Australian Government

Background Information on Lister's Gecko *(Lepidodactylus listeri*) and the Christmas Island Blind Snake *(Typhlops exocoeti)*

Prepared for the Department of the Environment and Heritage

by

Dr Hal Cogger

Prepared for the Department of the Environment and Heritage by Dr Hal Cogger, John Evans Memorial Fellow, Australian Museum, Sydney, August 2005.

The recovery plan linked to this paper is available from the Department's web site at: www.deh.gov.au/biodiversity/threatened/recovery, or from the Department's Community Information Unit:

Email:	ciu@deh.gov.au
Mail:	Community Information Unit Department of the Environment and Heritage GPO Box 787 CANBERRA ACT 2601
Freecall:	1800 803 772

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Contents

1. Preamble

This document provides background information assembled in the course of preparing the "National Recovery Plan for Lister's Gecko *Lepidodactylus listeri* and the Christmas Island Blind Snake *Typhlops exocoeti"* on Christmas Island. Currently, these two species are gazetted as ***Vulnerable*** under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). Christmas Island is one of Australia's island territories in the Indian Ocean.

While the conservation status of these two species will be determined, in large part, by a suite of common environmental factors and threatening processes, their ecologies are very different. Living specimens of Lister's Gecko were last found in 1987. The last living specimen of the Christmas Island Blind Snake that I am aware of was found in 1985. It is also important to stress that James (2004) has recorded significant declines in other, previously common endemic Christmas Island reptiles since the last targeted reptile survey in 1998 (Cogger & Sadlier, 2000).

2. Christmas Island – an overview

Christmas Island (Fig.1) lies in the north-eastern Indian Ocean in latitude 10°25' south and longitude 105°43' east, some 320km south of Java, 2630km north-west of Perth and 853km east of Cocos (Keeling) atoll. The island has a planar surface area of 13470ha and consists primarily of a series of Upper Eocene interbedded limestones and tuffs capping a basaltic volcanic cone which rises from oceanic depths of more than 4000m.

The present island attains an elevation of 357 m above sea level and is spectacularly terraced, presumably by wave action associated with eustatic sea level changes during the Pleistocene in possible combination with several epeirogenic uplifts.

The shallow soils of the island are derived from weathering from the volcanic lavas and tuffs which, combined with humus from decaying vegetation and the phosphatisation of the limestone by the action of decomposing guano, have permitted the development of a tropical rainforest over much of the island.

The rainforest is floristically depauperate but structurally diverse, as one might expect on an isolated oceanic island. The original vegetation has been grossly modified in some areas as a result of clearing (for open cut phosphate mining) and by the accidental or deliberate introduction of exotic and weed species. Gillison (1976) summarised knowledge of the island's vegetation, and identified two major structural vegetation types: a structurally simple mesophyll forest on the plateau, and a more complex and diverse flora associated with the limestone terraces.

Although Christmas Island lies in tropical latitudes, its climate is moderated throughout most of the year by the south-eastern trade winds, while in the period December to April the island comes under the cyclonic influence of the north-west monsoon. The island itself, by virtue of its size, vegetation and altitude, appears to influence local weather patterns with resulting local variation in microclimate, vegetation, etc. Cogger *et al*. (1983b) cited the annual variation in ambient temperature as only about 6°C, the mean annual ambient temperature as 25.3°C, the summer and winter means separated by only 1.5°C, the winter minimum as 23°C and the summer maximum is 29°C.

Rainfall averages *ca*. 2000mm per annum and although it occurs throughout the year the greater part falls during the monsoon season. Rain occurs on an average of 12 days per month.

Figure 1: Christmas Island, showing current broad land use patterns and boundaries of Christmas Island National Park (reproduced with permission of DEH)

Although the first recorded sighting of Christmas Island by Europeans is that of John Millward in 1615, the first recorded landing took place in 1688 by the crew of William Dampier's *Cygnet*. The island received its name in 1693 from Captain William Mynors of the British East India Company. Doubtless the island received many subsequent visits from passing mariners, but it was not until the 1860s that members of the Clunies-Ross community on Cocos (Keeling) commenced a series of visits to Christmas Island for soil, and boat-building timbers.

With the collection of phosphate (following earlier speculation) by the survey ship *Egeria* in 1887, the island was annexed for England in the following year by Captain W.H. May of H.M.S. *Imperieuse.* The subsequent history of exploitation of the phosphate deposits leading to the joint ownership by the Australian and New Zealand Governments in 1948, and the establishment of the island as an Australian territory in 1958 has been summarised in a report on the conservation of endangered species on Christmas Island (House of Representatives Standing Committee on Environment and Conservation, 1974).

A high proportion of the fauna of Christmas Island is endemic. The terrestrial crabs are undoubtedly the most conspicuous faunal elements, with the Red Crab *(Gecarcoidea natalis)* being present in such countless numbers that they dominate all but the barest and most exposed habitats. Within both the original forests and all secondary growth areas these crabs are often present in densities of several crabs per square metre; they are active both by day and by night and appear to feed almost exclusively on forest detritus: fallen leaves, tree trunks and carrion. The consequence is a rainforest floor surprisingly free of leaf litter, and this must have important repercussions for other faunal elements inhabiting the forest floor, as well as impacting heavily on energy flow and soil profiles. Other conspicuous crabs are the large Robber or Coconut Crab *(Birgus latro)* which attains a mass of more than 2.5kg and which is found in most parts of the island, and the Blue Crab *(Cardisoma hirtipes)* which is largely confined to moister areas on the terraces.

