 (Um2.12) Mm5 (GN3.42)	No
				Rg/i-SEQ (granitoid)	12.12.13/12.12.16/12.12.17	Fu5 (Um2.12) Mm5 (Gn3.42) Fu5 (Um2.12) Mm5 (Gn3.42) Fu5 (Um2.12) Fu5 (Um2.12)	No
3	Areas in Cinnabar SF	Mar 2001 Jan 2005	195–380	Neara Volcanics (mafites)	12.12.13 Hoop Pine plantation 12.12.24/12.12.28x1 12.12.7/12.12.8	LK8 (Um4.1) Rs1 (Db1.12) LK8 (Um4.1) LK8 (Um4.1) Rs1 (Db1.12) LK8 (Um4.1)	No No No No No No No No
4	Areas in Brooyar SF 2	Oct 2003	170–430	Woolooga Quartz Monzonite (granitoid)	12.11.11/12.11.10 12.12.5 12.12.13/12.12.16	Mm5 (Gn3.42) Mm5 (Gn3.42)	No No No
				Neara Volcanics (mafites)	12.12.5 12.12.13/12.12.16 12.12.5	Mm5 (Gn3.42) Mm5 (Gn3.42)	No No No

Site	Location	Survey date	Survey altitude range (altitude skink present) [m]	Geological rock name (dominant rock)*	Regional ecosystem#	Digital Soil Atlas soil map unit (soil type)*	Skink present
				Amamoor beds/b; (mafites)	Cleared	(Gn3.42) Mm5 (Gn3.42) Mm5 (Gn3.42) Mm5 (Gn3.42)	No
5	Areas in Wrattans NP	Oct 2003	460–490	Mount Mia Serpentinite (ultramafic rock)	12.11.10 12.11.14/12.11.3/12.12.1 2/12.12.15	Pu1 (Dr4.41) Pu1 (Dr4.41)	No No
				Gobongo Metamorphics (metamorphosed sedimentary rock)	12.11.10 12.11.14/12.11.3/12.12.1 2/12.12.15	Pu1 (Dr4.41) Pu1 (Dr4.41)	No No
6	Areas in The Breezer (private land)	June 2004	235–420	Neara Volcanics (mafites)	12.12.13 12.12.7/12.12/8	LK8 (Um4.1) LK8 (Um4.1)	No No
7	Areas in Jimmys Scrub SF	June 2004	420–560	North Arm Volcanic Group? (mixed mafites & felsites)	12.12.13 Hoop Pine plantation	Pu1 (Dr4.41) Pu1 (Dr4.41)	No No
				Neara Volcanics (mafites)	12.12.13 12.12.12/12.12.15 Non-remnant (=cleared)	Pu1 (Dr4.41) Pu1 (Dr4.41)	No No No
				Mt Mia Serpentinite (ultramafic rock)	12.12.13 Hoop Pine plantation	Pu1 (Dr4.41) Pu1 (Dr4.41)	No No
				PRg/g (granitoid)	Hoop Pine plantation	Pu1 (Dr4.41) Pu1 (Dr4.41)	No
				Claddagh Granodiorite (granitoid)		Pu1 (Dr4.41) Pu1 (Dr4.41) Pu1 (Dr4.41)	

Site	Location	Survey date	Survey altitude range (altitude skink present) [m]	Geological rock name (dominant rock)*	Regional ecosystem#	Digital Soil Atlas soil map unit (soil type)*	Skink present
8	Areas in Elgin Vale SF	April-May 2007	420-720	Neara Volcanics (mafites)	12.12.13 Hoop Pine plantation	Rh10 (Db3.12)	No No
	Areas in Wrattans NP	April-May 2007	500-740	Rg?-SEQ (felcites)	12.12.13 Hoop Pine plantation	Rh10 (Db3.12)	No No
				Neara Volcanics (mafites)	12.12.13	Rh10 (Db3.12)	No
				Rg?-SEQ (felsites)	12.12.13	Rh10 (Db3.12)	No
9	Areas in Mt Stanley SF	April-May 2007	400-540	Neara Volcanics (mafities)	12.12.13 Hoop Pine plantation	Rh10 (Db3.12)	No No
	Areas in Wrattans NP	April-May 2007	500-520	Neara Volcanics (mafities)	12.12.13	Rh10 (Db3.12)	No
10	Areas in East Nanango SF	March 2007	420-560	Main Range Volcanics (basalt)	12.8.13 12.9-10.17 Hoop Pine plantation	Fu3 (Um2.12)	No No No
				Esk Formation (sedimentary rock)	12.9-10.7 12.9-10.16 12.9-10.17	Fu3 (Um2.12)	No No No
				TQr-r-SEQ (colluvium)	12.8.13 Hoop Pine plantation	Fu3 (Um2.12)	No No
						Fu3 (Um2.12)	
						Fu3 (Um2.12)	
11	Areas in Googa SF	Mar 2007	540-560	Td-r-SEQ>Main Range Volcanics (ferricrete)	12.5.13/12.5.6 12.5.13 12.5.13/12.5.6	Mp4 (Gn3.11)	No No No No
				TQr-r-SEQ (colluvium)		Mp4	

