Little Fire Ant Invasion (*Wasmannia auropunctata*) as a Threat to New Caledonian Lizards: Evidences from a Sclerophyll Forest (Hymenoptera: Formicidae)

by

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ABSTRACT

Here we present results of an assessment of the threat that is represented by the spread of the introduced little fire ant for the lizard fauna in sclerophyll forest. The lizard fauna comprises nine endemic lizard species and one introduced, three of which are very scarce, and one is only known from the study site. As such, this ecosystem is of high conservation value for native lizards. However, a quantitative sampling of lizards, at both ground and canopy levels indicates threats from the invasive little fire ant, *Wasmannia auropunctata* (Roger). During a quantitative field survey 51 specimens belonging to 7 insectivorous species were captured. Between invaded and non-invaded plots, there is a sharp decrease in the overall abundance of this insectivorous guild (38 specimens versus 13). This decrease is especially marked for the two dominant species, *Bavayia cyclura* and *Caledoniscincus austrocaledonicus* (respectively from canopy and ground level). Their abundance is approximately one third of that encountered in forest without invasive ants. The means by which *W. auropunctata* impacts upon this vertebrate fauna remains unclear. Possibilities include: direct predation, monopolisation of resources (food or sheltering) or both. Nevertheless, these results represent the first quantitative assessment of an impact by *W. auropunctata* on higher trophic levels in a New Caledonian context. It also highlights the significant changes induced by *W. auropunctata* in the functional structure of native ecosystems. The spread of this exotic ant represents a major and immediate threat to the rich endemic New Caledonian herpetofauna, and more generally for the whole native fauna.

Key words: Biodiversity, biological invasion, tramp ant, lizards, dry forest, habitat conservation, island, New Caledonia, *Wasmannia auropunctata*.

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INTRODUCTION

New Caledonia could be described as a biodiversity hotspot, a mega-diversity country in the context of its contribution to world biodiversity given its relatively small land surface (Chazeau 1993, Myers *et al.* 2000). Although the higher vertebrate fauna is poorly represented, reptilian fauna is exceptionally diverse and species rich. With 71 terrestrial species of lizards, of which >85 % are endemic (Bauer 1999), New Caledonia is a "hot spot" of reptile diversity in the Pacific region (Adler *et al.* 1995; Bauer 1999). This herpetofauna was once even richer: a terrestrial meiolaniid turtle, a mesosuchid crocodilian, and a varanid have all disappeared since the arrival of man 3500 years ago (Balouet 1991). In this respect New Caledonia is similar to the Galapagos Islands, a unique area where lizards appear to occupy the higher trophic levels in many native ecosystems. There is still, however, a huge gap in our knowledge of this herpetofauna: in the past five years field and lab research has resulted in the discovery of more than 10 new species (an increase in species richness of 20%), including two new species which represent monotypic genera (Sadlier & Bauer 1997; Sadlier *et al.* 1997). This fauna is also characterised by a high level of micro–endemism: a sizeable proportion of species appearS restricted to small areas and are known from one or two locations, especially for recent described taxa (Bauer *et al.* 1998, 2000; Sadlier *et al.* 1998; Sadlier & Bauer 2000). Such endemism conditions reinforce threats of disappearance when facing perturbation.

Among the threats to the New Caledonian ecosystems, is the spread of exotic species through human agency. One of the most spectacular invasions is represented by the rapid spread of the ant *Wasmannia auropunctata* into the archipelago. The species is a representative of the "tramp ant" group (McGlynn 1999; Passera 1994; Hölldobler & Wilson 1990) which exhibits biological characteristics (unicoloniality, polygyny, opportunism for food and nest location) which have facilitated its spread in the tropics through human mediated dispersal. This tiny stinging ant (workers 1.5mm in length) was first identified in New Caledonia from Dumbea in 1972 (Fabres & Brown 1978). Its range now includes the lowlands of the main island, the Loyalty islands, the Isle of Pines, and even small remote uninhabited islands like Walpole (130km east of Isle of Pines). Its distribution encompasses anthropic habitats (where it had an economic impact on fruit and coffee harvesting, and on public health) as well as natural habitats (even on ultramafic soils) (Guilbert *et al.* 1994; Jourdan 1997a, 1999).

Among New Caledonian natural habitats, sclerophyll forest is recognised as the most threatened, now occupying only 3% (100km^2) of its original range (Bouchet *et al.* 1995). But it also appears as the most impacted by the spread of the invader: at ground level, up to 99% of arthropods caught by pitfall traps are *W. auropunctata* workers and the total abundance of other invertebrates caught may be reduced by 60% in comparison with uninvaded plot (Jourdan 1999; Jourdan & Chazeau 1999). Such domination of invertebrate communities threatens the maintenance of ecosystem balance. What does this overdominance imply for higher trophic levels, as represented by reptilians?