Prior to a targeted reptile survey in 1979 (Cogger *et al.*, 1983b) seven species of terrestrial reptiles were known from Christmas Island. Of these, all but one (the endemic blind snake, *Typhlops exocoeti)* were found during the 1979 survey, while three previously unrecorded species were added to the island's fauna: the gecko *Gehyra mutilata*, the skink *Lygosoma bowringii* and the typhlopid blind Flowerpot Snake *Ramphotyphlops braminus.* A further species, the Asian Wolf Snake *Lycodon capucinus*, became established on Christmas Island in the early 1980s (Smith, 1988). Five of the eleven reptile species currently known from Christmas Island, including the two species currently listed as Vulnerable under the EPBC Act, are endemic to the island.

3. The Threatened reptiles of Christmas Island

As indicated above two of the five species of reptiles endemic to Christmas Island are currently listed as Vulnerable under the EPBC Act; both are also listed as Vulnerable (VU D2) in the IUCN Red List of Threatened Species (IUCN, 2004). These species are:

3.1 *Lepidodactylus listeri* (Boulenger, 1889) - Lister's Gecko; Christmas Island Chained Gecko; Christmas Island Forest Gecko (Fig.2)

Lister's Gecko was first described in 1889 from a single male. No particular locations on Christmas Island were specified, nor were details of its habitat provided. Given that at the time of its first collection Christmas Island was covered for the greater part in primary forest, it has been long assumed that this is its preferred habitat. (see Fig. 9)

Figure 2: Adult Lister's Gecko from plateau primary rainforest, Christmas Island, 1979.

Boulenger (1889) regarded his new species as being most closely allied to *Lepidodactylus pumilis* from Torres Strait. However Brown and Parker (1977), in a taxonomic review of the genus *Lepidodactylus* from the Indo-Australian Archipelago and the islands of the western Pacific, examined 6 specimens of *L. listeri* from Christmas Island. As cited in Cogger *et al.* (1993b), they compared two males of *L. listeri* from Christmas Island with two males of *L. manni* from the Fiji Islands and found them to be virtually identical, concluding that *L. manni* might well be conspecific with *L. listeri*, and that either might represent an early, accidental translocation from the other's natural provenance.

However this was considered as highly improbable by Cogger *et al.* (1993) and *L. listeri* has since been recognised as a valid Christmas Island endemic species by all subsequent authors. Cogger *et al.* (1993) considered that given the isolation of Christmas Island from the Pacific and its close faunal relationship with Java and western Indonesia, that the preferred habitat of *L. listeri* is primary forest habitat (i.e. it has a low probability of being transported in traded materials), and that there is no evidence of past trading ties between Christmas Island and the Fijian Islands, morphological similarities between these two island endemics might well represent phenotypic convergence rather than genetic conspecificity. However either scenario will remain speculative until both taxa have been subject to comparative molecular genetic studies.

Of the 117 vouchered records of this species located in Australian and major overseas museum collections, most are from the 1979 survey of Cogger and Sadlier (Cogger and Sadlier, 1981) (Fig. 3). Most early records appear to have come from the eastern, settled parts of the island. For example, Gibson-Hill (1947) reported that in 1938-1940 Lister's Gecko "would seem to be the least plentiful of the lizards on the island" and recorded 12 specimens taken in 18 months "mostly on the plateau in the vicinity of Ross Hill and above Dolly Beach and Smith Point (11 specimens) and one immature specimen from "face of the inland cliff overlooking North-east Point". Gibson-Hill also cited 7 specimens collected in 1923 from "the neighbourhood of Panchoran Bay and on the inland plateau around Phosphate Hill". He also recorded two specimens said to have been collected in 1923 from the Cocos (Keeling) atoll, but whose provenance and/or identity remain in doubt.

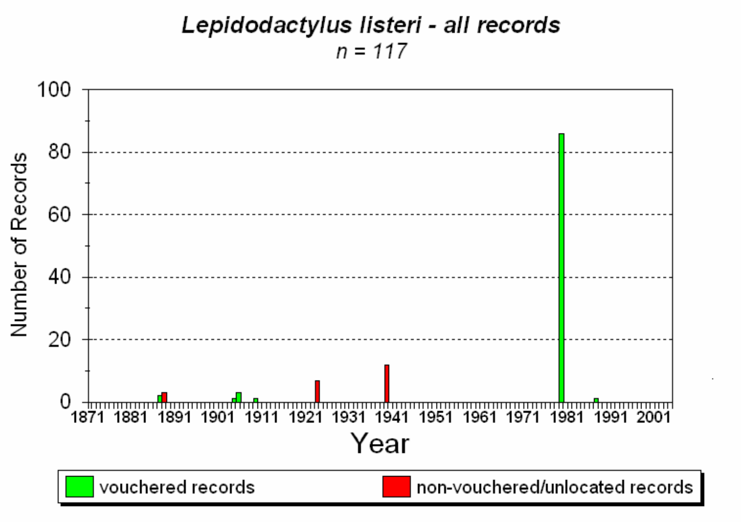

Figure 3: Historical record, based on voucher specimens in museums and non-vouchered records or unlocated specimens in museum collections, of Lister's Gecko, from the date of collection of its type specimens until June 2004.

All available historic records that have specified provenance other than either the generic "Christmas Island" or locality descriptions at a scale larger than the 30" grid (ca. 500m) used, are shown in Fig. 4, indicating that the species is, or was at least until 1979, widely distributed across Christmas Island.

