# The distribution and population status of *Nesiergus insulanus* (Araneae: Theraphosidae: Ischnocolinae) on Frégate Island, Seychelles

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## Summary

The theraphosid *Nesiergus insulanus* is a member of a genus endemic to the Seychelles archipelago. Very little is known about the finer-scale distribution, density, and total population size of the species, knowledge of which is essential for conservation purposes. We used transect sampling to estimate these variables on Frégate Island. We show that the species is widely distributed, but geographically restricted as a result of fragmentation due to human activity. Where found, densities can be very high (>100 m⁻²). The total population on the island was estimated to be well over 100,000, although limitations to dispersal ability may be of conservation concern.

## Introduction

The Theraphosidae have a pantropical distribution with 120 genera and over 900 species described (Platnick 2012), with *Nesiergus insulanus* Simon, 1903 belonging to the subfamily Ischnocolinae. It is one of three members of the genus, all of which appear to be endemic to the Seychelles archipelago. They are considered by some authors to be one of the more primitive spider groups (Dippenaar-Schoeman 2002) and, although most tend to be large, sedentary animals that seldom leave the burrows they inhabit (Coddington 2005), there are species that are arboreal (Stradling 1994; Gallon 2003; West *et al*. 2008) and those that regularly leave their burrows to hunt (Brunet 1996). Members of the genus *Nesiergus* are relatively small, with *N. insulanus* reaching a maximum body length of approximately 27 mm. Their status and biology are little known, with *N. insulanus* previously recognized from a single female specimen collected from an island where the species had not been recorded before. The presence of *N. insulanus* on Frégate Island (4°35′01.46″S 55°56′19.11″E) as well as L'Îlot Frégate (4°36′06.37″S 55°54′27.11″E) has been confirmed, and anecdotal and photographic evidence suggests that it may occur on at least one other island in the group (Gane pers. comm.). Frégate Island has been severely degraded, with most native vegetation replaced with alien species, and only remnant stands of fragmented native vegetation remaining. In this paper we establish the distribution and density as well as give an estimate of the population size of *N. insulanus* on Frégate Island, Seychelles.