Our aim is to give an account of the herpetofauna of the endangered sclerophyll forest as well as to evaluate the potential impact of the invading ant on that fauna.

MATERIAL AND METHODS

Sampling Site

Sclerophyll forests are restricted to small patches on the dry west coast of the main island, below 300m elevation where annual rainfall is less than 1100mm. It may be characterised as a dense formation with a 15m high canopy, an unstratified understorey, with a high contribution of vines (near 20% of the flora). This ecosystem has been decreasing in area since the first human settlement, with an increased decline in the recent decades because of large and repeated uncontrolled bush fires (Bouchet *et al.* 1995). Two experimental areas were selected in one of the largest remaining dry forest fragment, on the Pindaï Peninsula, 250km north of Nouméa, in the Northern Province of New Caledonia (Fig. 1). This location is also the subject of work on the impact of *Wasmannia auropunctata* on natural arthropod communities (Jourdan 1999; Jourdan & Chazeau 1999). One area is heavily invaded by *W. auropunctata*, while the other area is unaffected by the invaders (Fig. 1). The two places are less than 1km apart by road and are part of the same dry forest formation on sedimentary substrate with colluvial ultramafic layer. The endemic trees *Terminalia austrocaledonica* and *Acacia spirorbis* are dominant species in the two plots (a comprehensive study of Pindaï forest is given in Jaffré *et al.* 1993). In each plot, temperature and hygrometry measures were made to compare microclimatic conditions between the two areas. In the two areas, fluctuations were of the same magnitude, and differences between the two plots were low and never exceeded at maximum 0.7°C for temperature and less than 5% for hygrometry (in either one or the other plot). From this data it is assumed that microclimatic conditions are not significantly different and therefore, do not account for the observed differences in lizard species

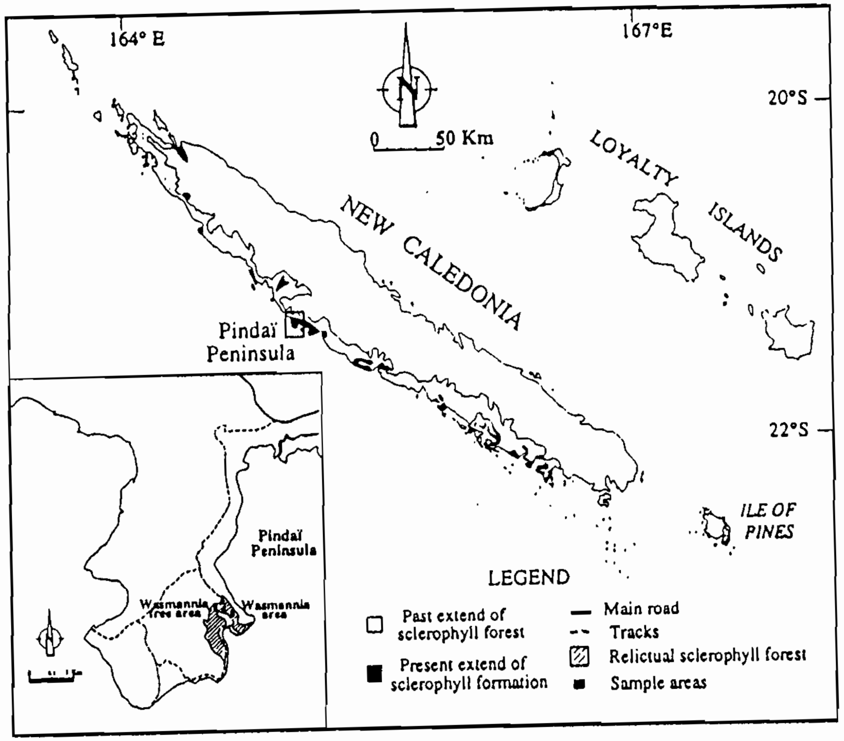


Fig. 1. Location of the two study sites.

richness or abundance between the two areas.

Sampling Methods

The sampling program took place in the summer wet season between February and April 1995, a period where reptile activity is high. Two quantitative sampling methods were used: sticky traps on trees to sample arboreal lizards, and pitfall traps to sample ground dwelling lizards. Timed visual search periods were also conducted along transects to complement the trapping program.

For arboreal lizards, sticky traps (as described by Bauer & Sadlier 1992) comprising 10 x 20cm Victor mouse glue traps (Woodstream, Inc.) were used. In each area 75 trees, with diameters of 10–30cm, were randomly selected along two transect lines. Sticky traps were attached to the bark, about 1.5m above ground level. The sampling period covered 6 consecutive days between 02/21/95 and 02/26/95. Traps were examined every morning and reptiles stuck to the traps were removed with crude vegetable oil.