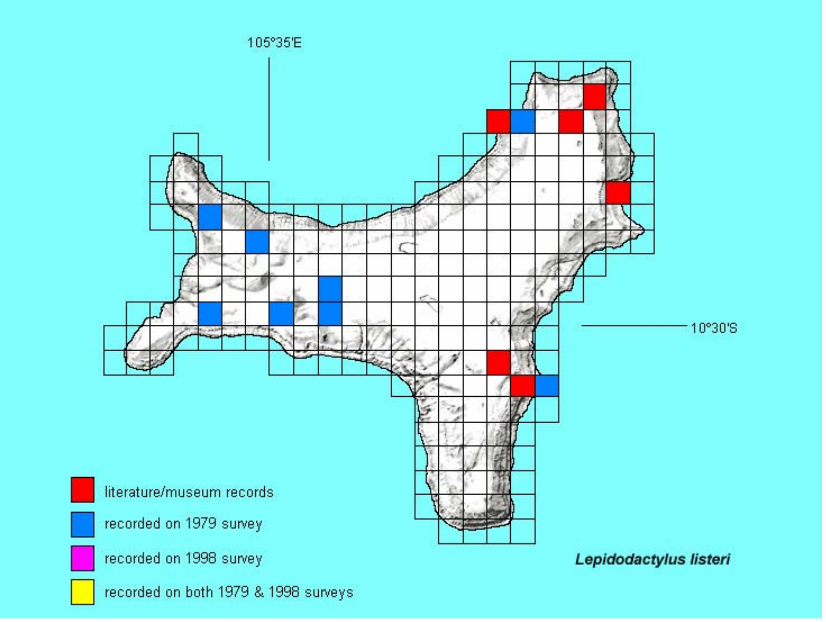

Figure 4: All records with specified provenance of Lister's Gecko from Christmas Island (from Cogger & Sadlier, 2000); grid at 30" intervals.

In 1979 more than 80 individuals of Lister's Gecko, including eggs and young (Fig 5; Cogger & Sadlier, 1981) were found at 8 different locations (Fig. 4) both within and outside the boundaries of Christmas Island National Park. Another targeted reptile survey (Cogger and Sadlier, 2000) and systematic monitoring of nearly 400 island-wide sites (James, 2004) has so far failed to locate any further specimens of this species, although the latter's arboreal habitat greatly reduces the likelihood of it being recorded in what are essentially terrestrial sampling sites; however searches were made under the bark of some hundreds of trees (D. James, *pers. comm*.) without locating any specimens of this species. Nor were any specimens found in systematic pre-and post-treatment studies of the impacts of the island-wide aerial distribution of the insecticide fipronil to control supercolonies of the Yellow Crazy Ant (*Anoplolepis gracilipes*) (Stork *et al*., 2003).

Consequently, while the species appears to have declined significantly since 1979, its distribution at that time still constitutes the baseline distribution on which the conservation of remaining stocks must be based.

Ecology and habitat relevant to threatening processes: Only a few basic aspects of the biology and ecology of Lister's gecko are known. Brown and Parker (1977) compared its morphology (based on six specimens) with that of other members of its genus from the Indo-Pacific region, while Cogger *et al.* (1983b) provided information on its morphology, diet, reproduction and ecology based on 34 individuals observed or collected in 1979.

It is a small gecko (mean snout-vent length 46.2 mm, maximum 51.5 mm) with a mean mass of only 2.3 g. It is bisexual, with an adult sex ratio of 1:1, and with each female producing two eggs in a clutch. Full-term eggs and hatchlings have been found in June, while female gonads displayed a range of developmental stages in June that suggested that reproduction occurred over an extended period, if not throughout the year (Cogger *et al*., 1983b).

Figure 5: Eggs and hatchling of Lister's Gecko from Christmas Island.

The species appears to be entirely arboreal. Adults were observed at night high on the trunks, at the lower canopy level, of large rainforest trees, while others were found low on the same trunks, suggesting that at night the adults descend almost to the ground to feed around the base of the trunk. Eggs were also found deposited under the bark of trees at these lower levels of the trunk, but as the remainder of these large trees were inaccessible to observers, the extent to which the remainder of these trees, including the canopy, were utilised for feeding and egg deposition is unknown.

3.2 *Typhlops exocoeti* Boulenger, 1887, **Christmas Island Blind Snake** (Fig.6)

The Christmas Island Blind Snake was described in 1887 from two specimens collected from "Christmas Island". It was assigned to the largely Australasian genus *Typhlina* by Hahn (1980), but Greer (1998) has shown that in possessing a left oviduct this species should be assigned to the widespread Asian genus *Typhlops*. *Typhlina* is a junior synonym of *Ramphotyphlops* Fitzinger, 1843, and so this species was cited as *Ramphotyphlops exocoeti* by Cogger et al. (1983a) - the combination under which it is listed in the EPBC Act and in the Red Data Book (IUCN, 2004).

The blind snake is known only from Christmas Island. Historic records are few and widely scattered over time, revealing no clear trends in abundance or distribution. Most records, which are few (22 located for the Recovery Plan, Fig. 7) and recorded sporadically over a period of nearly 120 years, are mostly unaccompanied by detailed provenance, so there are few records associated with particular sites, from which it would be possible to find correlations with broad or specific habitats or particular plant communities (Fig. 8). Gibson-Hill (1947) records a specimen from "near Rocky Point", but his description of juveniles ("up to at least 155 mm") also matches that of the introduced smaller parthenogenetic Flowerpot Snake (*Ramphotyphlops braminus*), at that time not known to occur of Christmas Island but which is now abundant in the Rocky Point area. The time of the introduction of the Flowerpot Snake to Christmas Island is unknown, but it might well have been present in 1938-1940 but confused with juveniles of the larger blind snake, as the two species possess the same number of mid-body scale rows. Gibson-Hill recorded the blind snake as "fairly common", but it remains uncertain as to whether this description refers, either in total or in part, to *T. exocoeti* or *R. braminus*, or both. Certainly, the Rocky Point locality must remain uncertain in the absence of a vouchered specimen.

