Advice to the Minister for the Environment and Heritage from the Threatened Species Scientific Committee (TSSC) on Amendments to the List of Key Threatening Processes under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act)

1. Name and description of the threatening process

Name

Nominated name: 'Loss of biodiversity and ecosystem integrity following invasion by the Yellow Crazy Ant (*Anoplolepis gracilipes)* on Christmas Island, Indian Ocean.'

The Yellow Crazy Ant, in addition to having been introduced to Christmas Island, has also been introduced to Arnhem Land, Northern Territory. Consideration was given to expanding the threatening process to cover mainland Australia rather than restricting the process to Christmas Island. However, while there has been much research leading to strong evidence to support the listing of the threatening process on Christmas Island, there has been relatively little research in Arnhem Land. Also, the threatening process described is specific to Christmas Island, an ocean island with a high number of endemic species, a highly impoverished native ant fauna, and an ecosystem that is greatly influenced by the large number of endemic Red Land Crabs that are present. A specific component of the described threatening process is the reduction in numbers of the Red Land Crabs that is occurring as a result of the invasion of Yellow Crazy Ants, and the subsequent impact this will have on the island's ecosystem.

Arnhem Land does not have such a unique ground-dwelling, keystone species dominating its ecosystem, and has an extremely diverse native ant fauna. Also, it is not clear to what extent Yellow Crazy Ant supercolonies form. In their review on invasive ants of the world, Holway et al (2002) state that species invading oceanic islands with few or no native ants may exhibit patterns of invasion different from those observed in regions with indigenous ants. The review summarized the reports of Yellow Crazy Ants impacting on other species of fauna from around the world, and impacts have only been reported from islands. Outside of Australia, there appears to be few published observations of Yellow Crazy Ants impacting on native fauna away from islands. For these reasons, the threatening process that was considered was restricted to Christmas Island.

Description

The Yellow Crazy Ant and its characteristics

The Yellow Crazy Ant (*Anoplolepis gracilipes*) is an ant that lives in colonies and is noted for its frenetic activity when disturbed (hence its common name, Yellow Crazy Ant). It is one of the five 'tramp ant' species that are well known for being invasive and ecologically damaging, the others being the Red Imported Fire Ant (*Solenopsis invicta*), the Big-headed Ant (*Pheidole megacephala*), the Little Fire Ant (*Wasmannia auropunctata*), and the Argentine Ant (*Linepithema humile*). All these species are very aggressive and competitive so that they are able to dominate food sources, are easily dispersed by human activities, and have the capacity to form 'supercolonies' with multiple queens that allows rapid and extensive colonisation.

Appearance: In Yellow Crazy Ants, workers have long, slender, yellow-brownish bodies, approximately 4-5 mm long. Queens are larger and much more robust than workers, averaging about 10 mm in length.

Defence and subduing prey: The Yellow Crazy Ant lacks a sting, but it sprays formic acid from the tip of its abdomen as a defence mechanism and to subdue prey. In areas of high ant density, the movement of an animal or human can disturb the ants, whereby the ants instinctively spray formic acid as a form of defence. Spraying can cause skin burns and eye irritation in humans.

Geographical range and habitats: The native range of the Yellow Crazy Ant is not known explicitly, although authors have speculated its origin as West Africa, India or China (Wilson & Taylor 1967). It has been widely introduced across the subtropics and tropics, including East Africa (two countries), South and Southeast Asia (nine countries), Australasia (two countries), and the Indo-Pacific Islands (20 island groups). It is reported to have an elevational limit of 1000-1200 m (Van der Goot 1916, but see Wetterer 1998). It is capable of invading both disturbed and undisturbed tropical/subtropical habitats, including urban areas, rural villages, plantations, coastal strand, grassland, savanna, woodland, and rainforest.

Colony organization and reproduction: The Yellow Crazy Ant is polygynous (multi-queened) and aggression among workers is not reported. Colonies can exist with relatively low densities of ants or can occur with extremely high densities of ants that are called 'supercolonies'. The species can form diffuse supercolonies, sometimes extending continuously over large areas (up to 750 ha). Most dispersal and foundation of new colonies appear to occur through colony budding, i.e. when mated queens and accompanying workers leave the nest to establish new nests. The mating flights have not been reported in the literature and the importance of aerial dispersal by winged queens is unclear. Single nests of Yellow Crazy Ant can contain upwards of 1000 queens and tens of thousands of workers. The life cycle of Yellow Crazy Ant has been estimated to be 76-84 days (Rao & Verresh 1991).

Nest sites: Yellow Crazy Ants have generalized nesting habits, nesting on the ground in soil, in and below woody debris, below rocks, at the base of trees, underneath leaf litter on the forest floor, and in animal burrows (e.g. O'Dowd et al 1999). They also nest on vegetation - in tree hollows and at the base of epiphytes. When supercolonies form, it is often difficult, if not impossible, to identify single nests (Way 1953). Researchers have found that in ant-infested areas on Christmas Island, the density of nest entrances on the forest floor ranges from 2.8 to 16.0/m^2, and virtually every canopy tree has many nest entrances encircling its base.

Nutrition: The Yellow Crazy Ant has a broad diet. Initially described as a scavenger, it has been called subsequently a "scavenging predator". It preys on a variety of litter and canopy fauna, from small isopods, myriapods, earthworms, mollusks, arachnids and insects to large land crabs, birds, mammals and reptiles (Lewis et al 1976; Haines et al 1994; O'Dowd et al 1999). In addition to these protein-rich foods, the Yellow Crazy Ant obtains carbohydrates and amino acids from both plant nectar and from honeydew excreted by Homoptera (aphids and scale insects), which the Yellow Crazy Ant tends on stems and leaves of a wide variety of tree and shrub species. Honeydew is particularly important in its diet (e.g. O'Dowd et al 1999, 2001).

Foraging activity: In ant-infested areas on Christmas Island, Yellow Crazy Ants in supercolonies forage night and day across every available surface on the forest floor and in the canopy. The density of foraging workers on the forest floor can average over 1000 individuals/m^2. Also, Yellow Crazy Ants forage intensively in the canopy on honeydew from a variety of sap-sucking scale insects with which the ants have a mutually beneficial relationship. In supercolonies, columns of foraging Yellow Crazy Ants continuously stream up and down the trunks of most large trees.

The Yellow Crazy Ant as an Invasive species: The Yellow Crazy Ant has accidentally been introduced across the world's tropics and subtropics as a result of commercial activities. Because it has very generalized nesting habits, it is readily transported through a variety of pathways to new locations. For example, it can be accidentally transported during the transport of timber, soil, horticultural products, machinery and road vehicles and packaging material (e.g. Stanaway et al 2001).

The Yellow Crazy Ant possesses a number of traits that, when combined, increase its potential to become a threatening, invasive species. For example, with its general omnivorous feeding behaviour (eating both animals and plants) and versatile nesting habits, it has a high chance of locating suitable food and nesting sites within any area that it invades. With such traits, the Yellow Crazy Ant can build up to high densities and form supercolonies, and become the most common consumer over large areas on the ground and in the forest canopy. Yellow Crazy Ants can have large direct and indirect impacts on the ecosystems in which supercolonies form. These impacts have been well documented on Christmas Island (see below), and described to various extents in disturbed forest in the Seychelles and Hawaii (Gillespie & Reimer 1993; Haines et al 1994; Feare 1998, 1999), riparian corridors in east Arnhem Land (Young et al 2001), plantations in East Africa, Papua New Guinea and the Solomon Islands (Way 1953; Greenslade 1972; Young 1996), and agricultural fields and villages in southern India (Verresh 1987).

Invasion in Australia: Yellow Crazy Ants have become established on Christmas Island and in east Arnhem Land, Northern Territory. They have also been reported or intercepted near ports in Brisbane, Townsville, Cairns, Darwin and Perth but have subsequently been eradicated. The nearest source areas for Yellow Crazy Ants occur directly to the north and north east of Australia, in Indonesia, Papua New-Guinea, the Solomon Islands and Vanuatu. These incursions demonstrate the ease with which this ant can translocate through human commerce and trade.

Christmas Island and the characteristics of its ecosystem

Christmas Island is located in the Indian Ocean, at latitude 10°25' south and longitude 105°40' east. It is isolated, being approximately 2600 km north-west of Perth and 360 km south of the western head of Java.

Christmas Island is the summit of an otherwise submarine mountain. The island rises steeply to a central plateau up to 361 meters high and is dominated by rainforest. The island's 80 km coastline is an almost continuous sea cliff, with the island's port located at Flying Fish Cove. The climate is tropical, with a wet season between November and April. Extensive phosphate deposits have been mined on the island for many years (DOTARS 2004).

The island covers approximately 135 km^2, of which about 85 km^2 (63%) is the Christmas Island National Park. Christmas Island supports a wide range of unique and unusual species and habitats, and until the invasion of Yellow Crazy Ants, it was considered that much of the natural ecosystem was intact. The National Park is managed by Parks Australia North - a division of the Department of the Environment and Heritage.