For ground dwelling lizards, pit trap were used. In each area, 4 parallel transect lines were defined, 30m in length, along which 6 plastic boxes (20cm long, 10cm wide, 15cm deep) were evenly placed. The boxes were sunk into the soil so the opening was flush with the soil surface. A fence line of PCV lawn edging (18cm high) ran the length of each transect. Boxes were examined twice a week (from 03/03 to 04/18). No sampling was carried out 13-22 March due to heavy rainfalls and flooding of the boxes. To complement the trapping program, a visual assessment of active diurnal ground lizards was also carried out in each area, 4 transect lines (50m) being walked for a 20 minute period. Transects were walked alternatively in each plot. Visual searches took place between 7.00 am and 3.00 pm over 3 consecutive days (04/11, 04/14, and 04/18), each transect line have been walked five times during this period. Quantitative visual assessment of nocturnal (primarily arboreal) lizard species was not attempted along the transect lines due to the dense structure of the forest understorey.

Trapped reptiles were taken as vouchers and preserved in formalin to allow ongoing taxonomic identification. Collected specimens have been deposited in the collections of the Australian Museum (AMS) and the California Academy of Sciences (CAS) and registered as follows: *Bavayia cyclura*: AMS R147786-91, AMS R147792-93, AMS R147795, AMS R147798-803, CAS 201054-9; *Bavayia exsuccida* AMS R147794, R147796; *Eurydactylodes vieillardi*: AMS R147797, AMS R147816, CAS 201060-1; *Caledoniscincus austrocaledonicus*: AMS R147805-9, AMS R147813-15, AMS R147817-25, CAS 201062-4; *Caledoniscincus festivus*: AMS R147812; *Caledoniscincus haplorhinus* AMS R147810; *Nannoscincus sp.*: AMS R147811.

We consider each day of capture as a replicate for each sampling procedure. Non parametric tests (Mann-Whitney U tests) were used to compare the serial data from the two places. We test the hypothesis that the two samples are not drawn from the same population. We express Z and p after corrections for ties.

RESULTS

Seven species of reptiles were recorded during the course of the quantitative survey. This included three species of geckos (*Bavayia cyclura, Bavayia exsuccida, Eurydactylodes vieillardi*) and four species of skinks (*Caledoniscincus austrocaledonicus, Caledoniscincus festivus, Caledoniscincus haplorhinus*, and *Nannoscincus sp.*). Two other native species (the large gecko *Rhacodactylus trachyrhynchus* and the arboreal skink *Lioscincus nigrofasciolatum*) were also encountered during the course of opportunistic day and night searching, but only from the

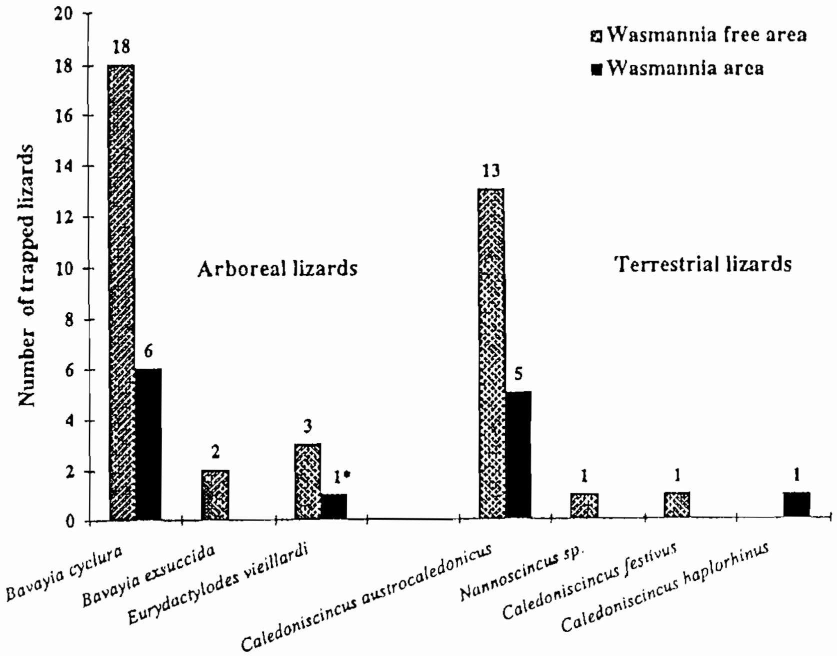
Table 1. Main characteristics of sclerophyll herpetofauna