Figure 6: A preserved example (Australian Museum specimen) of Christmas Island Blind Snake.

All known blind snake specimens of the past 50 years have been found serendipitously. Targeted reptile (Cogger *et al*., 1983b; Cogger & Sadlier, 2000) and recent biodiversity surveys (James, 2004), have so far all failed to locate this species. Consequently, like Lister's Gecko, its current conservation status is effectively unknown but unlike Lister's Gecko, the paucity of records in recent years cannot be used to infer a decline in numbers or range.

Without any clear evidence of a decline, the highest priority actions for its conservation are assigned to finding the species, determining the status and protecting the ecological integrity of known habitat. The entire island can be regarded as having been part of its original range, although widespread development of the eastern third of the island would suggest that most of this area would have been extirpated from the original range.

Ecology and habitat relevant to threatening processes: Virtually all known typhlopid snakes are fossorial (although at least one species, the Flowerpot Snake, is sometimes arboreal) that feed almost exclusively on the eggs and larvae of ants and/or termites. In body form they are worm-shaped and covered by tough, glossy scales that are virtually impervious to the bites of the workers of the ants and termites on which they feed. Their eyes are vestigial and reduced to a pair of small pigmented organs lying beneath the skin of the head, while the mouth is small and underslung, and closes tightly to avoid ingesting soil when burrowing. The very short tail ends in blunt spine that the snake uses to gain purchase in the soil when burrowing.

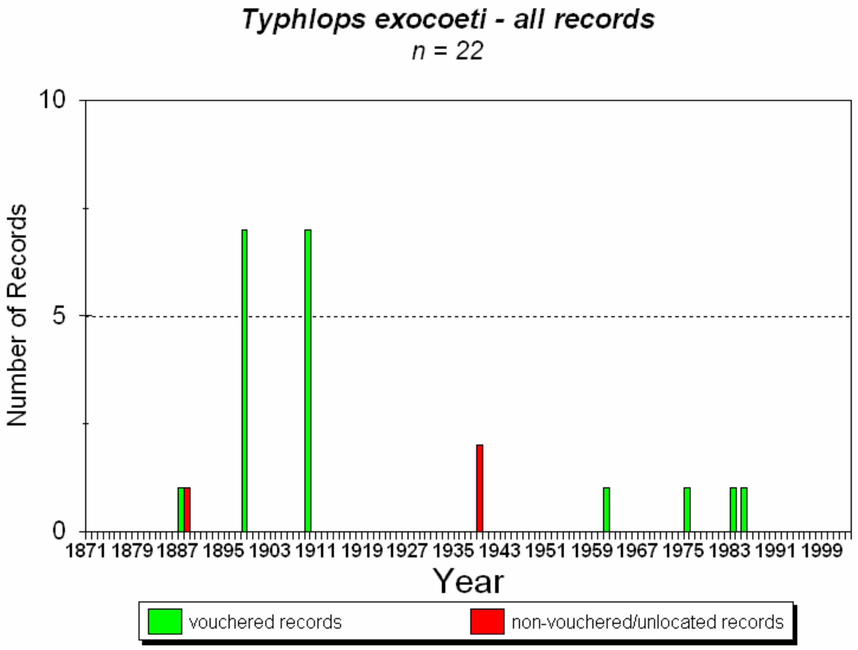

Figure 7: Historical record, based on voucher specimens in museums, non-vouchered published and unpublished observations, of the Christmas Island Blind Snake, from the date of collection of its type specimens until June 2003.

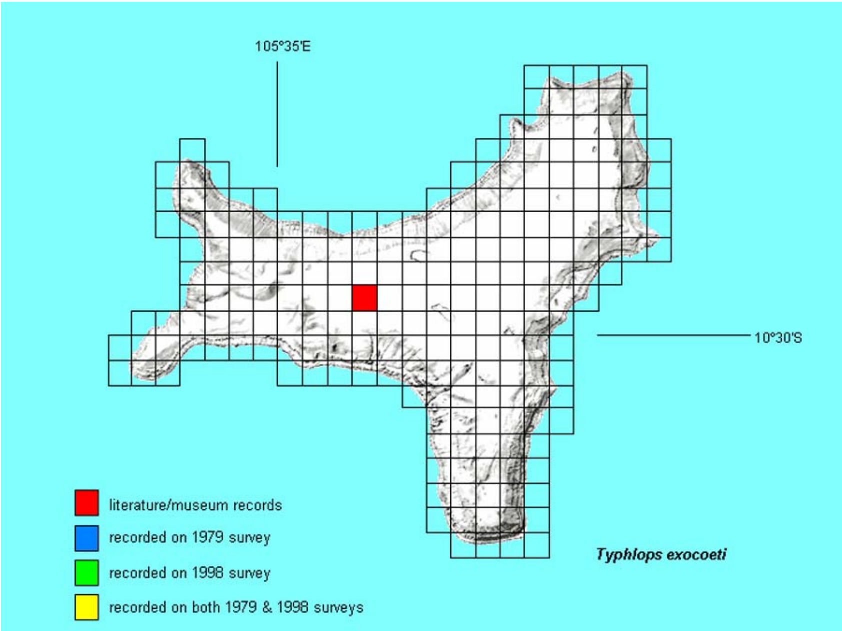

Figure 8: The only provenanced record of the Christmas Island Blind Snake - near Stewart Hill, in primary rainforest near the centre of the central plateau.