Christmas Island's ecology is considered to be unique due to its endemic flora and fauna and the presence of large populations of land crabs and seabirds. The natural vegetation on Christmas Island includes large areas of rainforest. There are approximately 411 plant species and approximately 18 of these are endemic to Christmas Island (Flora of Australia - Vol. 50, 1993). Approximately 126 of these species are not known to occur anywhere else in Australia and its Territories, and 28 species are currently considered rare or threatened (Dept of the Environment & Heritage 2004).

The inventory of the invertebrate fauna of Christmas Island is incomplete. There a number of ant species on the island and, though it has been reported that there are no native ant species on Christmas Island (Taylor in Lawrence 1990), there is some debate as to whether some of the species are native or not. The terrestrial fauna of Christmas Island is dominated by land crabs (which depend on the ocean for their larval development) and in particular the *Geocarcoidea natalis* (Red Land Crab). This crab is the dominant consumer on the forest floor, and plays a major role in determining the structure and function of the rainforest on Christmas Island. The diversity and abundance of land crabs are striking features of the invertebrate fauna, not matched on any other island in the world.

Most of the native terrestrial vertebrates, including all the land birds and three of the sea birds, are endemic. The island is a focal point for breeding seabirds in the area. BirdLife International has listed Christmas Island as an “Endemic Bird Area”. These areas harbour a high concentration of endemic bird species, and are regarded as being of the highest priority for the global conservation of bird biodiversity.

Invasion of Yellow Crazy Ants on Christmas Island: Yellow Crazy Ants were probably accidentally introduced to Christmas Island between 1915 and 1934 (O’Dowd et al 1999) with the species now widespread throughout rainforest and settled areas on the island. Supercolony formation on the island has been a relatively recent phenomenon; the first being discovered in 1989. This colony remained isolated and eventually declined (Dept of the Environment & Heritage 2004). In the mid 1990s more colonies were recorded and by the late 1990s supercolonies of Yellow Crazy Ants had formed in a number of areas and were spreading, with up to 10 fold increases in colony area in a year predicted (O’Dowd et al 1999). One expert commented that by September 2002, supercolonies had grown to cover 3000 ha in just 7 years. Before recent abatement programs, Yellow Crazy Ant supercolonies had formed in 24.4% of island’s rainforest (Orchard et al 2002), with researchers reporting densities as high as 79 million workers per hectare on the forest floor. 90% of known Yellow Crazy Ant supercolonies occurred within the Christmas Island National Park boundaries, or about 25 km^2, about 30% of the park, had been infested with Yellow Crazy Ants.

Management of Yellow Crazy Ants on Christmas Island: The possible impact of Yellow Crazy Ants on Christmas Island's unique habitat was apparent in the late 1990s. Since then, there has been a concerted effort by the Australian Government's Parks Australia North and experts to manage the Yellow Crazy Ant problem. An outline of the threat abatement work that has occurred to date is presented below when Threat Abatement Planning is discussed. While the program has been successful in destroying Yellow Crazy Ant supercolonies in most of the infested areas, smaller numbers of supercolonies are forming in other areas. It is too early to evaluate how well the previously infested areas are recovering and what the damaging long-term effects of the supercolonies have been. Also, at this stage, threat abatement is aimed at suppressing Yellow Crazy Ant supercolonies, and it may not be possible to completely eradicate Yellow Crazy Ants from Christmas Island.

The process - Overview

The loss of biodiversity and ecosystem integrity following invasion by the Yellow Crazy Ant results from its rapid increase to high populations or supercolonies, its rapid spread, its association with outbreaks of scale insects, and its broad foraging range and generalist feeding habits. When the Yellow Crazy Ant invades an ecosystem, it can directly impact on a range of fauna and flora within the ecosystem, which can in turn lead to changes in the structure of the habitat and alterations to the ecosystem processes. On Christmas Island, the combined impact of these is likely to lead to considerable losses of biodiversity.
There are a number of ways Yellow Crazy Ants are impacting on the Christmas Island ecosystem, and these can be divided into three main areas:

- the direct impact caused by direct predation[1] and competition with, other species;
- the impact caused by the removal of the keystone forest species; and
- the impact caused by the mutualistic relationship between Yellow Crazy Ants and scale insects.

The impact caused by direct predation and competition with other species

Yellow Crazy Ants in supercolonies are known to directly kill or compete with native species. The Yellow Crazy Ant is known to directly kill invertebrates, reptiles, hatchling birds, small mammals and other newborn animals. Yellow Crazy Ants also displace and interfere with local species, using resources such as tree hollows, and restricting access to food sources. On Christmas Island, Yellow Crazy Ant have directly affected, and inversely impacted on, a number of species. The impact on individual species is discussed under each assessment criteria.
The potential loss of biodiversity though direct means, such as predation and competition, may be considerable, but, the direct impact that the Yellow Crazy Ant has had on the Red Land Crab, a keystone species (a species that has a critical role in the structure of the biological community) on Christmas Island, is likely to lead to a further loss of biodiversity on the Island (O'Dowd et al 2003). As supercolonies form and spread across Christmas Island, the Red Land Crab, the dominant endemic consumer, is killed and displaced from ant-invaded forest. Furthermore, during the annual migration of the Red Land Crab, large numbers are killed in transit when migratory pathways intercept ant supercolonies. This depletes crab populations in extensive areas that are not yet directly invaded by the Yellow Crazy Ant (O'Dowd et al 2001, 2003).

[1] Predation is taken to include the killing and consumption of an animal that occurs as a result of the animal being attacked by Yellow Crazy Ants instinctively spraying formic acid in defence.

The impact caused by the removal of the keystone forest species

Alteration of ecosystem processes: The Red Land Crab is the major seed, seedling and litter consumer in the rainforest of Christmas Island. Their removal or reduction in numbers caused by Yellow Crazy Ants results in alterations in the rates of seedling recruitment and litter breakdown, alterations in the recruitment dynamics of rainforest trees and almost certainly changed patterns of nutrient availability. This leads to a rapid shift in forest structure and composition or a "state change" in the rainforest ecosystem.

This affect has been recently documented (e.g. O'Dowd & Lake 1989, 1990, 1991; O'Dowd et al 1999, 2001, 2003; Green et al 1997; 1999). Experiments conducted at a small spatial scale over the last decade show that removal of the Red Land Crabs leads to alterations in seedling recruitment, seedling species composition, litter breakdown, and the density of litter invertebrates. Elimination of the Red Land Crab by Yellow Crazy Ants copies these effects but at a landscape scale. As a consequence, forest processes in Yellow Crazy Ant supercolonies are indirectly affected: on average, litter cover has been found to be double, seedling densities 30-fold higher, seedling species richness 3.5-fold higher, and forest understorey structure markedly different in ant-invaded areas. Species composition of seedlings also changes in Yellow Crazy Ant supercolonies.

Thus, the direct impact of Yellow Crazy Ants on the Red Land Crab, the dominant native consumer, has long-term implications for forest structure and species composition. In turn, these changes will affect, to varying extents, the way other species of fauna are able to use the ant-invaded forests.

The impact of Yellow Crazy Ants on fauna, other than the Red Land Crab, may also lead to other indirect impacts on the ecosystem. For example Yellow Crazy Ants may impact directly on seed dispersing endemic birds such as the Christmas Island White-eye, Christmas Island Thrush and Christmas Island Emerald Dove, leading to changes in the ways seeds are dispersed on the island. Secondary invasions: Endemic Red Land Crabs provide "biotic resistance" to a wide range of potential alien invaders on Christmas Island (Lake & O'Dowd 1991). For example, crabs will eat the introduced Giant African Snail (*Achatina fulica)* that enter their habitat, thereby preventing the snails from becoming established. They also eat weeds. Therefore, the crabs' elimination from the rainforest by the Yellow Crazy Ant may pave the way for invasion by the Giant African Snail and a variety of environmental weeds (e.g. *Carica papaya*, *Capsicum frutescens, Muntingia calabura*) (e.g. Green et al 2001). It is unknown whether deletion of crabs facilitates rainforest invasion by feral mammals, including cats (*Felis cattus*), Black Rats (*Rattus rattus*), and House Mice (*Mus musculus*), or facilitates exploitation of primary rainforest by the Wolf Snake (*Lycodon capucinus*), a species introduced to Christmas Island in about 1987 and which, until recently, has been largely confined to disturbed habitats, including secondary growth. Secondary invasion by these species is a possibility as a result of the Red Land Crabs being removed from parts of the forest.

The impact caused by the mutualistic relationship between Yellow Crazy Ants and scale insects

Mutualism with scale insects: Yellow Crazy Ants get much of their food requirements from scale insects. Scale insects feed on sap of trees and release honeydew, a sugary liquid, onto the plant. On Christmas Island, Yellow Crazy Ants eat honeydew, and in return protect the scale insects from predators and parasites – it is sometimes considered that the ants are 'farming' the scale insects. This relationship is called mutualism. The honeydew not eaten by ants stays on the trees and encourages the growth of sooty mould (Capnodiaceae) over the leaves and stems, reducing the health and vigour of the plant. Mutualism between the Yellow Crazy Ant and introduced or cryptogenic (origin not known) scale insects can result in scale insect outbreaks. Therefore, in areas invaded by Yellow Crazy Ants, there are high densities of Yellow Crazy Ants streaming up and down trunks of trees foraging on honeydew in canopy trees, population outbreaks of scale insects, and honeydew-dependent sooty moulds on canopy stems and leaves. Population outbreaks of the cryptogenic lac insect *Tachardina aurantiaca* (Kerridae) and introduced *Coccus celatus* (Coccidae), in particular, are associated with Yellow Crazy Ant supercolonies on Christmas Island. These insects are associated with at least 21 and 10 tree species, respectively, including most canopy dominants (O'Dowd et al 2001, 2003).