## Methods

The distribution and habitat preference of the species was determined by initially conducting a pilot study. The island was divided into habitat types based on the vegetation map of Henriette & Rocamora (2009) (Fig. 1) and thoroughly and repeatedly searched for the presence of burrows.
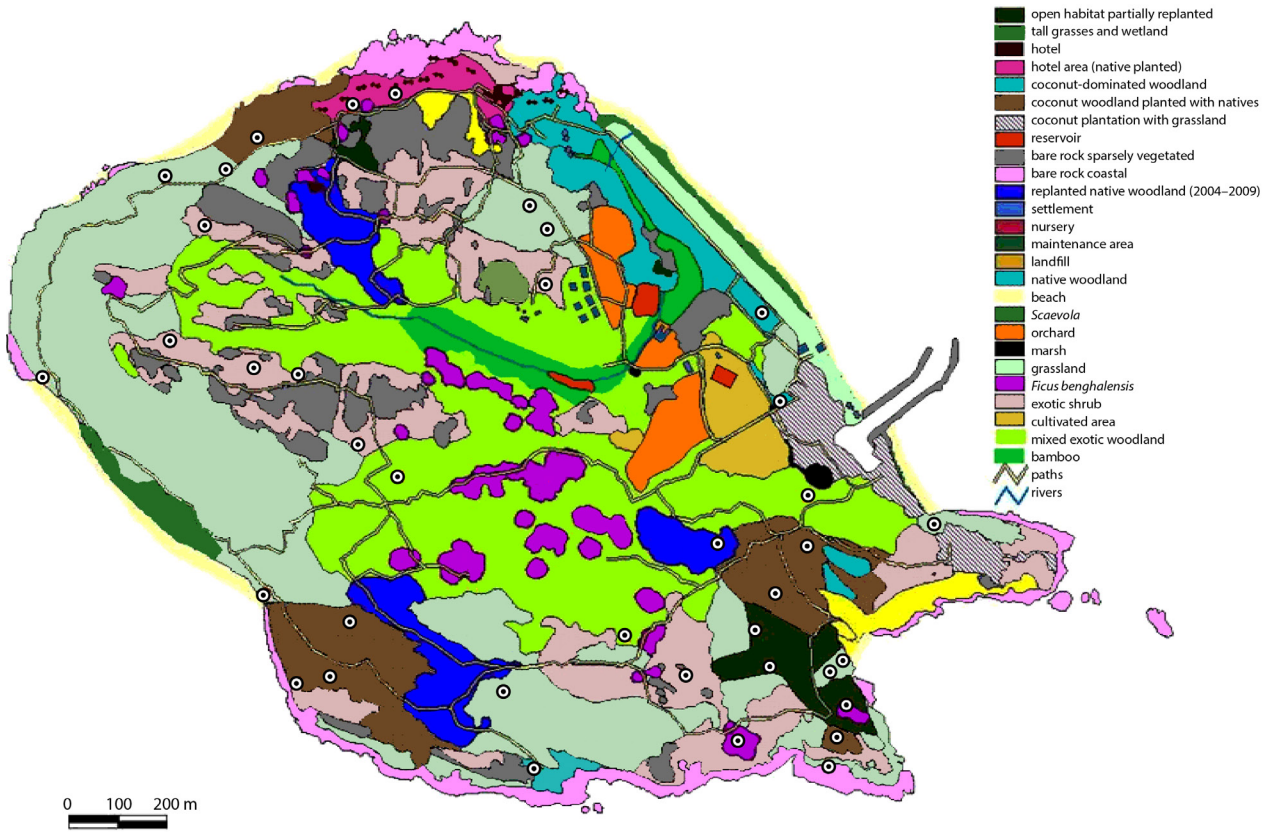
open habitat partially replanted
tall grasses and wetland
hotel
hotel area (native planted)
coconut-dominated woodland
coconut woodland planted with natives
coconut plantation with grassland
reservoir
bare rock sparsely vegetated
bare rock coastal
replanted native woodland (2004–2009)
settlement
nursery
maintenance area
landfill
native woodland
beach
*Scaevola*
orchard
marsh
grassland
*Ficus benghalensis*
exotic shrub
cultivated area
mixed exotic woodland
bamboo
paths
rivers

0    100    200 m

Fig. 1: Map of habitat types on Frégate Island, Seychelles, based on the vegetation map of Henriette & Rocamora (2009); sampling sites marked with ⊙.



Figs. 2–5: Habitat types on Frégate Island, Seychelles. **2** *Ficus benghalensis*; **3** native woodland; **4** replanted native woodland; **5** hotel area native planted.

Vegetation types are clearly distinguishable as a result of large-scale anthropogenically induced vegetation changes and ground truthing determined the precise location of these habitats. Leaf litter was searched through, rocks and logs were overturned and replaced, and all other litter was searched to find burrows. This allowed for a determination of habitats in which spiders occurred. Burrows were found in nine different habitat types: coconut-dominated woodland (CDW), *Ficus benghalensis* (FB) (Fig. 2), mixed exotic woodland (MEW), native woodland (NW) (Fig. 3), replanted native woodland (RNW) (Fig. 4), hotel area native planted (HANP) (Fig. 5), exotic scrub (ES), (natural) grassland (GL), and coconut woodland planted with natives (CWPWN).

Subsequent to the pilot study, the island was stratified into quadrats, each measuring $100 \times 100$ m and numbered. A random integer generator (www.random.org) was used to obtain random sample sites in each vegetation type in which spiders were present, ensuring that approximately 25% of the island was represented. Those habitats that were determined not to support the species in the pilot study were excluded from this process. 48 sites were generated by this method and all were sampled. Burrows of *N. insulanus* were found in 38 of these 48 generated sites. The number of sites per habitat type determined by random selection was as follows: CDW 8, FB 3, MEW 7, NW 6, RNW 6, HANP 4, ES 8, GL 3, CWPWN 3. Each site was sampled on three separate occasions during the day between 07h00 and 15h30 from May 2010 to July 2011. One-way ANOVA based on the number of spiders found in each quadrat of each habitat type determined choice of habitat type. Scheffe's post-hoc analyses determined the differences in habitat choice.