	Distribution	Microhabitat	Activity Period	Reproduction	Food	Conservation Status**
Gekkonidae Diplodactylinae						
Bavayia cyclura Günther, 1872	Endemic	Arboreal	Nocturnal	Oviparous	Insects	Common
Bavayia exsuccida Bauer *et al.*, 1998	Endemic	Arboreal	Nocturnal	Oviparous	Insects	Rare (restricted to sclerophyll forest, known from 2 localities)
Eurydactylodes vieillardi Bavay, 1869	Endemic	Arboreal/Terrestrial	Diurnal/Nocturnal	Oviparous	Insects	Rare
*Rhacodactylus trachyrhynchus** Bocage, 1873	Endemic	Arboreal	Nocturnal	Viviparous	Insects	Rare
Gekkonidae Gekkoninae						
*Hemidactylus frenatus** Duméril et Bibron, 1836	Introduced	Arboreal	Diurnal/Nocturnal	Oviparous	Insects	Very common, mostly in anthropic areas
Scincidae Lygosominae *Eugongylus* group						
Caledoniscincus austrocaledonicus Bavay, 1869	Endemic	Terrestrial	Diurnal	Oviparous	Insects	Very Common
Caledoniscincus festivus Roux, 1913	Endemic	Terrestrial	Diurnal	Oviparous	Insects	Common
Caledoniscincus haplorhinus Sadlier *et al.*, 1999	Endemic	Terrestrial	Diurnal	Oviparous	Insects	Common in edge habitat in coastal region
Nannoscincus n. sp.	Endemic	Terrestrial, burrowing species**	Diurnal	Oviparous**	Insects**	Rare (only known from Pindai)
*Lioscincus nigrofasciolatum** Peters, 1869	Endemic	Arboreal	Diurnal	Oviparous	Insects	Common

*: species caught in preliminary visit to the sites or after the trapping program (see text for more details); **: inferred from previously described *Nannoscincus* species

area without invasive ants. The introduced gecko, *Hemidactylus frenatus*, was also recorded opportunistically from the edges of the invaded area. So the herpetofauna occurring in sclerophyll forest consists at least of ten species. All the monitored species (except *H. frenatus*) are endemic to New Caledonia and at least four (*Bavayia exsuccida*, *Eurydactylodes vieillardi*, *Nannoscincus sp.* and *Rhacodactylus trachyrhynchus*) are uncommon or poorly known taxa (Table 1).

The specimens collected during the quantitative survey represented 51 individuals in total. Six species (all except *C. haplorhinus*) were collected from the area without little fire ants (Fig 2), and four species (the geckos *B. cyclura* and *E. vieillardi*, and the skinks *C. austrocaledonicus* and *C. haplorhinus*) were recorded from the area invaded by *W. auropunctata* (Fig. 2). Despite our intensive collecting effort, as well as opportunistic searches, sclerophyll forest do not seem to support large reptilian populations. *Bavayia cyclura* and *Caledoniscincus austrocaledonicus* are the dominant species in the canopy



*: Individual trapped at ground level (pit trap) in the invaded plot

Fig. 2. Summary of the results of trapping program.

and ground level, respectively. The scarcity of all but the two most common lizard taxa makes it difficult to draw conclusions on a case by case basis when comparing the areas with and without ants.

All the monitored lizards appear to have an insectivorous diet (Table 1). A sharp decrease appears in the overall abundance of this insectivorous guild (38 specimens against 13), between uninvaded and invaded plots. There are significantly fewer lizards in the area invaded by ants (Mann-Whitney Z=2.834, p=0.005).

At the arboreal level, sampling resulted in the capture of 23 geckos (of three species) in the area without ants compared to 6 (of one species) in the invaded area (Fig. 3). There are significantly fewer lizards in the invaded area (Mann-Whitney Z=2.175, p=0.03). The abundance of *Bavayia cyclura*, the arboreal dominant species, in the ant affected area, is approximately one third of that encountered in forest without invasive ants. This quantitative difference is significant (Z=2.179, p=0.03), indicating a negative association between the abundance of this species and the presence of *Wasmannia auropunctata*. It is interesting to note all specimens recorded from the invaded plot were caught on the first day of sampling, whereas in the uninvaded plot, captures occurred during in the following five days. This reinforces the hypothesis of a negative impact of the invasive ant, lowering lizard