Alteration of ecosystem processes: High densities of scale insects damage trees, and high levels of sooty mould cover can reduce photosynthesis in these trees. Outbreaks of sap-sucking scale insects associated with Yellow Crazy Ants are known to stress trees, leading to decreased seed production, and high mortality in some canopy species. For example *Inocarpus fagifer* (Tahitian Chestnut), one of the trees that dominates the forest, has been found to be heavily infested and infected by lac scale insects which has contributed to deaths of these trees and lower recruitment of seedlings (see Criteria 1 below).

As forest trees dieback, light gaps are created in the forest canopy. Light gaps, along with removal of crabs, encourages seedling growth and weed invasion into the forest.

Summary of process

Yellow Crazy Ants are generalist predators as well as competitiors that directly impact on species, and their introduction to an area has general implications for food web structure, and specific implications for a wide variety of endemic invertebrate and vertebrate species. Their killing and displacement of the Red Land Crab and direct mutualism with scale insects is in turn causing a rapid state transformation in the forest ecosystem structure and composition on Christmas Island.

2. How judged by TSSC in relation to the *Environment Protection and Biodiversity Conservation Act 1999* criteria

Section 188(4) of the Environment Protection and Biodiversity Conservation Act 1999 states:
A threatening process is eligible to be treated as a key threatening process if:
a) it could cause a native species or an ecological community to become eligible for listing in any category, other than conservation dependent; or
b) it could cause a listed threatened species or a listed threatened ecological community to become eligible to be listed in another category representing a higher degree of endangerment; or
c) it adversely affects 2 or more listed threatened species (other than conservation dependent species) or 2 or more listed threatened ecological communities.

Research on the impact of the Yellow Crazy Ant on the biota of Christmas Island indicates that a diverse range of taxa – from litter invertebrates to canopy vertebrates to canopy trees - are likely to be adversely affected by the Yellow Crazy Ant. The following is a discussion on the key species to support the listing of this process as a key threatening process.

A) Could the threatening process cause a native species or an ecological community to become eligible for listing in any category, other than conservation dependant?

A list of native species and ecological communities which could become eligible for listing due to the threatening process is at Attachment (i).

Impacts on native plants

Inocarpus fagifer (Tahitian Chestnut) is one of the native species that dominates the rainforest canopy on Christmas Island. In one study, both seedlings and trees of the Tahitian Chestnut were found to be heavily infested with, and especially affected by, the lac scale insect *Tachardina aurantiaca* in areas of supercolonies, and a higher proportion of deaths of Tahitian Chestnut trees was occurring. At sites free of Yellow Crazy Ants, seedlings of the Tahitian Chestnut comprised 24% of all seedlings, but in Yellow Crazy Ant supercolonies, they comprised just 0.1% of all seedlings. As a consequence of the lac scale outbreaks caused by Yellow Crazy Ants, the Tahitian Chestnut is suffering from canopy dieback, high tree mortality, reduced fecundity and high seedling mortality (O'Dowd et al 2001; also unpublished data). This species could become eligible to be listed as vulnerable because of this threatening process.

Impacts on native mammals

There are three endemic mammals on Christmas Island - *Pteropus melanotus natalis* (Christmas Island Flying Fox), *Crocidura attenuata trichura* (Christmas Island Shrew) and (Christmas Island Pipistrelle (*Pipistrellus murrayi*), a bat. The latter two are threatened species and there is some evidence that Yellow Crazy Ants are impacting on them (see assessment under Criterion 2). One expert states that there is evidence that the Christmas Island Pipistrelle has declined significantly, though the reason for decline is not known, and that Yellow Crazy Ants may be directly interfering with bats or young at roosts. In addition, Yellow Crazy Ants may compete for food, and may be causing the decline of rainforest plants that are important to this bat. It has also been reported that supercolonies have formed in areas where three of the five larger camps of this bat reported by Tidemann (1985) are located. This threatening process could cause the Christmas Island Flying Fox to become eligible for listing as a threatened species under the EPBC Act.

Impacts on native birds

Assessing the impacts of Yellow Crazy Ants on the birds of Christmas Island is difficult. There are a number of factors that suggest Yellow Crazy Ants are having a detrimental affect on native bird species in areas where ant supercolonies occur, such that they could become eligible for listing as threatened (other than as conservation dependent).

Direct impacts: There are a few observations in supercolonies of Yellow Crazy Ants swarming over dying birds that have for some reason been grounded. These species include *Turdus*

poliocephalus erythropleurus (Christmas Island Thrush), *Zosterops natalis* (Christmas Island White-eye), *Papasula abbotti* (Abbott's Booby), *Phaethon lepturus fulvus* (Christmas Island White-tailed Tropicbird), *Accipter fasciatus natalis* (Christmas Island Goshawk), *Ducula whartoni* (Christmas Island Imperial-Pigeon), and *Chalcophaps indica natalis* (Emerald Dove). About 25 birds in total have been found over 3 years, and grounded birds were rarely found in forest that was not affected by Yellow Crazy Ants. These observations suggest that Yellow Crazy Ant may attack and kill a range of native bird species on Christmas Island, but the lack of bird carcasses found in intact forest may also be explained by the presence of scavenging land crabs eating the carcasses. Therefore, it is not clear if the Yellow Crazy Ants kill healthy birds on Christmas Island. On Bird Island in the Seychelles, invasion by Yellow Crazy Ants led to about 60,000 pairs of *Sterna fuscata* (Sooty Tern), which nest in colonies on the ground, being displaced from their nesting sites and also caused the death of *Gygis alba* (White Tern) chicks (Feare 1999). Yellow Crazy Ants may also take over nesting sites of known tree-hollow nesting birds.

Indirect impacts: In the long-term, if control measures were to cease, fail or become less effective in the future, then it is highly possible that the ecosystem changes brought about by Yellow Crazy Ants would have a profound effect on terrestrial birds species. As well as issues such as how suitable the changed habitat would be for the existing birds species, there is the issue of secondary invasion of the forest by Black Rats and cats. Terrestrial birds can be susceptible to extinction on small islands, and it is often related to the introduction of cats and rats. On Christmas Island, introduced rats and cats seem to have difficulties maintaining feral populations away from the settlement. Nowhere do rats and cats appear to be numerous in the forest, although they do occur throughout the island. Rugged terrain, lack of surface water in years of low rainfall and lack of dependable food supply, coupled with competition with Red Crabs may be the reason for the lack of proliferation of these feral species. Through the elimination of Red Crabs, Yellow Crazy Ants may facilitate a proliferation of Black Rats and cats, which could further impact upon bird species.

Species studies: There has only been one study (Davis 2002) that has investigated the impact of the Yellow Crazy Ant on native Christmas Island birds that are not listed as threatened. This was a short-term study from September 2001 to January 2002 on the Christmas Island White-eye, Christmas Island Thrush, Christmas Island Emerald Dove and Christmas Island Imperial-Pigeon (Davis 2002; Davis et al 2002). The study provides some data to support the claim that non-threatened native birds are being adversely affected by Yellow Crazy Ant. In areas where Yellow Crazy Ant supercolonies were established, altered behaviours, including altered foraging patterns, were noted in the Christmas Island Thrush, Christmas Island Emerald Dove and Christmas Island White-eye. The study indicated that the Yellow Crazy Ant has the potential to directly cause population declines in at least the Christmas Island Thrush and Christmas Island Emerald Dove, as well as to indirectly alter the structure, function and integrity of the island's ecosystems through negative impacts on seed dispersion. There was little evidence that the Christmas Island Imperial Pigeon was impacted upon by Yellow Crazy Ants and the degree of impact on Christmas Island White-eye was uncertain (Davis 2002). The following details the impacts of Yellow Crazy Ants on the dove and thrush.

*Chalcophaps indica natalis (*Christmas Island Emerald Dove*)*: This subspecies of Emerald Dove is endemic to Christmas Island, and there is reasonable evidence that this threatening process could cause it to become threatened if abatement actions are not undertaken or are unsuccessful. The Yellow Crazy Ants affect Emerald Doves in a number of ways. Direct attacks on injured Emerald Doves have been observed in supercolony areas, though it was unclear whether attack by Yellow Crazy Ants was the initial cause of injury, as healthy birds appeared to be able to dislodge the ants before serious injury occurred. A report that Yellow Crazy Ants were responsible for killing Emerald Dove nestlings (Garnett & Crowley 2000) has not been verified.