To the best of current knowledge all typhlopid blind snakes are oviparous, though the eggs are rarely found. Adult snakes are often found under fallen timber or rocks embedded in soil, or are exposed during major earth-moving activities such as mining, road-building or land-clearing.

Little is known of any aspect of the ecology of the Christmas Island Blind Snake. Gibson-Hill (1947) comments that this species is "...usually found in dampish situation under the trunks of fallen trees. It only comes out into the open on dark, overcast days, or during heavy rain." This description, lacking any reference to nocturnal activity, cannot be specifically associated with any confidence to one particular species as it could as well apply to the Flowerpot Snake; moreover, these observations appear to be largely based on those of C.W. Andrews, cited in Boulenger (1900): "... Mr Andrews, who found them in damp places, under rocks and fallen trees. Only seen out on dark rainy days." A specimen in the Natural History Museum, London collected in 1883 from SW Christmas Island was found "under bark of rotten *Hernandia*".

The few records with associated information on locality or macrohabitat suggest that this species occurs primarily where the deeper soils and primary rainforests occur on the island's central plateau (see Fig. 9). Most of this area is now located within the boundaries of Christmas Island National Park and is therefore secure so far as land tenure. However, as indicated above, this original primary habitat is currently being subject to immense environmental stress due to recent droughts and the explosive increases in populations of the Yellow Crazy Ant and its mutualist scale insects (*Tachardina aurantiaca* (Kerridae) and introduced *Coccus celatus* (Coccidae), *vide* O'Dowd *et al*., 2003).

Being fossorial and almost certainly, like most of its congeners, preying on the eggs, larvae and pupae of ants and termites that it devours in large numbers, this species is occupying microhabitats – sub-surface soil layers and surface litter - that are also exploited by Crazy Ants for foraging and nest construction. As indicated above, blind snakes have tough, smooth, high-gloss scales that make it almost impossible for ants to grasp or bite; a tightly-closed mouth and anal openings, together with vestigial eyes lying beneath the scales of the head, a complete suite of external adaptations to both a burrowing habit and the ability to invade ant and termite nesting chambers for prey with impunity to attack by workers.

Thus the Christmas Island Blind Snake is, in one sense, pre-adapted to coping with Crazy Ant supercolonies and may find that they provide an additional source of food. However it is also possible that the sensory environment of Crazy Ant colonies, in which formic acid and other secretions could be expected to be high when confronted by a nest predator, might cause the blind snake to avoid them. Of potential concern is that if the blind snake does utilise crazy ants as a source of food then it also has the potential to ingest large quantities of any poisoned bait that the ants bring to their nests.

Figure 9: Characteristic Christmas Island plateau rainforest, primary habitat of both Lister's Gecko (*Lepidodactylus listeri*) and the Christmas Island Blind Snake (*Typhlops exocoeti*).

4. Threatening processes in general and the special vulnerability of oceanic islands

In preparing the Action Plan for Australian Reptiles (Cogger et al., 1993), an assessment was made of the contribution of a variety of threatening process to the decline (to threatened status) of the 52 species of Australian reptiles ranked as at most risk of decline to extinction. They identified the 18 broad threatening processes that were most implicated in these declines (Table 1). The numbers in this Table indicates the number of threatened species of reptiles in which each threatening process was considered to be significantly implicated.

As these rankings were determined from an assessment of all Australian threatened reptiles, 73% of which have continental ranges, many of these major threatening processes are those that tend to operate at broadscale, continental landscape levels.

However, note that these processes did not include the impacts of invasive species of animals other than direct predators, in large part because the significance of such impacts, while suspected to be high for many species, are essentially undocumented and unquantified. For example, feral cats are known to consume large numbers of reptiles as a proportion of total prey items (e.g. Bamford, 1995; Meek, 1998; Risbey et al., 2000), but the extent of such impacts are virtually unknown and unresearched for particular species of threatened reptiles.

THREATENING PROCESS	No. threatened species affected
Habitat clearance	30
Over-grazing by stock	21
Cropping	21
Predation	14
Urban development	14
Pasture improvement	12
Fire regime	10
Soil degradation	9
Visitor disturbance	8
Soil &/or water pollution	7
Mining	6
Native forest logging	6
Climatic variation	5
Rabbit grazing	6
Habitat fragmentation	5
Weed invasion	5
Habitat drainage	4
Rock removal	4

Table 1: Major threatening processes identified in the Action Plan for Australian reptiles, ranked by number of species affected (from Cogger *et al*., 1993).

Islands, however, are especially susceptible to a particular suite of threatening processes, often acting synergistically, and this susceptibility is reflected in the high extinction rates of species endemic to oceanic island; 43 species of the 253 species of reptiles in the Endangered or Vulnerable categories on the 1996 IUCN Red List (IUCN, 1996) were from oceanic islands.

The major threatening processes on oceanic islands are:

Anthropogenic habitat fragmentation and loss – fragments may be too small to maintain viable populations, especially on small islands, where fragmentation can also expose potential refugia to greater environmental stress from events such as droughts, storms or invasive plants and animals. Often the only viable refugia are isolated offshore satellite islands (as in the case of both Norfolk and Lord Howe Islands), but such refugia do not exist on Christmas Island.