To determine whether a mark-resight strategy was an appropriate method to use to estimate the population density and size, a single control site of 1 m$^2$ was established. This control site was used to determine whether population density changes in the field were significant for the duration of the study and whether initially marked burrows were still visible on subsequent sampling occasions. The control site was in an area of native woodland and was specifically chosen for the high burrow density as well as ease of access. This control site was examined weekly from January to September 2010. All burrows at the control site were initially marked by using a $150 \times 1$ mm steel rod with a white marker at the end. The number of burrows observed weekly was recorded and a one-sample t-test was used to determine whether the significance of temporal changes in mean density of this single statistical population took a particular value.

Considering the sedentary nature of *N. insulanus*, transect sampling was determined to be the most appropriate method to give an accurate estimate of the population size. In the field, a standard line transect of $100 \times 2$ m was placed in each quadrat at right angles to the contour. Each burrow encountered was enumerated (Table 1) and marked with a $150 \times 1$ mm steel rod with a white marker at the end for ease of re-encounter. The distance of each burrow from the start of the transect was measured, as well as the perpendicular distance from the centre of the line transect. Burrow densities were determined by using the computer program DISTANCE 6.0 release 2 (www.ruwpa.st-and.ac.uk/

distance). Variables included the encounter rate, detection probability, expected aggregation size, and density, with the parameter estimation specification for DISTANCE data using a conventional distance-sampling analysis, based on all data being combined. Analysis of distances is based on exact distances. Aggregation analysis is based on exact sizes with the expected value of aggregation computed by regression of $\log(s(i))$ on $g(x(i))$. Estimator models are half-normal cosine with distances scaled by right truncation. Estimator selection is minimum AIC constrained to be nearly monotonous and non-increasing. Goodness-of-fit cut points were chosen by the program DISTANCE.

An estimate of the population size was determined using the mixed logit-normal mark-resight model in the computer program MARK2 (warnercnr.colostate.edu/~gwhite/mark/mark.htm), with the variables for the data being the survival probability and the resighting probability and the parameters that these variables are constant over time [$\varphi(.)p(.)$]. Individual spiders were not marked; their burrows were considered a surrogate for the individual spider. The spiders were not marked due to the fact that they are fossorial and difficult to extract from their burrows without damaging or destroying the burrows. Spiders disturbed by removal from or damage to burrows, would potentially be displaced, thus compromising the analysis.

Ecdysis also leads to loss of marking and would further compromise the analysis. On the first sampling occasion all burrows were marked and enumerated. During subsequent sampling occasions all open burrows were recorded, including marked and unmarked burrows, and these data were entered into MARK. Those burrows that had initially been marked but that were found to be closed or collapsed on subsequent sampling occasions were not entered into MARK. Spider numbers from all three sampling occasions were combined. Seasonal variation was not taken into consideration in the analysis; however it would appear that there is limited seasonal variation in spider numbers. Wandering, mature males were not included in the analysis as they are active only for short periods during breeding and none were encountered during sampling.

L'Îlot Frégate is a windswept, rugged islet of 2.3 ha lying three kilometres southwest of Frégate Island, consisting of jagged rocks and granite boulders, with little vegetation; other than struggling, stunted groundcover and occupied by a significant seabird colony. This islet was visited to determine whether the species was present here as well. No sampling was conducted on this islet and all observations on this islet as described in the results section are merely anecdotal.