Site	Location	Survey date	Survey altitude range (altitude skink present) [m]	Geological rock name (dominant rock)*	Regional ecosystem#	Digital Soil Atlas soil map unit (soil type)*	Skink present
						(Gn3.11) Fu3 (Um2.12)	
12	Areas in Yarraman SF	Mar 2007	630-645	Tdvr-SEQ (ferricrete)	12.5.13	Gd4 (Um6.21)	No
				Main Range Volcanics (basalt)	12.8.13	Mp4 (Gn3.11)	No
13	Areas in Bunya Mountains NP	Mar 2007	620-820	Main Range Volcanics (basalt)	12.8.16 12.8.21 12.8.21/12.8.23	Gd4 (Um6.21)	No
					12.8.21	Gd4 (Um6.21)	No
						Kb6 (Ug5.13)	
14	Areas in Reinke Scrub CP	Mar 2007	350-430	Tdvr-SEQ (ferricrete)	11.5.2 11.5.15	Mp5 (Gn3.11)	No
					11.11.4/11.11.4a Non-remnant (=cleared)	Mp5 (Gn3.11)	No
				Fifer Creek Metamorphics (metamorphosed sedimentary rock)	11.11.4/11.11.4a 11.11.5	Ub71 (Dy3.42)	No
						Mp5 (Gn3.11)	No
						Mp5 (Gn3.11)	
						Ub71 (Dy3.42)	
						Ub71 (Dy3.42)	
15	Areas in Waroon NP	Sept 2005	270-340	Aranbanga Volcanics Group (mixed mafites & felsites)	12.8.21	Tb67 (Dy3.41)	No
				Tdvr-SEQ (ferricrete)	12.8.21	Tb67 (Dy3.41)	No
16	Areas in Jack Smith CP	Jan 2005	490-500	Tdvr-SEQ (ferricrete)	12.5.13	Mz11 (Gn2.11)	No

Site	Location	Survey date	Survey altitude range (altitude skink present) [m]	Geological rock name (dominant rock)*	Regional ecosystem#	Digital Soil Atlas soil map unit (soil type)*	Skink present
17	Areas in Boat Mountain Conservation Park (CP)	Oct 2001 Jan 2005	480–580	Main Range Volcanics (basalt) Td/r-SEQ (ferricrete)	12.5.1 12.5.13 12.5.1 12.5.13 12.8.13/12.8.21	Me6 (Gn3.11) Me6 (Gn3.11) Me6 (Gn3.11) Me6 (Gn3.11) Me6 (Gn3.11)	No No No No No
18	Areas in Grongah NP (Teebar section)	Sept 2005	185–205	Mount Marcella Volcanics/v (granitoid)	12.12.13/12.12.26/12.12.8 12.12.13/12.12.26/12.12.8	Mn6 Cd5 (Uc2.12)	No No
19	Areas in Grongah NP	Mar 2001	405–505	Aranbanga Volcanic Group (mafites & felsites) Cedarton Volcanics (mafites)	12.12.13 12.12.8 12.12.13	Cd5 (Uc2.12) Cd5 (Uc2.12) Cd5 (Uc2.12)	No No No
20	Areas in Mudlo NP	Mar 2001	275–445	Neara Volcanics/s (sedimentary rock) CPh–SQ (Strat) Rg/i–SEQ (granitoid) Rg/d–SEQ (granitoid)	12.11.10/12.12.13 12.11.10/12.12.13 12.11.10/12.12.13 12.11.10/12.12.13	Cd5 (Uc2.12) Cd5 (Uc2.12) Gd7 (Um6.21) Gd7 (Um6.21) Gd7 (Um6.21)	No No No No

+ Geological data (Natural Resources and Water 2007)

* Map units descriptions, *Digital Atlas of Australian Soils* (Bureau of Rural Science 1991)

Queensland regional ecosystem mapping version 6b (Queensland Herbarium 2009)