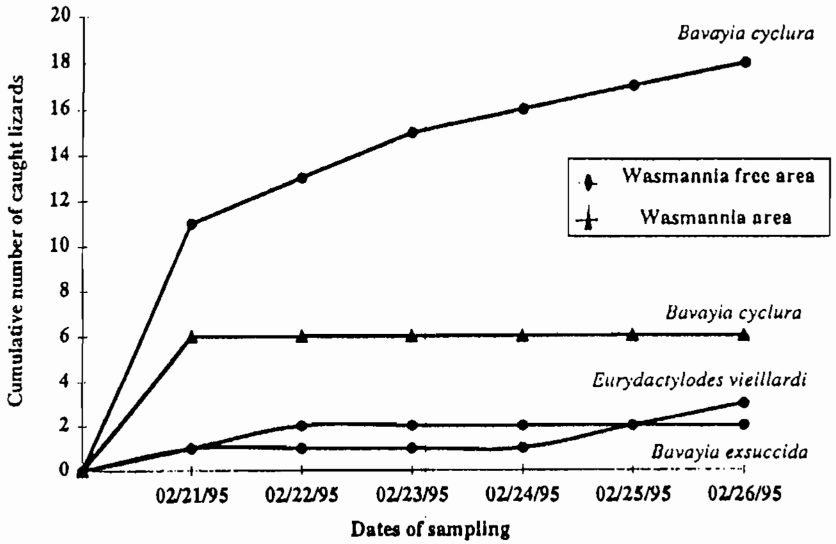


Fig. 3. Results of the aboreal trapping program.

populations in the invaded plot to a level that does not yield a measurable influx of animals into the trap array within the sampling period (Fig. 3).

Ground sampling resulted in the collection of 15 specimens (of three species) in the area without ants, and 7 (of three species) from the invaded area (Fig. 2). The skinks *C. festivus* and *Nannoscincus sp.* were only collected from the pitfalls once in the area without ants during the entire sampling period, and the gecko *E. vieillardi* and skink *C. haplorhinus* were collected only once in the invaded area during sampling period. Nevertheless, further specimens of *C. haplorhinus* have been seen opportunistically at the edge of the two site edges. Most of captures from pitfall trapping were specimens of the ground dwelling *Caledoniscincus austrocaledonicus* (Figs. 2,4). This ground dominance was also evidenced by time visual searches in which eighteen *C. austrocaledonicus* specimens were recorded in the area without ants and eight in the invaded area (Fig. 5). The difference between the two areas for this dominant ground dwelling species is also significant (Mann-Whitney Z=1.923, p=0.03), when data from pit traps are combined with those of visual searches.

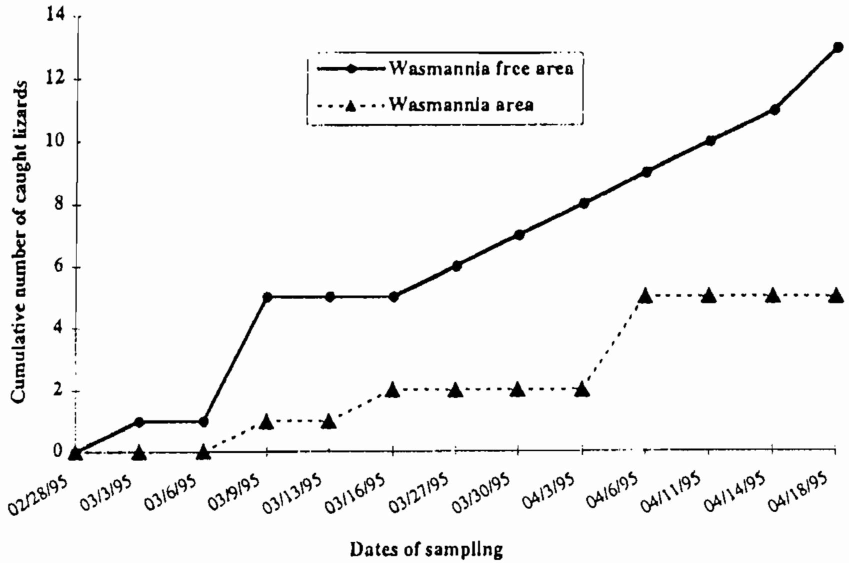


Fig. 4. Results of pitfall trapping for *C. austracaledonicus*.

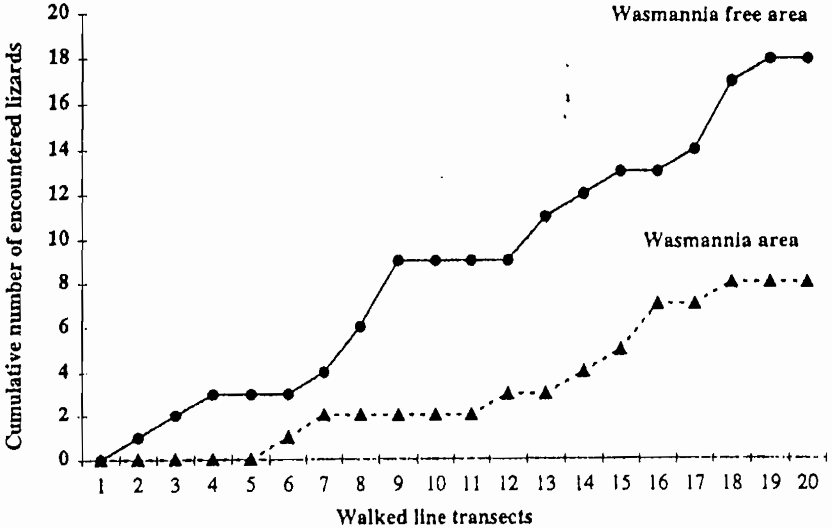


Fig. 5. Results of the visual assessment of ground dwelling lizards (*C. austrocaledonicus* individuals only).