## Results

*N. insulanus* is widely distributed over the island, from 6 to 109 m a.s.l. and at slopes that vary between 0° and 37.7°. Analysis of variance, based on the density of burrows in each habitat type determined that the choice of habitat was statistically significant (F = 2.89, df = 47; p < 0.05) and that there were significant differences among the means. A Scheffé's post-hoc analysis determined significant differences between means of the following habitats with Scheffé's

critical value (S) = 0.11: FB and CWPWN (0.17); NW and CWPWN (0.17); FB and GL (0.17); NW and GL (0.16); FB and MEW (0.15); NW and MEW (0.15); ES and FB (0.14); ES and NW (0.14); NW and CDW (0.12). Habitat types found not to support a population of spiders were those that had been significantly changed by humans and those that did not provide burrowing opportunities or readily available prey. These habitat types included bamboo, coconut plantations with grassland, cultivated areas, orchards, *Scaevola* sp. and areas of bare rock.

Although no quantitative sampling was conducted on L'Îlot Frégate, the population would appear to occur in relatively high densities with the burrows being found in greatly exposed areas where grass growth is stunted. Burrow aggregations appear more dispersed and the individual burrows are not within such close proximity to one another as on Frégate Island. This is possibly due to competition between individuals due to lower densities of prey being available and further, more intense sampling of the population on this island is needed.

The number of burrows at the control site varied weekly between 96 and 115 with a mean of 106 (s = 12.1). It was determined that initially marked burrows were not necessarily visible on subsequent sampling occasions and this implied that assumptions of the model used to determine a population estimate in the field were valid. The changes in temporal density of burrows at the single control site was determined by a one sample t-test to be statistically non significant (t = 0.73, df = 17; p > 0.05). The statistical non-significance of changes in burrow density was considered in determining the population estimate for the island, with the underlying assumption from this result being that changes in density over the time of the study did not bias the estimate and accurately reflected the population. Data from the control site showed the following:

Burrows are occupied by a single spider, except when spiderlings are present shortly before emergence as independent individuals.

Burrows collapse easily and shortly after spiders vacate the burrow, meaning that abandoned burrows were not likely

| Habitat | 1st count | 2nd count | 3rd count | Total | Mean |
|---|---|---|---|---|---|
| Exotic Scrub | 33 | 13 | 13 | 59 | 19.6 |
| | 8 | 12 | 8 | 28 | 9.3 |
| | 17 | 8 | 0 | 25 | 8.3 |
| | 14 | 11 | 31 | 56 | 18.6 |
| | 3 | 3 | 0 | 6 | 2 |
| | 8 | 3 | 0 | 11 | 3.6 |
| | 7 | 4 | 7 | 18 | 6 |
| | 0 | 0 | 0 | 0 | 0 |
| | | | | 203 | 8.4 |
| Native Woodland | 92 | 46 | 25 | 163 | 54.3 |
| | 16 | 13 | 32 | 61 | 20.3 |
| | 30 | 39 | 77 | 146 | 48.6 |
| | 90 | 56 | 134 | 280 | 93 |
| | 0 | 0 | 0 | 0 | 0 |
| | 0 | 0 | 0 | 0 | 0 |
| | | | | 650 | 36 |
| Coconut-Dominated Woodland | 7 | 1 | 0 | 8 | 2.6 |
| | 27 | 19 | 28 | 74 | 24.6 |
| | 5 | 2 | 1 | 8 | 2.6 |
| | 18 | 8 | 15 | 41 | 13.6 |
| | 19 | 13 | 12 | 44 | 14.6 |
| | 35 | 17 | 13 | 65 | 21.6 |
| | 13 | 8 | 8 | 29 | 9.6 |
| | 2 | 3 | 1 | 6 | 2 |
| | | | | 275 | 11.4 |
| *Ficus benghalensis* | 93 | 33 | 29 | 155 | 51.6 |
| | 32 | 33 | 32 | 97 | 32.3 |
| | 24 | 27 | 26 | 77 | 25.6 |
| | | | | 329 | 36.5 |