Appendix 2: Descriptions of the digital soil atlas map units and associated soils for the 20 *N. spinosa* survey sites

Map unit attributes taken from the Explanatory Notes file for the *Digital Atlas of Australian Soils*. File downloaded January 2010 from: <http://www.asris.csiro.au>

- Cd5:** Granite--steep hilly land with some low hilly areas--many steep slopes with much bare rock: chief soils are leached sands (Uc2.12) with some (Uc4.1) soils. Other soils are (Dy5.81) on slopes, (Dy3.81) and (Dy3.41) on foothill slopes and narrow valley floors, and (Gn3.11) and (Gn2.14) on small areas in some localities.
- Fu3:** Steep hilly to mountainous terrain on metasediments and phyllites rising to 2800 ft above sea level: chief soils on the slopes are shallow and stony leached loams (Um2.1), and also (Um5.2) loams. Associated are: (Dr2.11) and (Dy2.11) soils in less elevated sites; (Uc6.11) sands with some (Dr5.81) and (Dy5.81) soils on included granites; and (Gn3.11) soils on small basaltic residuals. As mapped, narrow terraced valleys of unit MM9 are included in some localities.
- Fu5:** Steep hilly to mountainous land on shales and phyllites, with narrow crests and steep to very steep slopes to narrow valleys: chief soils are leached loams (Um2.12) on crests and slopes. Associated are (Um4.1), (Uc2.12), (Uc4.1), and (Dy3.41) on slopes. Other soils include (Dr3.41) on slopes and (Gn3.12) and (Gn3.42) on dyke rocks.
- Gd4:** Steep hilly to submountainous basaltic uplands: crests and steep slopes of flat-topped and also rounded hills, with dark shallow porous loamy soils (Um6.21), shallow friable clays (Uf6.11), shallow cracking dark clays (Ug5.12), and red friable earths (Gn3.12), all often very stony. Both (Gn3.41) and (Dr4.11) soils are present on some steep eastern slopes in the Sheet 4 occurrences of this unit. Unit Gd4 grades into: soils of unit Kb6 at lower levels and in the drier portions of the area; and soils of unit Mp3 at higher levels in the wetter portions of the area. Minor areas of other undescribed soils are likely.
- Gd7:** Steep hilly to mountainous serpentine country with much rock outcrop in places: chief soils are probably dark porous loamy soils (Um6.21), dark plastic clays (Uf6.32), and dark friable earths (Gn3.42): other soils may include (Ug5.12) on slopes, and (Dd) and (Dg) soils on creek flats. As mapped, areas of unit Fu5 and low hilly areas of unit Mm4 along some streams are included.
- Kb6:** Rolling basaltic uplands: chief soils are dark cracking clays (Ug5.13) in association with many other soils, as follows: (i) crests and steep slopes of the flat-topped and rounded hills at the relatively higher elevations of dark shallow porous loamy soils (Um6.21), shallow friable clays (Uf6.11), and shallow cracking dark clays (Ug5.12); passing to (ii) gentle slopes on flat-topped hills, ridges, steps, and knolls of (Um6.21), red friable earths (Gn3.12), and shallow dark cracking clays (Ug5.12 and Ug5.13); passing to (iii) long gentle slopes of deeper, dark cracking clays (Ug5.13 and Ug5.S) with linear gilgai, also with smaller areas of (Uf6.21) and (Gn3.12) soils; and passing to (iv) narrow valley plains of unit Kd5 soils in the lower-lying situations.