DISCUSSION

Significance of the Reptile Fauna of the Sclerophyll Forest

This is the first inventory attempt of the herpetofauna inhabiting sclerophyll forest, a habitat which has long been ignored. The results of this field research indicate a richer and far more interesting array of herpetofauna than would otherwise have been expected (Table 1). Of the ten species of reptiles recorded during the survey, three (*Rhacodactylus trachyrhynchus*, *Bavayia exsuccida*, and the skink *Nannoscincus* sp.) seems to have restricted distributions and are considered of particular conservation concern. The occurrence of the gecko *Rhacodactylus trachyrhynchus* was totally unexpected, this species was only known from scattered closed forest habitats. *Bavayia exsuccida* was only recently described (Bauer *et al.* 1998) from specimens collected during this survey. It has since also been found at two other sites (in a maquis shrubland and a sclerophyll patch) which suggests a scattered and restricted distribution to dry habitats. The discovery of *Nannoscincus sp.* is a result of this study and it is still known only from Pindaï area. It does not seem to be assignable to any of the species of *Nannoscincus* currently described even if several allopatric species are in the process of being described (Sadlier unpublished). On the basis of current knowledge and given the pattern of micro–endemism that seems to

characterise species of burrowing *Nannoscincus*, the species from Pindaï should be regarded as of particular conservation significance.

Five others species (*Caledoniscincus austrocaledonicus*, *C. festivus*, *Lioscincus nigrofasciolatum*, *Bavayia cyclura* and *Eurydactylodes vieillardi*) have island wide distributions and are relatively common where they occur. Nevertheless, the Pindaï sclerophyll forest appears as a significant site for *Eurydactylodes vieillardi*. This gecko is known from a number of scattered locations throughout the island and our limited experience so far indicates the Pindaï population is one of the largest ever surveyed. From other opportunistic observations, *B. cyclura* appears to be particularly abundant in sclerophyll forests. However, it almost certainly consists of several cryptic species, the distribution of which has yet to be determined (Wright *et al.* 2000). In this respect and given the high level of disturbance of lowland dry forest, sclerophyll forest could be of importance for the conservation of *B. cyclura* complex. The three others skinks (*Caledoniscincus austrocaledonicus*, *C. festivus*, *Lioscincus nigrofasciolatum*) are not regarded as being of particular conservation concern, because of their widely ranging habitats. Lastly, *C. haplorhinus* and *H. frenatus* should be considered of low value to characterize the sclerophyll forest habitat. *C. haplorhinus* has only recently been recognised as distinct from *C. austrocaledonicus* (Sadlier *et al.* 1999) and unlike other *Caledoniscincus* spp., it is common in edge and opened habitats particularly in coastal locations, and is rarely encountered within the forest, as witnessed by our sampling effort. *Hemidactylus frenatus* has a widespread distribution outside New Caledonia and tends to only occur at the forest edges. Thus our results emphasise the high conservation value of the sclerophyll forest. Further studies and sampling are urgently required to more completely assess its diversity.

Wasmannia auropunctata threats

There is a clear difference in the overall abundance of the insectivorous guild of lizards between the study sites. One might assume that the differences in capture rates, especially for arboreal lizards, may be due to differences in lizard behaviour in ant–affected and ant–free areas (rather than differences in real abundance), but no evidence for variation in habitat conditions (vegetation or abiotic) suggest such behavioural differences. Further, eight species have been recorded from the uninvaded plot versus five in the invaded plot. The dominant taxa, *B. cyclura* and *C. austrocaledonicus*, are present in both plots, however, nearly all the uncommon taxa (*B. exsuccida*, *Nannoscincus sp.*, *R. trachyrhynchus*) were located only in the area without *Wasmannia* of osteoderms, may be particularly affected by the sting of ants and excluded from vital resources including sheltering and nesting sites.