Table 1 continued

| Habitat | 1st count | 2nd count | 3rd count | Total | Mean |
|---|---|---|---|---|---|
| Mixed Exotic Woodland | 4 | 3 | 2 | 9 | 3 |
| | 12 | 2 | 3 | 17 | 5.6 |
| | 2 | 3 | 2 | 7 | 2.3 |
| | 10 | 1 | 2 | 13 | 4.3 |
| | 0 | 0 | 0 | 0 | 0 |
| | 0 | 0 | 0 | 0 | 0 |
| | 0 | 0 | 0 | 0 | 0 |
| | | | | 46 | 6.5 |
| Grassland | 11 | 8 | 10 | 29 | 9.6 |
| | 1 | 1 | 1 | 3 | 1 |
| | 0 | 0 | 0 | 0 | 0 |
| | | | | 32 | 3.5 |
| Hotel Area Native Planted | 11 | 22 | 24 | 70 | 23.3 |
| | 42 | 31 | 42 | 115 | 38.3 |
| | 0 | 0 | 0 | 0 | 0 |
| | 0 | 0 | 0 | 0 | 0 |
| | | | | 185 | 15.4 |
| Coconut Woodland Planted with Natives | 3 | 8 | 2 | 13 | 4.3 |
| | 2 | 1 | 0 | 3 | 1 |
| | 0 | 0 | 0 | 0 | 0 |
| | | | | 16 | 1.7 |
| Replanted Native Woodland | 34 | 35 | 5 | 74 | 24.6 |
| | 9 | 8 | 1 | 18 | 6 |
| | 40 | 31 | 53 | 124 | 41.3 |
| | 47 | 52 | 57 | 156 | 52 |
| | 4 | 3 | 0 | 7 | 2.3 |
| | 0 | 0 | 0 | 0 | 0 |
| | | | | 379 | 21 |

Table 1: Burrow counts of *N. insulanus* in various habitat types on Frégate Island, Seychelles.

to be enumerated, thereby affecting the data. Collapsed burrows are not easily observed, given the small size of the burrow entrance.

Burrows are closed in adverse weather conditions, when spiders are moulting, when the female is incubating an egg sac, and when females have spiderlings with them in the burrow. These burrows, during these periods, are closed with soil and are extremely difficult, if not almost impossible, to locate. Unless disturbed, spiders are sedentary within a single burrow for extended periods.

The total density of burrows using DISTANCE was estimated at 0.52 m$^{-2}$ (LCL = 0.35, UCL = 0.79). Burrow aggregations vary considerably, depending on the habitat type. The mean burrow aggregation was determined to be 3.80 (LCL = 3.54, UCL = 4.43). The total encounter rate of burrows across all habitat types was determined to be 0.23/m (LCL = 0.16, UCL = 0.32) at a detection probability of 0.39 (LCL = 0.28, UCL = 0.41). The population estimate using programme MARK, determined that the population for the surveyed area is 936 (UCL = 947 and LCL = 926). The estimated total population for the island, based on available habitat, was, therefore, 167553 (UCL = 169556 and LCL = 165696). The available habitat on Frégate that this species occupied was approximately 136 ha. The population estimate was determined by multiplying the determined estimate per square metre, for the surveyed area, by the area over the entire island that is available for the species to occupy. The area available to be occupied by these spiders was determined by using Google Earth Pro, version 6.0.3.2197 (www.google.com/enterprise/mapsearth/products/earthpro.html).

## Discussion

The population size and density of a small fossorial species such as *N. insulanus* is difficult to determine accurately. Analysis of control site data allowed an attempt at density estimation in the field, albeit with a number of assumptions. The underlying assumption made was that each burrow in the density and population estimate was assumed to be occupied by a single spider, and the presence of closed burrows was not considered in the assessment. With no completely satisfactory method available for the estimation of spider population density (Jass 1982); the method used needs to be the most appropriate for the situation. As with most theraphosids, *N. insulanus* is habitually sedentary, which lends itself to transect sampling, and results from sampling at the control site determined that a mark-resight strategy is an accurate means of determining density and population estimates for this species. Other common methods used to estimate spider populations include: Tullgren-Berlese extraction, hand sorting, suction sampling, and mark-recapture, depending on their guild (Tolbert 1977). Quadrat sampling and pitfall trapping are methods that have been used to estimate population densities in cursorial species in the ground stratum (Uetz & Unzicker 1976), and transect sampling has also been found to be an effective method of sampling spiders (Kapoor 2006).