There is evidence that the Yellow Crazy Ant may be reducing population numbers of the Emerald Dove by altering the forest habitat in areas where supercolonies occur and where Red Crabs have been eliminated so that it is less suitable for doves. Davis (2002) found that in areas where supercolonies occurred, there was a 5-10 fold decline in abundance of Emerald Doves, compared to uninvaded forest. This may have been because Emerald Dove's normally feed on fruit on the ground, where the Yellow Crazy Ants occur at their highest densities. Within supercolonies, the doves would be exposed to competition for food and aggressive attacks by Yellow Crazy Ants. In addition, in areas of forest where Yellow Crazy Ants have eliminated Red Crabs, it was found that the seeds that were previously consumed by the Red Crabs were germinating, and the forest structure had altered, with dense layers of seedlings covering the forest floor. This makes foraging on the ground more difficult for the Emerald Dove and may result in a possible long-term alteration of forest structure and composition.

The study also suggests that though Emerald Doves are attempting to nest in ant-invaded areas, many attempts are failing. It is thought that nesting Emerald Doves may be particularly vulnerable to ant predation as their nests are often low in the vegetation where the threat of interference by ants is high (Davis 2002). While healthy adult Emerald Doves are unlikely to suffer from direct predation by Yellow Crazy Ants, it is possible that their reproductive success could be reduced by Yellow Crazy Ant's harassing nesting adults (e.g. adults incubating eggs), and predating on nestlings and juvenile birds. Therefore, areas occupied by Yellow Crazy Ant supercolonies are likely to provide much poorer breeding habitat compared to unoccupied areas.

The Emerald Dove occurs throughout most habitats on the island, and as an endemic species has a restricted geographic distribution. A number of impacts on this species have been demonstrated or observed in areas where Yellow Crazy Ant supercolonies occur. As Yellow Crazy Ant control programs are currently being implemented effectively, significant decreases in abundance are unlikely in the future. However, if control measures were to cease, fail or become less effective in the future, this could cause the Emerald Dove to become eligible for listing as threatened.

Turdus poliocephalus erythropleurus (Christmas Island Thrush)*:* This subspecies of Island Thrush is endemic to Christmas Island, and common on most habitats on the island (Davis 2002). It normally feeds on or near the ground. Davis (2002) found that Yellow Crazy Ants had no significant impact on the reproductive success of this species' nests, but that the number of juveniles and the availability of nest sites appeared lower in ant-invaded forest compared to uninvaded forest. The study also found that some behaviours of the Island Thrush altered in areas where ant supercolonies were present – the Thrushes appeared to adjust foraging behaviour in ant-invaded areas to minimise direct encounters with ants. Healthy adults appeared to be able to avoid direct predation, and to remove ants from their bodies if needed.

However, the elimination of Red Crabs in large areas of Christmas Island by the Yellow Crazy Ant may facilitate a secondary invasion, or increase in abundance, of the Black Rat, which may also impact on the Island Thrush. Black Rats have been implicated in the extinction of Island Thrushes elsewhere – for example, the *Turdus poliocephalus vinitinctus* (Vinous-tinted Thrush) on Lord Howe Island.

Like the Emerald Dove, this ground-frequenting endemic bird has a restricted distribution and has been observed to be impacted upon by Yellow Crazy Ants. If control measures were to cease, fail or become less effective in the future, this could cause the Christmas Island Thrush to become eligible for listing as threatened.

Other species: There is some anecdotal evidence available that indicates the impact Yellow Crazy Ants are having on other species of birds. For example, the Christmas Island White-tailed Tropicbird primarily nests in forest trees, and there is potential for high densities of foraging Yellow Crazy Ants to cause chick mortality and nest abandonment. However, there is little information on the impact supercolonies have on this species.

Impacts on native reptiles

Outside Australia, Yellow Crazy Ants are known to have had a detrimental affect on some reptiles. In the Seychelles, on Mahé Island, searches for the endemic skink *Mabuya seychellensis* found 10-fold fewer skinks in Yellow Crazy Ant-infested areas (Haines et al 1994). Similarly, on Bird Island, no *M. seychellensis* were found in areas where Yellow Crazy Ant supercolonies occurred (Feare 1999). Yellow Crazy Ants were seen carrying an about 5 cm *Ramphotyphlops brahminus* (burrowing blindsnake) to their nest (Feare 1998).

There is some evidence that Yellow Crazy Ants are impacting on reptiles on Christmas Island. The distribution of three native reptiles, *Cyrtodactylus sadlieri* (Christmas Island Giant Gecko), the *Cryptoblepharus egeriae* (Blue-tailed Skink) and the *Emoia nativitatis* (Forest Skink), overlap with that of Yellow Crazy Ant supercolonies, and these species are located in microhabitats where Yellow Crazy Ants forage intensively. Hatchlings, juveniles and adults of these three species are likely to be attacked and eaten by the Yellow Crazy Ant.

In 1998, in areas free of supercolonies, the Christmas Island Giant Gecko appeared widespread, abundant and secure (Cogger & Sadlier 1999). Searches for this species have found that this gecko still inhabits ant-infested forests but at lower numbers than in forests free of supercolonies (Cogger & Sadlier 1999; Stork et al 2002), though this has not been substantiated. Though the Blue-tailed Skink has contracted recently in range, its contraction appears to be associated with threats other than those posed by the Yellow Crazy Ants (Cogger & Sadlier 1999). The Forest Skink, as its name suggests, is primarily a forest species. This species is unlikely to survive in areas of ant supercolonies, and the impact of Yellow Crazy Ants on this species is potentially catastrophic (Cogger & Sadlier 1999).

While there is evidence that Yellow Crazy Ants are impacting on some reptile species of Christmas Island, there is little data on the degree of impact. The information available suggests that the endemic Christmas Island Giant Gecko and Forest Skink may be particularly vulnerable to the Yellow Crazy Ant invasion, and that the Forest Skink, with its preference for forest habitat, has the potential to become threatened. In the long-term, it is likely that if the Yellow Crazy Ant were allowed to spread unabated, then the ecosystem changes are likely to have a profound effect on terrestrial reptiles.

Impacts on invertebrates

Land Crabs: The terrestrial fauna of Christmas Island is dominated by land crabs and, in particular, by the Red Land Crab. Red Land Crabs are the dominant consumers on the forest floor, and play a major role in determining the structure and function of the rainforest on Christmas Island. One of the most significant impacts of Yellow Crazy Ants on Christmas Island occurs as a result of the Yellow Crazy Ants' direct predation and competition with the Red Land Crab. Yellow Crazy Ants have also been reported to attack and kill land crabs in the Seychelles and in the Marshall Islands (Feare 1999, National Biodiversity Team of the Republic of the Marshall Islands 2000).

Gecarcoidea natalis (Red Land Crab)*:* The Red Land Crab is by far the most obvious of the 14 species of land crabs found on Christmas Island. These large bright red crabs occur in the millions. They live in a variety of habitats, including coastal shore terraces, but are most common in the moist environment of the rainforest. For most of the year, these crabs live near their burrows, and during the dry season, they stay in their burrows for 2-3 months. Their diet consists mainly of fallen leaves, fruits, flowers and seedlings, but they also eat other dead crabs, and the introduced Giant African Snail. Before the build up of Yellow Crazy Ants numbers, the Red Land Crab had virtually no competition from other species for their food resources, due to their high numbers and dominance of the forest floor (National Parks 2004).

Once a year, most adult Red Land Crabs undergo a synchronized migration from the forest to the coast, to mate and release fertilized eggs into the sea. Masses of crabs gather into broad "streams" as they move toward the coast following traditional routes. After breeding, the adults return inland, and then, after about a month in the ocean, young crabs return to the shore and begin their "march" inland. Here young crabs seem to disappear and are rarely seen, living in rocky outcrops and under fallen tree branches and debris on the forest floor for the first three years of their life (National Parks 2004).

Yellow Crazy Ants are known to directly impact on the Red Land Crab. In areas of Yellow Crazy Ant supercolonies, the movement of the Red Land Crab disturbs the ants, and an alarm response ripples through the ant workers that results in the spraying of formic acid repeatedly and indiscriminately. These crabs are frequently blinded by hundreds of workers spraying acid on or near their eyestalks. Red Land Crabs under attack show signs of stress, frothing at the mouth, and exhibiting extreme lethargy. Death usually results in 24-48 hours. As the supercolonies of Yellow Crazy Ants spread across Christmas Island, ants attack Red Land Crabs on the ground and in burrows and the ants occupy the crabs' burrows and use them for their nest sites (O'Dowd et al 1999, 2001). As well as being killed round their burrows, Red Land Crabs are killed in transit, when migratory pathways intercept ant supercolonies. This depletes crab populations in extensive areas not yet directly invaded by the Yellow Crazy Ant (O'Dowd et al 2001).

Therefore, once a supercolony forms, Yellow Crazy Ants eliminate or displace all the resident Red Land Crabs from that area, and any crabs that subsequently migrate through that area.

Since 1995, it is estimated that Yellow Crazy Ants have killed 10-15 million red crabs, about one quarter to one-third of the total island-wide population (P.T. Green in O'Dowd et al 2003), a catastrophic decline in this keystone species on Christmas Island. The direct impacts of Yellow Crazy Ants on both resident and migrating red crabs are most evident in the western third of the island where comparatively few red crabs remain. The Yellow Crazy Ant could cause the Red Land Crab to become eligible for listing as a threatened species.