Exotic/invasive plants – with or without habitat fragmentation, invasive weeds can seriously degrade and/or modify original habitats. Newly-arrived invasive species of both plants and animals may be anthropogenic in origin or, less often, the result of natural dispersal events

Exotic/invasive animals – many exotic animal introductions have the potential to impact on native animal species. Often such impacts are subtle and difficult to identify and quantify, especially when the effects are subtle changes in ecosystems, including food webs and system energetics. However in many cases an exotic or invasive species can have direct and measurable impacts as a predator, competitor, disease vector or habitat degrader. On Christmas Island, examples include black rats (*Rattus rattus*) that prey on small reptiles and their eggs and young; the wolf snake and the Nankeen Kestrel (*Falco cenchroides*) that are also major lizard predators (the former primarily on nocturnal reptiles, the latter on diurnal species); and the dramatic changes wrought upon the forest ecosystems by the Yellow Crazy Ant (documented by O'Dowd *et al.*, 2003).

Pathogens - Island species, especially those on remote oceanic islands, are especially vulnerable to the introduction of new pathogens. The highest risk usually comes from the chance introduction of confamilial or more closely-allied species that might carry pathogens to which their parent populations have developed high levels of immunity, but to which the island populations have never been exposed. A wide range of exotic species have become established on Christmas Island, including at least four species of reptiles (the gekkonid lizards *Hemidactylus frenatus* and *Gehyra mutilata*, the scincid lizard *Lygosoma bowringii* and the wolf snake; their impacts on the native reptiles are essentially unknown, including their potential to introduce new parasites and pathogens.

5. Known or potential threats to the endemic reptiles of Christmas Island

As indicated above the ecologies and preferred microhabitats of Lister's Gecko and the Christmas Island Blind Snake are very disparate. The former occupies and completes its life cycle in arboreal habitats (including the forest canopy), while the latter is a fossorial species that spends most of its life cycle underground, only occasionally coming to the surface to forage in ground litter, or to climb among low rock outcrops. Nevertheless both species are likely to be affected by a common suite of threats, although the impact of each threatening process may invoke a different response in each species.

The actual threats to Lister's Gecko are essentially unknown, but given the absence of any sightings since 1987 it seems clear that major threats were operating at that time and have significantly impacted on the population. Indeed, the species could possibly have become extinct or near-extinct since that time.

Threats to the blind snake are also unknown. However, given the small number of confirmed sightings in the past century, and the absence of any sightings since 1985, the only measurable trend on which to base conclusions about rarity or declines is a presumed correlation with anthropogenic reduction of habitat. Consequently, any threatening processes other than habitat loss, if they are operating, must be extrapolated from their effects on other reptilian species or by a qualitative assessment of likely impacts of these threats on the ecosystems in which the species occurs.

However, there are several major processes (some of them co-related or acting synergistically) currently threatening other native taxa, including reptiles, which are therefore potentially implicated in the decline of both threatened species:

1. *Predators*

Potential predators on Lister's Gecko adults, young and/or its eggs include the Black Rat, domestic and feral cats (*Felis cattus*), the Wolf Snake, the Yellow Crazy Ant and the giant centipede. There is a high probability that the Wolf Snake is a major threat to all endemic reptiles of Christmas Island (Fritts, 1993). There are many examples of cats and rats having dramatic impacts on the endemic fauna of oceanic islands, but their potential impacts on the two threatened reptiles of Christmas Island are unresearched and unknown. Other potential predators which were sympatric with the Lister's Gecko before their declines include the Christmas Island Hawk-Owl (*Ninox squamipila natalis*) the Christmas Island Shrew (*Crocidura fuluginosa trichura*); the latter may now be extinct. The current relationship between these endemic predators and the threatened reptiles is unknown.

Lister's Gecko may be highly susceptible to predation by the crazy ant, as the ants forage from the forest floor to the outer branches of large rainforest trees, so the geckos have little or no opportunity to find refuges from ants in those areas where ant supercolonies occur. The blind snake may be less susceptible, due to the adaptations to coping with ant aggression and toxic or irritant ant secretions.

However there is no direct, only inferred, evidence the snake possesses such immunity to crazy ants, especially when the ants occur in the vast numbers that characterise the supercolony developments on Christmas Island.

The Nankeen Kestrel (*Falco cenchroides),* apparently introduced to Christmas Island in the 1950s (Gray, 1981) and which has since become very abundant, preys commonly on diurnal lizards and small snakes, but presumably would have little opportunity to take nocturnal lizards such as Lister's Gecko or nocturnal/fossorial snakes such the blind snake. Indeed, the latter's most likely major natural predator (pre-settlement) would likely have been the native shrew, and occasional specimens are probably also taken by Robber Crabs (*Birgus latro*).

The Asian Wolf Snake is largely terrestrial but it is an able climber that is frequently found in buildings where it climbs into wall and roof cavities. It is also found in shrubs and low trees in urban areas, but it is not known whether it has either the habit of, or ability to, climb large rainforest trees or to move about in their canopies, although it seems unlikely. However because this snake was introduced to Christmas Island after Lister's Gecko was last seen in reasonable numbers in 1979, it should be treated as a potential threat to this species until shown otherwise.