- LK8:** Mountainous country of volcanic rocks and boulder-beds with steep to very steep slopes, scarps, and rock outcrops: chief soils are shallow loamy soils (Um4.1) having an A2 horizon and dark porous loamy soils (Um6.21). Associated are (Uf6.32) and (Gn3.14) soils on the more moderate slopes and crests. Other soils include (Db1.12), (Dd3.12), and (Gn3.42) on volcanic rocks and (Uc2.12) and (Dy3.41) on included sedimentary rocks.
- Me6:** Close pattern of hills with rounded crests and short moderate to steep slopes below the scarp of the adjacent (Gn3.11) plateau; sedimentary and igneous rocks; some outcrop on crests: chief soils are brown friable earths (Gn3.22) on mid to lower slopes. Associated are (Um4.1) soils on ridge crests and upper steep slopes, (Gn3.42 and Gn3.41) on mid to lower slopes, and some (Ug5.16 and Ug5.14) on low broad crests and lower slopes. Minor soil occurrences include (Um4.2 and Um4.3) soils on ridges. Several small plateau areas of units Mp4 and/or Mz12 are included.
- Mm5:** Steep hilly terrain on volcanic rocks and shales with steep slopes to V-valleys, and some alluvial flats in the foothills: chief soils are neutral and acid dark friable earths (Gn3.42 and Gn3.41) on the volcanic rocks and (Dy3.41) soils on the shales. Associated are (Db1.12), (Um4.1), and (Gn3.11) soils on volcanic rocks, and (Um2.12) and (Dr3.41) soils on shales. Other soils include: (Dy2.41) and (Uc2.12) on granite; (Gn2.14) on granodiorite; (Gn3.22) on andesite; (Um6.21) and (Uf6.32) on ultrabasic rocks; and (Dd1.33) soils on minor creek flats.
- Mp4:** Plateaux and plateau remnants of lateritized basalts, and basalts, at moderate elevations (less than 2000 ft above sea level)-generally pedimented lateritic landscapes of undulating to rolling relief with flat-topped ridges (some cuestas) and knolls: chief soils on the long smooth but uneven slopes are acidic red friable earths (Gn3.11) with variable amounts of laterite. Associated are shallow to deep forms of acidic red earths (Gn2.11); in some areas of these soils smooth peds become apparent from a depth of 3 ft. Other soils include: yellow earths (Gn2.2) and shallow (Um) soils all with variable amounts of lateritic materials on or around the ridges, cuestas, knolls, and low convex rises; some (Gn3.71), (Gn3.74), and (Gn3.51) soils with variable laterite content on floors of the broad shallow valleys; some (Gn3.12) soils on slopes; and some (Uf6.21) soils on escarpments. Some local variations between different areas of this unit are to be expected.
- Mz11:** Low hilly upland of broad gently sloping ridges and short moderate to gentle slopes grading to almost rolling terrain: chief soils are red earths (Gn2.11 and Gn2.14) on gently sloping broad crests. Associated are (Dr2.41) and other (Dr) soils with (Dy3.41) and (Dy2.41) on dissection slopes, (Dy3.43) and (Ug5.15) on lower slopes and flats, and (Ug5.24) and (Gn3.43) on broad rises and knolls slightly below the (Gn2.1) soil areas.
- Pu1:** Strongly hilly to mountainous country on metasediments and granites with andesites; narrow ridge crests and short moderate to steep slopes to valleys: chief soils are friable acid red soils (Dr4.41) with (Dr5.41), (Dr4.21), and (Dr4.11). Associated are: gritty (Um2.12), (Um4.1), and (Uc2.12) soils on crests and upper slopes; some (Gn3.11) and (Gn3.71); some (Dy5.21), (Dy5.41), (Dy4.41), and (Dy4.21) soils; and some (Dy3.41), (Dy2.41), (Db1.41), and (Dr2.41) soils on exposed slopes and around the margins of the unit.

- Rs1:** Low hilly to hilly country on volcanic rocks and boulder beds, with gentle to moderate slopes; open valleys with relatively wide stream flats: chief soils are hard neutral brown soils (Db1.12) in complex with friable neutral dark soils (Dd3.12) on crests and slopes. Associated are (Gn3.42), (Dr2.12), and (Gn3.12) soils on hill slopes. Other soils include (Dd1.33), showing very weak gilgai, along stream flats.
- Tb67:** Hilly granitic country of moderate relief with broad convex slopes, some tors, some small flat-topped lateritic knolls and hills; narrow drainage-ways: chief soils on the hills and broad convex slopes are hard acidic yellow and yellow mottled soils (Dy3.41) and (Dy3.31) with (Dy2.41) and (Dy2.31). Associated are a wide range of soils including: (Dy3.11), (Dy5.41), (Dr2.41), and (Dr2.21); (Dy2.42) and (Db1.43) on the broad convex slopes; gravelly (Gn2.11) soils on some lateritic scarps and crests; (Uc2.12) soils on some crests; and (Ug5.16) along some of the narrow valleys. Minor soil occurrences include (Gn3.11) and (Gn2.24) on some slopes below lateritic scarps.
- Ub71:** Moderately hilly granitic country with short moderate to steep slopes covered with granitic boulders and tors; some scattered mesas: chief soils are hard neutral and acid yellow mottled soils (Dy3.42 and Dy3.41). Associated are (Dr2.42) soils on slopes; (Um4) soils on silcrete (billy) capped mesas; and (Uc2.12) and (Uc4.1) soils on crests. Minor areas of other (D) soils also occur.