Other crab species: The Red Land Crab is only one of three major land crab species in the rainforest proper on Christmas Island. All these species migrate to the sea to spawn. In Yellow Crazy Ant supercolonies, *Birgus latro* (Robber Crabs) and *Geograpsus grayi* (Little Nippers) are also killed. The Christmas Island National Park is a major refuge for the Robber Crab, once widespread throughout the Indo–Pacific region but now in rapid decline across its range. Yellow Crazy Ants also attack and kill the *Cardisoma hirtipes* (Blue Crab). Though a widespread species, the Blue Crab occurs in its blue form only on the Christmas Island.

Although Yellow Crazy Ants are killing these other species of crabs, there does not appear to be much data to indicate that they will become eligible for listing as threatened as a result of the impact from Yellow Crazy Ants. However, in the long-term and if the threat of Yellow Crazy Ant were allowed to spread unabated, then the ecosystem changes could have a profound effect on land crabs.

Other Invertebrates: Yellow Crazy Ants have been observed feeding on a wide range of invertebrates including cockroaches, mantids, Orthoptera, caterpillars, fly larvae, beetles, spiders and other species of ants. Yellow Crazy Ants are renowned for the rapidity in which they forage on insect prey (e.g. Townes 1946; Haines 1994 et al; Feare 1999). The few overseas studies that have investigated the impact of the Yellow Crazy Ant on invertebrates suggest that it is a serious threat to invertebrate biodiversity. In Hawaii, the Yellow Crazy Ant is implicated in the loss of diversity of endemic forest spiders (Gillespie & Reimer 1993) and riparian insects (Hardy 1979). In the Solomon Islands, East Africa and India, Yellow Crazy Ants can displace other ant species, including *Oecophylla smaragdina* and *Pheidole megacephala* (Way 1953; Greenslade 1971, 1972; Soans & Soans 1971). In the Seychelles, Yellow Crazy Ants have been found to affect litter invertebrate communities (Hill et al 2003).

The list of native invertebrates (other than land crabs) presented at Attachment (i) is a subset of endemic invertebrates described by Lawrence (1990) that occurs in rainforest microhabitats on Christmas Island that is heavily used by Yellow Crazy Ants. It is considered to be a conservative list. Knowledge of the endemic invertebrate fauna of Christmas Island is not complete, nor is knowledge of their conservation status. A group of invertebrates that is relatively well known is the Coleoptera (beetles) and this group contains a high number of endemics (Lawrence 1990), suggesting that invertebrate fauna more generally may include a high number of endemics.

Though the nomination claims that it is likely that the Yellow Crazy Ant, either directly or indirectly, adversely affects many litter-inhabiting and arboreal invertebrates on Christmas Island, there have been only a few limited studies. In one study, the densities of litter-inhabiting invertebrates were found to be lower in ant-infested forest than intact forest (Davis et al 2002), and in another, Yellow Crazy Ants did not appear to affect the density of canopy arthropods. Anecdotal observations suggest that Yellow Crazy Ants may adversely affect invertebrates. For example, one expert has observed Yellow Crazy Ants on Christmas Island directly attacking, by spraying of formic acid and dismembering, a number of species including earthworms, praying mantises, stick insects, cicadas and cockroaches. Another expert recorded stridulating katydids less often in the rainforest canopy in ant-infested forest than in other areas (G. Richards in Schulz & Lumsden 2004). In addition, the endemic *Oxypleura calypso* (Christmas Island Cicada), which undergoes its final moult on the trunks of trees, would be exposed to foraging columns of Yellow Crazy Ants, and a group of endemic orthopterans (an order of cricket-type insects that includes *Clitumnus stilpnoides* (Christmas Island Stick Insect) and *Psyra pomona* (tettigoniid) would encounter Yellow Crazy Ants on foliage.

At this stage, there is not much data available to indicate whether this threatening process will cause native invertebrates (other than land crabs) on Christmas Island to become eligible for listing as threatened. However, in the long-term and if the Yellow Crazy Ant were allowed to spread unabated, then the ecosystem changes could have a profound effect on many of the Christmas Island native invertebrates.

Impacts on Christmas Island ecological communities:

Ecological Communities

The following ecological community could become eligible for listing as threatened under the EPBC Act because of this threatening process: Rainforest on Christmas Island, Indian Ocean, which encompasses six broad habitat types (Christmas Island National Park Management Plan 2002).

- Terrace rainforest – open, semi-deciduous rainforest on the coastal terraces
- Shallow soil rainforest on the higher terraces
- Limestone scree slopes and pinnacles
- Deeper plateau and terrace soils evergreen forest
- Mangrove forest
- Perennially wet areas

About 100 km^2 of rainforest remains on the island, most of which occurs in the National Park, but some occurs on the adjacent vacant crown land. The rainforest is unique and, until Yellow Crazy Ant invasion, was relatively intact. The expansion of Yellow Crazy Ant supercolonies throughout the ecological community was very rapid, having occurred over about 7 years (c. 1995 to 2002). Before the recent abatement programs, Yellow Crazy Ant supercolonies had formed in 24.4% of the island's rainforest (Orchard et al 2002) with some estimates being as high as 28% by September 2002. Research has shown that in those areas of rainforest where supecolonies occur, the rainforest is rapidly degraded and changes in a number of ways. For example, in these areas more seedlings and species of seedlings are found on the forest floor, and larger infestations of scale insects are also found, resulting in canopy dieback and death of trees (e.g. O'Dowd et al 2003).

The Christmas Island rainforest ecological community is likely to become threatened if the Yellow Crazy Ants abatement plan ceases or is unsuccessful. It has a highly restricted distribution (100 km^2) with a demonstrable threat, as do the many endemic taxa that comprise the community. The major changes to the ecosystem that result from this threatening process would lead to major changes in the structure and composition of the fauna and flora of the area such that the currently defined rainforest ecological community would be lost from those areas.

Conclusion to A: Based on the information provided and summarised above, the TSSC consider that the threatening process:

- has the potential to cause a native plant, a number of animal species and an ecological community to become threatened.

The threatening process could cause a number of native species and an ecological to become eligible for listing as threatened, and **is therefore eligible under this criterion**.

B. Could the threatening process cause a listed threatened species or a listed threatened ecological community to become eligible to be listed in another category representing a higher degree of endangerment?

C. Does the threatening process adversely affect 2 or more listed threatened species (other than conservation dependent species) or 2 or more listed threatened ecological communities?

The discussion of Criteria B and C have been combined as the available evidence for both criteria are similar. There are no invertebrate species on Christmas Island presently listed as threatened, and there is no information available on the impact of Yellow Crazy Ants on listed threatened plants.

Impacts on listed threatened mammals

Pipistrellus murrayi (Christmas Island Pipistrelle): This endemic insectivorous bat is listed as endangered under the EPBC Act and was reported by Lumsden et al (1999) to have declined markedly and contracted in its distribution from the mid-1980s to 1998. Reasons for the decline were unclear, but there was concern that that Yellow Crazy Ants may have a role in threatening this species. However, it was considered that there were also likely to be other threatening processes at work, as the decline was occurring in both the areas where Yellow Crazy Ant supercolonies were present and those they were not (Lumsden et al 1999). Since 1998, areas of high or moderate levels of pipistrelle activity, considered to be the stronghold for the species, were either invaded by ant supercolonies or were within a supercolonies' foraging range (Schulz & Lumsden 2004).

Yellow Crazy Ants may impact directly on the Christmas Island Pipistrelle in a number of ways. These bats roost on tree trunks and in hollows, microhabitats that are heavily used by Yellow Crazy Ants. The bats have been attacked and killed by ants: one individual captured in a trap died as a result of Yellow Crazy Ant attack in 1998 (Lumsden et al 1999). Bats contacted by Yellow Crazy Ants that are not killed directly may be adversely affected by exposure to sprayed formic acid leading to blindness and physiological stress (O'Dowd et al 1999). In areas of Yellow Crazy Ant supercolonies, it is thought that the pipistrelle may be forced to find alternative roosts, if available, and these may offer less protection. Maternity sites of this bat are also considered to be vulnerable. Although no maternity sites for the pipistrelle have been located, they are likely to be situated in the hollows of rainforest canopy trees, a microhabitat also used by Yellow Crazy Ants. Given the small size of the pipistrelle (adults weigh 3-4.5 g with new-born young likely to weigh approximately 1 g) individuals at maternity sites within supercolony areas would be considered at risk. The availability of the invertebrate prey of the Pipistrelle may also have decreased due to the foraging activity of the ants (Schulz & Lumsden 2004).

There are also indirect impacts that may occur as a result of this process. The removal of Red Land Crabs may allow greater penetration into the rainforest of Wolf Snakes, which are thought to have had a major role in the initial decline in pipstrelles, as well as other predators such as feral cats and rats.

Currently, it is not known what impact the Yellow Crazy Ant has on the Christmas Island Pipistrelle. The recovery plan for the Christmas Island Pipistrelle (Schulz & Lumsden 2004) states that it is likely that the Yellow Crazy Ants are compounding the impact of earlier declines and that the continuing spread of the ant would be harmful to the long-term survival of the pipistrelle.