The wolf snake is not known to construct burrows, but it is known to pursue burrowing prey within their burrows. It is also known to prey on any small reptile that it encounters on the surface. And as both wolf snakes and blind snakes are nocturnally active on the surface, wolf snakes may be a predator on the threatened blind snake. A program of trapping and killing wolf snakes and examining their gut contents might provide valuable data on the distribution and abundance of both threatened species of reptiles. Such a program should discover whether there have been any significant shifts in wolf snake dietary habits since the study conducted by Rumpf (1992).

2. Habitat loss, fragmentation and degradation

Any increase in direct anthropogenic impacts on the ecological integrity of primary forest areas of Christmas Island is likely to have deleterious impacts on Lister's Gecko. Such impacts may include further habitat fragmentation, increased disturbance from light or noise, or clearing of vegetation for works or mining and other infrastructure.

One of the most profound suites of impacts on the integrity of Christmas Island's ecosystems has been caused by the invasive Yellow Crazy Ant, which appears to have been accidentally introduced in about 1934. From about the late1980s, supercolonies of this species began to develop, with consequent dramatic and disastrous impacts on the island's rainforests (Green *et al.*, 2001). At the beginning of 2003, supercolonies had formed within approx. 25% of the island's rainforests (O'Dowd *et al*., 2003), resulting in very high mortalities among many of the animal species living within, or traversing, the areas of their colonies. The ants, which occur in great densities, forage from the ground to the outer canopy branches of rainforest trees, leaving virtually no ecological niche unaffected, especially when accompanied by outbreaks of mutualist host homopteran insects. These outbreaks coincide with the decline of many species, with the direct mortality of some organisms (such as the Red Crab) readily attributed, through observation, to the depredations of this ant. The profound impacts of these ants on forest floristics and structure (through their impact on food chains) implicates them in the decline of other taxa.

3. Information Gaps

Knowledge of the biology, ecology, habitat preferences and spatial distribution of both Lister's Gecko and the Christmas Island Blind Snake is fragmentary and insufficient to inform actions for their specific recovery. Consequently priority must be given to first determining the location and relative abundance of any remaining populations through survey and monitoring, and then by targeted research on the species' ecologies. Interim actions will be aimed at maintaining the ecological integrity of known or suspected habitats based on the use of surrogate taxa to determine the effectiveness of those actions.

4. New Invasive Species

A number of exotic species have been introduced to Christmas Island, including the crazy ant, rats, cats, the scincid lizard *Lygosoma bowringii* (sometime before 1979) and the Wolf Snake (*ca*. 1983). All but one (*Gehyra mutilata*) of the introduced reptilian species (*Hemidactylus frenatus, Ramphotyphlops braminus, Lycodon capucinus,* and *Lygosoma bowringii*) have extensively penetrated new areas and habitats on Christmas Island during the past 30 years.

The more recent colonisation of Christmas Island by Lygosoma *bowringii* and the Wolf Snake represent failures, at the time of entry, of the quarantine mechanisms then in place, and are indicative of the special vulnerability of isolated oceanic islands to the impacts of exotic species. The exclusion of further exotic species may clearly be a critical factor in maintaining remaining populations of Christmas Island's native and endemic biota, and may require increased vigilance for its achievement.

If Lister's Gecko still persists, probably its greatest competitive risk is the introduction of a tramp species, *Lepidodactylus lugubris*, that has greatly expanded its global range as a result of human agency during the past century. It occurs on Cocos (Keeling) and Java, and is now on continental Australia, New Guinea and most Indo-Malaysian and Pacific Islands. Its continued exclusion from Christmas Island may be critical to the survival of Lister's Gecko if the latter still survives.

5. Diseases

While the introduction of a new threat such as an exotic pathogen would have gone unnoticed due to the absence of sightings since 1987, such a possibility cannot be dismissed. There is currently no evidence to suggest that exotic pathogens may be all or partly responsible for the recorded declines (Cogger et al., 1983b; James, 2004) in endemic reptiles, including Lister's Gecko. However reptile diseases are poorly documented and their impacts on living populations essentially unknown, so any serious declines in resulting from disease would almost certainly go unnoticed, even if mortality were massive and/or rapid. Without regular populations monitoring, as currently being undertaken by PAN, pathogenic mortalities have little chance of being identified.

6. Competition

There appears to be only minor vertical spatial overlap (on the lower trunks of large rainforest trees) between Lister's Gecko and the other, larger native gecko *Cyrtodactylus sadleiri*. This spatial and size difference suggests there is likely to be only marginal competition between these species for food and other resources. The introduced geckos *Hemidactylus frenatus* and *Gehyra mutilata* are both arboreal and feed on small arthropods, and so are potential competitors with Lister's Gecko. These species tend to occupy more disturbed habitats, but the occurrence of both at sites in 1998 that were occupied solely by Lister's Gecko in 1979 (Cogger & Sadlier, 2000), suggests either that they have succeeded in displacing it or have moved into such areas following the latter's decline from other causes.

Currently there is no information available on potential competition between the blind snake and the introduced Flowerpot Snake (*Ramphotyphlops braminus*). Both are primarily fossorial species feeding mostly or solely on the eggs, larvae and pupae of ants and termites, indicating that there could be significant competition for food and preferred space.

Both Lister's Gecko and the blind snake are likely to compete with the crazy ant for food. The latter preys on a wide range of invertebrate taxa, including all taxa likely to be eaten by both the gecko and the blind snake. In addition, crazy ants forage from the forest floor to the outer branches of large rainforest trees, all the areas in which geckos feed.