In sclerophyll habitat, the consequences of invasion are probably not limited to reptiles and arthropods. Incidental observations indicate the ants might also impact nesting birds. In Pindaï area, we were able to observe an abandoned nest of the grey-eared honeyeater (*Lichmera lichemera incana*) with a little fire ant colony inside, as well as small feathers in a little fire ant nest. Local people (kanaks) have also reported unexplained local declines of ground nesting bird populations (especially *Rallus* spp.) in coastal lowlands since the establishment of little fire ants. Clark *et al.* (1982) found also feathers in a little fire ant nest in the Galapagos. These observations, although not supported by quantitative data, are, however, consistent with a similar decrease in ground nesting bird populations reported by Allen *et al.* (1994), Lockley (1995) and Mount (1981) in Alabama and Georgia coastal plains concomitant with the spread of *Solenopsis invicta*.

CONCLUSION

The data presented here are preliminary in nature, given the limited area surveyed, however, they suggest a significant negative interaction between lizards and the little fire ant in the sclerophyll habitat. The way in which *Wasmannia auropunctata* affects lizard populations in New Caledonia is as yet unclear, i.e., directly through ant-lizard interactions or indirectly by affecting some aspects of their biology, or a combination of both. What is now required are detailed studies of other sclerophyll patches under variable invasive pressure regimes to monitor the progressive impact of this exotic ant. Of particular interest would be dietary analysis (stomach contents or pellets analysis) of different lizards to assess whether there is a difference in dietary composition between areas with and without *W. auropunctata*, as well as to evaluate their abilities to eat exotic ants. In this respect, a search for cryptic reptilian species should be conducted, in particular typhlopid snakes. Indeed Torres *et al.* (2000) have shown the prevalence of *W. auropunctata* in diet of a West Indian typhlopid snake. But, the fragmented and relictual nature of the sclerophyll habitat, along with the invasion of the ant, make the forest and its fauna one of the most threatened in New Caledonia. It is thus difficult to find a place able to intensify collecting effort without further threatening survival of local lizard populations, already facing the pressure of the invader. Given these facts, as well as the low level of reptilian population supported, experimental studies should be promoted to investigate interactions between exotic ants and lizard.

Regardless, various authors (MacDonald & Cooper 1995; Simberloff 1995; Vitousek 1988; Williamson 1996) have reviewed the invasion process on islands and have stated that exotic species are more likely to survive and produce a major ecological impact on islands than on continental land masses. Comments by Mount (1981) on *S. invicta* in USA indicate that up to 20 years are generally required before an obvious impact on wildlife is registered. The process seems more rapid in New Caledonia where the invasion is quiet recent and an impact upon the native fauna is already noticeable. Based on the range of natural habitats invaded and the high invasion rate, (unlike in its natural range where it is not a dominant species (Levings & Franks 1982)), its spread is a serious concern for the conservation of New Caledonian biodiversity, which is already threatened by a range of human activities (Myers *et al.* 2000). The most urgently needed action is the prevention of the spread of *W. auropunctata* to uninvaded sclerophyll patches, and more generally, to other uninvaded natural habitats. These preliminary results should alert the relevant authorities to the threat posed by the spread of this exotic ant to the rich and unique New Caledonian lizard fauna, which are considered as patrimonial ones.

The data presented here also raises the question of maintenance of natural communities (herpetofaunal and otherwise) in New Caledonia in a long term perspective. What is the situation in other habitats on the island? Are larger and more continuous stands of forests more resistant to invasion by *Wasmannia auropunctata* than sclerophyll forest islands isolated in an ocean of shrub savanna (which is a suitable habitat for the progression of *W. auropunctata*)? Further investigations into the community structure of natural communities (both ground and canopy level) in different natural conditions are required in order to evaluate the impact of *W. auropunctata*, and evaluate the dynamics of this impact. From a perspective of community trophic organisation (trophic cascades which are now widely recognised in terrestrial ecosystem (Schmitz *et al.* 2000)), the lowering of lizard predation control should rapidly result in consequences at the ecosystem scale. The lowering of *top down* forces on lower trophic levels (especially herbivorous arthropods) would reinforce the bottom up forces depending only on avlability of vegetation resources (even if the occurrence of *W. auropunctata* establishes new top down forces). Study of these trophic cascades from the perspective of the spread of *W. auropunctata* should help to elucidate the functional dynamics of the sclerophyll forest ecosystem and anticipate ecosystem evolution through invasive perturbation.

auropunctata. *C. haplorhinus* and *H. frenatus* are present in the plot with little fire ant, but this of minor significance because of the preference of these species for forest edges. These empirical qualitative observations reinforce the hypothesis that presence of little fire ant has an overall negative impact on lizard species populations and richness.