As nearly all of the areas of greatest activity of the pipistrelle have been affected by Yellow Crazy Ants supercolonies, and the pipistrelle appears to use microhabitats that are heavily used by Yellow Crazy Ants, the threatening process is considered to be adversely affecting the Christmas Island Pipistrelle, and it could become eligible to be listed in a category representing a higher degree of endangerment as a result of this process.

Crocidura attenuata trichura (Christmas Island Shrew): In the recovery plan (Schulz 2004) for this nationally endangered entity, Yellow Crazy Ants have been identified as one of the threatening processes. The species was widespread and abundant on Christmas Island at the time of European settlement, occurring in rainforest. It appeared to decline rapidly, with the only records after 1908 being an accidental finding of two single individuals in 1985. The species has not been recorded since this finding despite targeted surveys, and is considered by some to be possibly extinct (Schulz 2004). Yellow Crazy Ant supercolonies have subsequently formed at the site of the 1985 sightings. The shrew was recorded to shelter in holes in rocks and roots of trees, and to forage on small beetles (Andrews 1900).

The direct effects of Yellow Crazy Ants on the shrew are unknown, but it is likely that breeding, shelter and foraging sites would be severely affected. It is also likely the ants would kill young animals in the nest and, possibly, adults in severely affected areas (Schulz 2004). This threatening process is considered to be adversely affecting the Christmas Island Shrew, and it could become eligible to be listed in a category representing a higher degree of endangerment as a result of this process.

Impacts on threatened listed birds

Papasula abbotti (Abbott's Booby)*:* There has been much concern about the impact of Yellow Crazy Ants on the endangered listed species, Abbott's Booby, which now nests only on Christmas Island but used to nest on many other islands in the Indian and Pacific Oceans (Garnett & Crowley 2000). The conservation status of this seabird has been of concern since the 1960s and its conservation was central to the creation of the Christmas Island National Park. It has been observed that as of September 2002, 12% of the population nested in ant-infested areas and that 96% of all Abbott's Booby nests are found in the canopies of species of trees that are preferred by Yellow Crazy Ants. This species has a low intrinsic rate of increase and previous studies have shown that even a small decline in breeding success could have significant long-term consequences for the population (Olsen 2002). A study has been conducted comparing the density of breeding sites of Abbott's Boobies in areas that contain supercolonies with those that do not, and no significant differences were found. A similar comparison was undertaken for non-breeding sites of Abbott's Boobies (roosting sites) and a small, significant decline was found in the number of birds using non-breeding sites in areas containing supercolonies. It was also found that nest success did not differ significantly between ant-infested and intact forest. However, it is considered that this study was limited, being designed to detect only very large impacts caused by Yellow Crazy Ants. A recent survey of nests did not indicate a change in nest activity around Yellow Crazy Ant distributions (Olsen 2002). Experts still consider that given the importance that minor variation in breeding success might hold for the species, there are insufficient data to conclude that Yellow Crazy Ants do not pose a serious threat to Abbott's Booby. Yellow Crazy Ants have been recognized as potentially the most serious threat to Abbott's Bobby in the draft recovery plan for Abbott's Booby (Olsen 2002).

There is sufficient information to suggest that this threatening process may be impacting on the Abbott's Booby, and is adversely affecting this species. However, there is insufficient data to indicate the extent of this impact, and whether the species may become eligible to be listed in a category representing a higher degree of endangerment as a result of this process.

Fregata andrewsi (Christmas Island Frigatebird): This is the rarest endemic seabird on Christmas Island and is listed as vulnerable under the EPBC Act. It breeds in tall trees in terrace forests in only three small areas totalling about 170 ha in extent. The total population size, last estimated in the early 1980's, was approximately 1620 pairs. The recovery plan for this species (Hill & Dunn 2004) includes the impact of Yellow Crazy Ants as a threat. The ants are considered to potentially threaten individual breeding birds as well as the nesting trees. Christmas Island Frigatebirds are especially at risk from Yellow Crazy Ants because supercolonies concentrate on terrace forests of the islands where all Christmas Island Frigatebirds nesting habitat occurs.

There is sufficient information to suggest that this threatening process may be impacting on the Christmas Island Frigatebird, and is adversely affecting this species. However, there is insufficient data to indicate the extent of this impact, and whether the species may become eligible to be listed in a category representing a higher degree of endangerment as a result of this process.

Accipter fasciatus natalis (Christmas Island Goshawk*):* This subspecies is currently listed as endangered under the EPBC Act. It is considered to be the rarest endemic land bird on Christmas Island, and it occurs in all habitats from primary and marginal rainforests to suitable areas of secondary regrowth vegetation. The recovery plan (Hill 2004a) states that the total population size may be as few as 100 adults, and is probably limited by the availability of suitable rainforest habitat. It considers that Yellow Crazy Ants pose a potentially critical threat to the survival of this bird.

As such large areas of Christmas Island rainforest have been disrupted by this threatening process, there is sufficient information to suggest that this process may be impacting on the Christmas Island Goshawk, and is adversely affecting this species. However, there is insufficient data to indicate the extent of this impact, and whether the species may become eligible to be listed in a category representing a higher degree of endangerment as a result of this process.

Ninox natalis (Christmas Island Hawk-Owl): The Christmas Island Hawk-Owl is endemic to Christmas Island, and is currently listed as vulnerable under the EPBC Act. The recovery plan (Hill 2004b) states the species' territories are found in all habitats, and the total population is estimated to be about 820-1200 birds. The recovery plan considers supercolonies of the introduced Yellow Crazy Ant to potentially pose an extreme risk to this species. There have been no specific studies on the impact of Yellow Crazy Ants on Hawk-Owls, but it is considered that if the birds were grounded for some reason, ant supercolonies would most probably result in the death of the bird. Although research has shown that Yellow Crazy Ants have little impact on canopy insects, these studies are considered limited, and it is possible that the ants may reduce insect populations, the primary prey of the Hawk-Owl (Hill 2004b).

There is sufficient information to suggest that this process may be impacting on the Christmas Island Hawk-Owl, and is adversely affecting this species. However, there is insufficient data to indicate the extent of this impact, and whether the species may become eligible to be listed in a category representing a higher degree of endangerment as a result of this process.

Impacts on listed threatened reptiles

The two rarest endemic Christmas Island reptiles are the vulnerable *Lepidodactylus listeri* (Christmas Island Gecko) (a primary forest species last recorded in 1979, when it was relatively abundant) and the *Ramphotyphlops exocoeti* (Christmas Island Blind Snake), last seen in 1975. Both are found in areas where Yellow Crazy Ant supercolonies have formed and are located in microhabitats where Yellow Crazy Ants forage intensively.

Lepidodactylus listeri (Christmas Island Gecko): This is a small nocturnal lizard that forages from the lower trunk to the canopy of large forest trees. It is considered that both eggs (laid under the bark of rainforest trees) and individuals may be vulnerable to direct predation by Yellow Crazy Ants. Cogger & Sadlier (1999) were unable to account for an absence of this species in a 1998 survey of the island compared to an earlier one in 1979. They suggested a marked decline had occurred and that Yellow Crazy Ants may be implicated though were unlikely to be the principal threatening process, as many of the survey areas where the Gecko had been found in 1979 were free of ants in 1998. With the spread of Yellow Crazy Ants since 1998, it is likely that Christmas Island Gecko, already under threat, has been adversely affected by Yellow Crazy Ants. The direct effects of Yellow Crazy Ants on the shrew are unknown, but it is likely that breeding, shelter and foraging sites would be severely affected. It is also likely the ants would kill young animals in the nest and, possibly, adults in severely affected areas (Schulz 2004).

This threatening process is considered to be adversely affecting the Christmas Island Gecko, and it could become eligible to be listed in a category representing a higher degree of endangerment as a result of this process.

Ramphotyphlops exocoeti (Christmas Island Blind Snake): This is a burrowing snake that has a number of adaptations to avoid both biting and spraying ants, and might even prey on the Yellow Crazy Ant colonies. Its subterranean habits would make it difficult for the ants to attack it in large numbers. There is little evidence at present that this species is being affected by Yellow Crazy Ants.

Turtles: Yellow Crazy Ants may also represent a threat to hatchling turtles. Small numbers of *Chelonia mydas* (Green Turtles) and very occasionally *Eretmochelys imbricata* (Hawksbill Turtle) nest on sandy beaches of Christmas Island. Both these species are listed a vulnerable. Yellow Crazy Ants are reported to forage on sandy beaches on Christmas Island, in Micronesia, and in the Seychelles (Townes 1946; Feare 1998; unpublished observations). On Christmas Island, there is little information or data on the likely affect of this process on the Green and Hawksbill Turtles.

Conclusion to B: Based on the information available and summarized above, the TSSC considers that the threatening process:

- has the potential to cause a number of nationally listed threatened species to become eligible for listing in another category representing a higher degree of endangerment. These species are the: *Pipistrellus murrayi* (Christmas Island Pipistrelle), *Crocidura attenuata trichura* (Christmas Island Shrew) and *Lepidodactylus listeri* (Christmas Island Gecko).

Therefore the threatening process **is eligible under this criterion**.