7. Crazy ant control measures

Since 1999 a program to control the diverse and dramatic impacts of the Yellow Crazy Ant on a large variety of native plant and animal taxa, and on Christmas Island's forest ecosystems, has involved manual and aerial (one application only) dispersal of insecticides across large sections of the island (Stork *et al.*, 2003). Although the active component used to date has been *fipronil,* a compound that is relatively toxic to a range of reptilian species (Peveling, 2000; Tingle and McWilliam, 1999), it has been used in what are considered to be safe dilutions for non-target species, and there is no evidence to suggest that fipronil at the concentrations used has an effect on reptiles. In addition, a recent experiment on North West Point strongly suggests that Blue-tailed skinks, *Cryptoblepharus egeriae* survive fipronil (James 2005). However alternatives to fipronil are currently being explored, including the use of insect growth regulators instead of toxins.

While trials of manual and aerial baiting with fishmeal-based fipronil have included pre-and post-baiting surveys of the impact of baiting on non-target species, including reptiles, no individuals of Lister's Gecko or the blind snake have been seen in any of these surveys (Stork *et. al.*, 2003) and so the effects, if any, of baiting programs on these species are unknown. While it may well be that the overall impacts of the crazy ant on the Christmas Island biota and ecosystems are so severe that their control should be given priority over the conservation of any individual species, there is still potential for the control program to affect Lister's Gecko and the blind snake.

Lister's Gecko is a small, arthropod-feeding species, is not known to descend to the ground, so can only leave its home tree by moving between the overlapping canopies of individual trees or shrubs. Fipronil is known to be highly toxic to lizards, so insects feeding on fipronil following aerial drops are likely to be ingested by geckos before the insects die and drop to the ground. The canopy habitat makes Lister's Gecko much more vulnerable to fipronil ingestion from aerial spraying than the more common endemic gecko, *Cyrtodactylus sadleiri*. The latter is normally found on the ground or in low trees and shrubs well below the canopy, and as indicated above has been found in small numbers in both pre-and post-baiting surveys (Stork *et al.*, 2003). If further aerial spraying is planned, the potential for possible toxicological impacts on the Lister's Gecko should be investigated.

The blind snake occupies microhabitats (sub-surface soil layers and surface litter) that are also exploited by crazy ants for foraging and nest construction. Typically, blind snakes have tough, smooth, high-gloss scales; tightly-closed mouth and anal openings; and vestigial eyes lying beneath the scales of the head - a suite of external adaptations to both a burrowing habit and the ability to invade ant and termite nesting chambers for prey with impunity to attack by workers. Thus the blind snake is pre-adapted to coping with crazy ant supercolonies and well find that they provide an additional source of food. However it is also possible that the sensory environment of crazy ant colonies, in which formic acid and other secretions could be expected to be high when confronted by a nest predator, might cause the blind snake to avoid them. Of potential concern is that if the blind snake does eat crazy ants it has the potential to ingest large quantities of any poisoned bait the ants bring to their nests.

8. Displacement from preferred habitat by the crazy ant

Displacement of both Lister's Gecko and the Christmas Island Blind Snake could occur through either physical distress when traversing areas with swarming ants, or through olfactory responses to ant secretions in gecko-ant and snake-ant interactions. The susceptibility of the blind snake to this process may be low, as typhlopid snakes typically live in close association with ant colonies, feeding on the ants' eggs, larvae and pupae. Morphologically and physiologically blind snakes are highly adapted to coping with ant aggression and toxic or irritant ant secretions. However there is no direct (only inferred) evidence that the Christmas Island Blind Snake possesses immunity to crazy ants, especially when they occur in the vast numbers that characterise the supercolony developments.

6. Benefits to other species/ecological communities

The roles and contributions of Lister's Gecko and the Christmas Island Blind Snake to the ecological dynamics of their primary rainforest habitat is unknown. In the absence of any known species-specific causal factors, it is reasonable to assume that the apparent decline of Lister's Gecko on Christmas Island is likely to reflect critical changes in the ecology and/or physical integrity of its rainforest habitat. Past records of the blind snake are too few, infrequent and lacking in detail to provide any indication of trends in range or population numbers over time, nor of any response of the species to ecological changes in its environment.

The most obvious changes in forest habitats since the last records of these species were made has been the development, since about 1990, of supercolonies of the crazy ant, which have dramatically changed the ecology of the more than 30% of the island so far affected (O'Dowd *et al*., 2003; Green et al., 2001; Carrick, 2004). The impacts of the crazy ant on the island's biota have been so dramatic and profound that it has been listed as a Key Threatening Process under the EPBC Act. Other endemic species inhabiting Christmas Island's rainforests are also threatened, and so recovery of these species (including Lister's Gecko and the Christmas Island Blind Snake) will depend in large part on restoring the ecological integrity of the island's forests.

Surveys conducted to determine the range and abundance of Lister's Gecko and Christmas Island Blind Snake would have the potential to be integrated into much broader surveys of forest floor fauna (both terrestrial and burrowing forms) that would be part of wider ecological studies of forest, litter and soil dynamics. Indeed, given the failure of past targeted surveys to locate the species, it would be difficult to justify costly surveys for these species alone, and so studies of it should be integrated into broader biological survey programs and ecological studies.

Nevertheless it is reasonable to assume that efforts to conserve primary forest habitat and to abate the known threats to other native species are likely to benefit both threatened reptile species.

Existing biodiversity survey programs (James, 2004) must be maintained and extended to include more intensive sampling for these species in order to determine their current status - whether they have become extinct and, if not, their distribution, numbers, population biology and ecology. It is also reasonable to assume that any effective recovery actions for these species will benefit a suite of other declining species occupying the same habitats.

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