The population decrease is especially marked for the two dominant species, *Bavayia cyclura* and *Caledoniscincus austrocaledonicus*, (respectively from canopy and ground level). Their abundance is approximately one third of that encountered in forest without invasive ants. This decline observed in Pindaï is consistent with previous inferences of a decline of gecko populations through the spread of the little fire ant on the northeast coast of New Caledonia (Bauer & de Vaney 1987; Bauer & Sadlier 1993).

Few previous studies have referred to ant–reptile interactions in the context of a biological invasion, except for the spreading of the red fire ant, *Solenopsis invicta* (Buren) in the USA and some observations for two crazy ants, *Paratrechina fulva* (Mayr) in Colombia (Zenner–Polonia 1990) and *Anoplolepis gracilipes* (Jerdon) in the Seychelles (Haines *et al.* 1994), as well as for argentine ants, *Linepithema humile* (Mayr), in California (Suarez *et al.* 2000).

Despite the confusing similarity of common names little fire ant and red fire ant, the genera *Wasmannia* and *Solenopsis*, respectively, have no close affinities and belong to two distant tribes in the subfamily Myrmicinae (Blepharidattini and Solenopsidini). Nevertheless, similarities in their biology (especially their extensive and unique ability to use their venom as an offense and defense weapon (Schmidt 1986)) allow us to make some inferences based on what has occurred elsewhere when the red fire ant has invaded areas.

Direct impacts of fire ants upon the herpetofauna have been noticed by various authors, in their native range (Chalcraft & Andrews 1999) as well in introduced ranges (Allen *et al.* 1994; Mount 1981; Mount *et al.* 1981; Vinson 1994). The impact of the spread of *S. invicta* on local lizard, snake or tortoise populations in the southern USA (Texas, Alabama and Georgia) included predation on eggs and newly hatched young. In the case of *W. auropunctata*, specific cases of interaction with lizards are limited to reports of attacks on young land tortoises and iguanas in the Galapagos (Williams and Wilson 1988 – in Patterson 1994). Given these different reports of attacks on eggs or hatchling reptiles, we can assume that such attacks may occur in New Caledonia, although none were observed during our study. Most of the reptiles encountered may be susceptible to such predation as most of them are oviparous (Table 1), and geckos in particular may be more sensitive, as their eggs are likely to be deposited in limb hollows or superficially beneath leaf litter on the forest floor, where *W. auropunctata* are present in high numbers.

In the United States, the spread of *Solenopsis invicta* has been responsible for the decline of native arthropod communities (Camilo & Philips 1990; Porter & Savignano 1990), and Vinson (1994) proposed that this reduction may affect vertebrates by reducing food abundance and thus reducing carrying capacity of the invaded areas. Such decline of native arthropod communities is also established for *Linepithema humile* in California (Human et Gordon 1997; Holway 1998, 1999), and similar indirect processes have been proposed in the southern Californian desert, to explain abundance decrease in populations of the threatened horned lizards (*Phrynosoma sp.*) (Suarez *et al.* 2000). An indirect such effect by the exclusion or extirpation of a part of insect communities that make up the lizards diet, may be assumed for *W. auropunctata*. Studies in the Galapagos Archipelago (Silberglied 1972; Clark *et al.* 1982; Lubin 1984) have shown an alteration to the structure of arthropod communities following the invasion of *W. auropunctata*. In New Caledonia, we also have evidence that the little fire ant is altering native arthropod communities: in an invaded sclerophyll patch, we observed a lowering of overall arthropod abundance at the ground level by 60%, and 20% at the canopy level, ant richness drop from 24 species to 5, as well as the alteration of trophic guild balance (Jourdan 1997b, 1999; Jourdan & Chazeau 1999). On the basis of current knowledge, all the lizards encountered have an insectivorous diet with a high contribution of native ants (Bauer & Devaney 1987). So there is a potential for exploitative competition for prey between *W. auropunctata* and lizards, because of the lowering of the arthropod availability and the resultant lowering of the carrying capacity of sclerophyll habitat.

As proposed by Vinson (1994) for fire ants, the stinging habit of *Wasmannia auropunctata* could be another factor involved in the decline of lizards. These species make an extensive use of their powerful venom in offense and defense behaviors (Schmidt 1986), so it is likely that heavily stung lizards would be subject to abnormal stress (lowering their fitness) and have a greater chance to be excluded from vital resources such as resting, sheltering and nesting sites. The stinging habit may result in the occurrence of an interference competition leading to a monopolisation by exotic ants of sheltering and nesting sites. This type of interaction may be of greater consequence when the heavy rate of invasion by exotic ants in sclerophyll forest is taken into account: from 20 quadrat counts (1m^2 each), up to seven *Wasmannia* nests per m^2 have been registered in Pindaï with a mean number of 3.65 ± 1.35 nests/m^2 (Jourdan 1999). Geckos, which have soft skin devoid

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