Conclusion to C: There is considerable data indicating that Yellow Crazy Ant supercolonies have caused major changes in the Christmas Island ecosystem. These changes are likely to represent profound alterations to threatened species habitat, and it is reasonable to conclude that they are most likely adversely affecting threatened species. While the threat abatement activity (outlined below) has been successful in destroying Yellow Crazy Ant supercolonies, it is too early to evaluate how well the ecosystem has recovered and the consequences that Yellow Crazy Ants have had on threatened species. Also, at this stage, threat abatement is aimed at suppressing Yellow Crazy Ant supercolonies, and it may not be possible to completely eradicate Yellow Crazy Ants from Christmas Island.
Therefore, the TSSC considers that:

- this threatening process adversely affecting two or more species listed under the EPBC Act. These species are: *Pipistrellus murrayi* (Christmas Island Pipistrelle), the Christmas Island Shrew (*Crocidura attenuata trichura*), *Papasula abbotti* (Abbott's Booby), *Fregata andrewsi* (Christmas Island Frigatebird), *Accipter fasciatus natalis* (Christmas Island Goshawk), *Ninox natalis* (Christmas Island Hawk-Owl) and *Lepidodactylus listeri* (Christmas Island Gecko).

Therefore the threatening process **is eligible under this criterion**.

CONCLUSION –The abatement actions that are being undertaken to eliminate Yellow Crazy Ant supercolonies have been highly successful. However, the actions are ongoing, and the full eradication of Yellow Crazy Ants on Christmas Island is unlikely at this stage. It has been shown that Yellow Crazy Ants can very rapidly spread through the rainforest of Christmas Island, threatening many species and profoundly altering the functioning of the ecosystem. The threatening process meets s188(4)(a), s188(4)(b) and s188(4)(c) of the EPBC Act. The threatening process could cause a native species or ecological community to become listed as threatened, could cause listed threatened species to become listed in another category representing a high degree of endangerment and adversely affects 2 or more listed threatened species (other than conservation dependent species).

3. Threat Abatement Plan

Current situation and control activity

Christmas Island National Park Management Plan: The Yellow Crazy Ant invasion has been recognized in the Christmas Island National Park Management Plan (2002) as a key threat to biodiversity on Christmas Island. The Management Plan specifically states that a program to research, control, manage and monitor the impacts of the Yellow Crazy Ant will continue as a high priority.

Action Plan for Invasive Ants on Christmas Island: Management and threat abatement of Yellow Crazy Ants on Christmas Island is currently being addressed in the *Action Plan for Invasive Ants on Christmas Island* (Action Plan) which is overseen by the Christmas Island Yellow Crazy Ant Steering Committee. This committee is made up of representatives from government agencies, including Parks Australia, and experts. This Action Plan has been operational for about four years and the current Action Plan (PANCI 2003) prescribes three years of forward planning. Its primary aim is to eliminate Yellow Crazy Ant supercolonies using fipronil-based baits; island-wide eradication of the species is not a current goal. Control is achieved using a fish-meal bait with the active constituent of fipronil, a broad spectrum, neurotoxic insecticide. Research, monitoring of target and non-target impacts, surveillance, and community awareness and education are also key components of the Plan. The program has progressed from a focus on experimental ground baiting in 2000-2001 to an island-wide aerial baiting campaign in September 2002. Combined, these efforts treated almost 2900 ha (371 ha by foot, 2500 ha by helicopter) of ant-infested forest. Wherever bait was dispersed, knockdown of supercolonies has been immediate and impressive. Overall, baiting resulted in a 98-100% reduction in ant activity within two weeks, with very few identifiable non-target impacts (Green 2002).

This Action Plan and its results to date indicate that the impacts of Yellow Crazy Ants on Christmas Island can feasibly, effectively and efficiently be abated through such an approach.

Threat Abatement Plan (TAP) for Tramp Ants in Australia: The TSSC's advice for listing the key threatening process: 'The reduction in the biodiversity of Australian native fauna and flora due to the red imported fire ant, *Solenopsis invicta*' recommended:

> *The development of a threat abatement plan, which provides a national framework to mitigate the potential impact of the group of ants known as tramp ants (including the fire ant), is considered to be a feasible, effective and efficient way to abate the impacts of these species. This TAP should not duplicate activities already underway in Queensland, but focus on actions such as public education, surveillance and monitoring, quarantine and border control, and development of contingency plans in the other States and Territories.*

The Yellow Crazy Ant is one of those tramp ants that will form part of this TAP. This TAP will focus on issues of preventing and responding to new invasions rather than detailed actions that abate advanced invasions such as that of the Yellow Crazy Ant on Christmas Island.

CONCLUSION

It is considered that between them, the current Action Plan for Invasive Ants on Christmas Island and the planned TAP for tramp ants will adequately outline all the threat abatement actions needed to address the Yellow Crazy Ant invasion on Christmas Island. It is considered that the Action Plan for Invasive Ants on Christmas Island specifically addresses the problem of threat abatement for this key threatening process, and that the action plan should be investigated to determine if it can be adopted as the TAP for this key threatening process. The relationship between such an adopted TAP and the tramp ant TAP will also need to be considered.

4. Recommendations

TSSC recommends that:

A. The list referred to in section 183 of the EPBC Act be amended by including in the list as a key threatening process: **'Loss of biodiversity and ecosystem integrity following invasion by the Yellow Crazy Ant (*Anoplolepis gracilipes)* on Christmas Island, Indian Ocean'**

B. The development of a TAP is considered to be a feasible, effective and efficient way to abate the impacts of this threatening process, and that the current "Action Plan for Invasive Ants on Christmas Island" should be investigated to determine if it can be adopted as the TAP.

TSSC Revised Recommendation 2010

The TSSC reviewed its original recommendation regarding the requirement for a TAP in April 2010 and recommended that based on the current threat abatement actions and new proposals for whole of island biodiversity management for Christmas Island, the development of a TAP for the KTP is not required at this time

The development of an additional TAP would duplicate current abatement actions. Current actions include the 'Action Plan for Invasive Ants on Christmas Island', and the 'Threat abatement plan for reduction in impacts of tramp ants on biodiversity in Australia and its territories'. In addition, the development of a specific new TAP at this time would interfere with the efforts being made by the Christmas Island Expert Working Group to improve the ongoing management of Christmas Island for the preservation of its biodiversity in general

Publications cited and used to assess the nomination

Andrews, C.W. 1900. *A Monograph of Christmas Island (Indian Ocean)*. British Museum of Natural History, London.

Australian Biological Resources Study. 1993. *Flora of Australia*. Vol 50, Oceanic Islands 2. AGPS, Canberra.

Christmas Island National Park Management Plan. 2002. Commonwealth of Australia, Canberra.

Cogger, H. & Sadlier, R. 1999. *The terrestrial reptiles of Christmas Island – a reappraisal of their status.* Consultancy for Parks Australia North, Christmas Island. 30 pp.

Davis, N. 2002. *The Invasive Yellow Yellow Crazy Ant (*Anoplolepsis gracilipes*) on Christmas Island, Indian Ocean: Impacts on the frugivorous bird fauna*. Hons thesis, Monash Univ., Melbourne.

Davis, N., O'Dowd D.J., Green P.T. & Mac Nally, R.N. 2002. *The invasive yellow Yellow Crazy Ant (*Anoplolepis gracilipes*) on Christmas Island, Indian Ocean: impacts on endemic land birds.* Report to Environment Australia.

DOTARS 2004. *Territories of Australia, Christmas Island*. Dept of Transport and Region Services, Canberra, viewed 20 March 2004 <http://www.dotrs.gov.au/terr/xmas/ >

Dept of the Environment & Heritage 2004. *Christmas Island National Park*. Dept of the Environment & Heritage, viewed 20 March 2004 <http://www.deh.gov.au/parks/christmas/ >

Duncan, A. Baker G.B. & Montgomery N. 1999. *The action plan for Australian bats*. Environment Australia, Canberra.

Feare, C. 1998. *The sustainable exploitation of sooty tern eggs in the Seychelles. Sixth annual report, June 1998*. Unpublished report to the Division of Environment, Republic of the Seychelles.

Feare, C. 1999. Ants take over from rats on Bird Island, Seychelles. *Bird Conservation International* 9: 95-96.

Garnett, S.T. & Crowley G.M. 2000. *The action plan for Australian birds.* Environment Australia, Canberra.

Gillespie, R. & Reimer, N. 1993. The effect of alien predatory ants on Hawaiian endemic spiders. *Pacific Science* 47: 21-33.

Green, P.T. 2002. *The management and control of the invasive alien Yellow Crazy Ant (Anoplolepis gracilipes) on Christmas Island, Indian Ocean: The aerial baiting campaign*

September 2002 – An appraisal of project objectives and key outcomes. Unpublished report to the Yellow Crazy Ant Steering Committee, December 2002.

Green, P.T., Lake, P.S. & O'Dowd, D.J. 1999. Monopolization of litter processing by a dominant land crab on a tropical oceanic island. *Oecologia* 119: 235-244.

Green, P.T., O'Dowd, D.J. & Lake, P.S. 1997. Control of seedling recruitment by land crabs in rain forest on a remote oceanic island. *Ecology* 78: 2474-2486.

Green, P.T., O'Dowd, D.J. & Lake, P.S. 2001. *From resistance to meltdown: secondary invasion of an island rainforest*. Pp. 451-455 in Ganeshaiah, K.N., R. U. Shaanker, K.S. Bawa (eds) Tropical ecosystems. Structure, diversity and human welfare. Oxford & IBH, New Delhi.

Greenslade, P. J. M. 1971. Phenology of three ant species in the Solomon Islands. *J. Aust. Entomol. Soc*. 10: 241-252.

Greenslade, P.J.M. 1972. Comparative ecology of four tropical ant species. *Insect. Soc*. 19: 195-212.

Haines, I.H., Haines, J.B. & Cherrett, J.M. 1994. *The impact and control of the Yellow Crazy Ant, Anoplolepis longipes (Jerd.), in the Seychelles*. pp. 206–218 in Williams, D.F. (ed.), Exotic ants. Biology, impact, and control of introduced species. Westview, Boulder, CO.

Hardy, D.E. 1979. *An ecological survey of Puaaluu Stream*. Part III. Report on a preliminary entomological survey of Puaaluu Stream, Maui, Coop. Nat. Park Resources Study Unit. Univ. of Hawaii, Manoa. Tech. Rept. 27: 34-39.

Hill, R. 2004a. *National Recovery Plan for the Christmas Island Goshawk (*Accipter fasciatus natalis). Commonwealth of Australia, Canberra.

Hill, R. 2004b. *National Recovery Plan for the Christmas Island Hawk-Owl* (Ninox natalis). *Commonwealth of Australia, Canberra.*

Hill, R. and Dunn A. 2004. *National Recovery Plan for the Christmas Island Frigatebird (*Fregata andrewsi*).* Commonwealth of Australia, Canberra.

Hill, R.S., Hom, K., Vel, T., Shah, N.J. & Matyot, P. 2003. Impact of the introduced yellow Yellow Crazy Ant *Anoplolepis gracilipes* on Bird Island, Seychelles. *Biodiversity & Conservation* 12: 1969-1984.

Holway, D.A., Lach, L., Suarez A.V., Tsutsui, N.D. & Case, T. 2002. The Causes and Consequences of Ant Invasions. *Annu. Rev. Ecol. Syst* 33: 181-233.

Lake, P.S. & O'Dowd, D.J. 1991. Red crabs in rain forest, Christmas Island: biotic resistance to invasion by an exotic snail. *Oikos* 62: 25-29.

Lawrence, J. 1990. Report: *CSIRO Entomological Survey of Christmas Island. Phase 2 and final report.* Unpublished report to Australian National Parks & Wildlife Service. 67 pp.

Lewis, T., Cherrett, J.M., Haines, I., Haines, J.B. & Mathias, P.L. 1976. The Yellow Crazy Ant (*Anoplolepis longipes* (Jerd.)(Hymenoptera, Formicidae)) in Seychelles, and its chemical control. *Bull. Entomol. Res*. 66: 97-111.

Lumsden, L., Silins J., & Schulz, M. 1999. *Population dynamics and ecology of the Christmas Island Pipistrelle, Pipistrellus murrayi, on Christmas Island. Consultancy for Parks Australia North, Christmas Island.* Arthur Rylah Institute for Environmental Research, Dept Natural Resources & Environment, Heidelberg, Victoria.

Mitchell, B.A. 1985. *A vegetation survey of Christmas Island, Indian Ocean*. Consultancy for the Australian National Parks & Wildlife Service, 1984/1985. 21 pp.

National Biodiversity Team of the Republic of the Marshall Islands. 2000. *The Marshall Islands – Living atolls amidst the living sea. The National Biodiversity Report of the Republic of the Marshall Islands.* Global Environmental Facility/United Nations Development Programme Project. St. Hildgard Publishing Co., Santa Clarita, CA, USA.

O'Dowd, D.J. & Lake, P.S. 1989. Red crabs in rain forest, Christmas Island: removal and relocation of leaf litter. *Journal of Tropical Ecology* 5: 337-348.

O'Dowd, D.J. & Lake, P.S. 1990. Red crabs in rain forest: differential herbivory of seedlings. *Oikos* 58: 289-292.

O'Dowd, D.J. & Lake, P.S. 1991. Red crabs in rain forest, Christmas Island: removal and fate of seeds and fruits. *Journal of Tropical Ecology* 7: 113-122.

O'Dowd, D.J., Green, P.T. & Lake, P.S. 1999. *Status, impact, and recommendations for research and management of exotic invasive ants in Christmas Island National Park*. Darwin, Northern Territory, Environment Australia.

O'Dowd, D.J., Green, P.T. & Lake, P.S. 2001. *Invasional meltdown in island rainforest*. Pp. 447-450 in Ganeshaiah, K.N., Shaanker, R. U. & Bawa, K.S. (eds) Tropical ecosystems. Structure, diversity and human welfare. Oxford & IBH, New Delhi.

O'Dowd, D.J., Green, P.T. & Lake, P.S. 2003. Invasional 'meltdown' on an oceanic island. *Ecology Letters* 6: 812-7

Olsen, P. 2002. *Draft Abbott's Booby recovery plan*. Environment Australia.

Orchard, M, S. Comport and P. Green. 2002. *Control of the Invasive Yellow Yellow Crazy Ant (*Anoplolepis gracilipes*) on Christmas Island, Indian Ocean; progress, problems, and future scenarios.* Unpublished Discussion Paper 1 February 2002.

PANCI. 2002. *Invasive ants on Christmas Island. Action Plan February 2000-February 2003.* Parks Australia North, Christmas Island, Indian Ocean.

PANCI. 2003. *Invasive ants on Christmas Island. Draft Action Plan, February 2003, with appendix*. Parks Australia North, Christmas Island, Indian Ocean.

Rao, N. S. & Veeresh, G. K. 1991. Nesting and foraging habits of Yellow Crazy Ant *Anoplolepis longipes* (Jerdon) (Hymenoptera: Formicidae). *Environmental Ecology* 9(3): 670-677.

Schulz, M. (2004). *National Recovery Plan for the Christmas Island Shrew* (Crocidura attenuata trichura*)*. Department of the Environment and Heritage, Canberra.

Schulz, M. and Lumsden, L.F. 2004. *National Recovery Plan for the Christmas Island Christmas Island Pipistrelle (*Pipistrellus murrayi*).* Commonwealth of Australia, Canberra.

Simberloff, D. & Von Holle, B. 1999. Positive interactions of non-indigenous species: Invasional meltdown? *Invasion Biol.* 1: 21-32.

Soans, A.B. & Soans, J.S. 1971. A case of intergeneric competition and replacement in the ants *Oecophylla smaragdina* (Fab.) and *Anoplolepis longipes* (Jerdon) (Hymenoptera: Formicidae). *Journal of the Bombay Natural History Society* 68: 289-290.

Stanaway, M.A., Zalucki, M.P., Gillespie, P.S. & Rodriquez, C.M. 2001. Pest risk assessment of insects in sea cargo containers. *Aust. J. Entomol*. 40: 180-192.

Stork, N., Kitching, R., Cermak, M., McNeill, K. & Davis, N. 2002. *The impact of aerial baiting for control of Yellow Crazy Ant*, Anoplolepis gracilipes*, on the canopy-dwelling vertebrates and arthropods on Christmas Island.* Interim report to Parks Australia North.

Tidemann, C. 1985. *A study of the status, habitat requirements and management of the two species of bat on Christmas Island (Indian Ocean).* Consultancy for the Australian National Parks & Wildlife Service, Canberra. 80 pp.

Townes, H. 1946. *Results of an entomological inspection tour of Micronesia*. Unpublished report to U.S. Commerical Company, Economic Survey, Honolulu, USA.

Van der Goot, P. 1916. Verdere onderzoekingen omtrent de oeconomische beteekenis der gramang-mier. Mededeelingen van het Proefstation Midden-Java, Salatiga 22: 1-222.

Veeresh, G.K. 1987. *Pest status of Yellow Crazy Ant* Anoplolepis longipes *(Jerdon) in Karnataka, India, and causes for its outbreak*. In Chemistry and biology of social insects. J. Eder & H. Rembold. Munich, Peperny: 667-668.

Way, M.J. 1953. The relationship between certain ant species with particular reference to biological control of the coreid, *Theraptus* sp. *Bull. Entomol. Res*. 44: 669-691.

Wetterer, J.K. 1998. Nonindigenous ants associated with geothermal and human disturbances in Hawai'i Volcanoes National Park. *Pacific Science* 52: 40-50.

Wilson, E.O. & Taylor, R.W. 1967. The ants of Polynesia (Hymenoptera: Formicidae). *Pacific Insects Monogr*. 14: 1-109.

Young, G.R. 1996. The Yellow Crazy Ant, *Anoplolepis longipes* (Jerdon) (Hymenoptera: Formicidae) on coconut palms in New Guinea. Papua New Guinea Journal of Agriculture, Forestry and Fisheries. 39(2): 10-13.

Young, G.R., Bellis, G.A., Brown, G.R. & Smith, E.S.C. 2001. The Yellow Crazy Ant *Anoplolepis gracilipes* (Smith)(Hymenoptera: Formicidae) in east Arnhemland, Australia. *Aust. Entomologist* 28: 97-104.