The density of burrowing spiders has been determined in various studies and they vary widely between the species.

The lycosid *Lycosa godeffroyi* Koch, 1865 displays densities between 0.01 and 1.3 m$^{-2}$ (Humphreys 1976) and *Geolycosa domifex* Hancock, 1899 was determined by McQueen (1983) to have densities between 5 and 13 m$^{-2}$. The idiopid trapdoor spider *Misgolas rapax* Karsch, 1878 has been determined to have a density of 0.04 m$^{-2}$ (Bradley 1996) and another idiopid trapdoor species, *Cantuaria toddae* Forster, 1968, has densities ranging from 1.5 to 292 m² (Marples & Marples 1972). Kotzman (1990) found very low densities of 0.001 m$^{-2}$ for the theraphosid *Selenocosmia stirlingi* Hogg, 1901. The much higher densities of *N. insulanus* may be accounted for by the smaller size of the species and their limited dispersal from the maternal burrow, as well as high prey densities. Intraspecific agonistic behaviour was not observed, even when spider burrows were adjacent to one another, implying that density limits would be determined by suitable habitat type and the availability of resources. As theraphosid spiders do not balloon as a means of dispersal (Jankowski-Bell & Horner 1999) and spiderlings do not wander greatly if a suitable patch is found in which the spiderling is able to burrow (Cutler & Guarisco 1995), a high density of juvenile burrows may be found around the maternal burrow. Observations of burrows at the control site indicate that juveniles remain close to the maternal burrow for at least nine months and likely longer, or even permanently. A flood that inundated the control site prevented observations longer than this as the spiders abandoned their burrows for safer ground. In the absence of competition, or with limited competition and an abundance of prey, there would be little reason to move, other than to prevent mating with siblings, which Baerg (1958) suggests is the reason that male tarantulas wander large distances.

Patch isolation acts as a barrier to the dispersal of spiders (Upamanya & Uniyal 2008) and habitat structure strongly influences the distribution and abundance of arachnids (Riechert 1977, 1979, 1981; Bradley 1986). This is reflected in the density of this species between habitats with these spiders appearing in high densities only in suitable habitats. The invasion of alien plants further negatively impacts on the abundance of spiders (Mgobozi, Somers & Dippenaar-Schoeman 2008). The severely fragmented and altered state of the island limits the ability of the species to disperse into suitable habitat. With edge effect influencing soil temperatures which in turn impacts on invertebrate and microbial activity (Klein 1989; Parker 1989); as well as increased temperatures reducing water retention in the soil altering growth rates and phenology of vegetation (van Dyke 2003), the distribution of the species is affected.

The isolation of individuals from one another as a result of fragmentation is a grave threat to species survival (Laurance *et al*. 2002). With the inability to supplement numbers, decreased gene flow, and diminished possibility of re-colonization in suitably restored habitats, as well as increased chance of mortality during dispersal in poorly connected areas (Bennett & Saunders 2010), the welfare of the species is cause for concern. It is important that conservation measures such as the creation of effective and suitable corridors are implemented for the species. Due to their limited dispersal capacity, recruitment into restored habitat is likely to be a slow process, and the isolation of individuals between habitat types may have damaging consequences for

the species. Despite thorough searching of bamboo, habitats heavily encroached by invasive species, and habitats that have been landscaped and manicured, the species appears to be absent. In habitat types where the ground is heavily covered in leaf litter, such as in coconut-dominated woodland, *N. insulanus* is found in higher densities within the edge habitat, with far lower densities, or complete absence, within the core habitat. This does not imply that it is an edge species, but rather that there is limited habitat available within the interior of the particular habitat type. This species is often found along pathways and adjacent to roads, rocks, and decaying logs. Logs and rocks, as well as roads and pathways, provide ecotones that support increased biodiversity and productivity (Risser 1995). Those habitats that provide an abundant source of prey items are preferred with sites with a light layer of leaf litter being preferred to areas with a thick layer of leaf litter.

As spiders are strongly associated with biotopes (Whitmore *et al*. 2002) the creation of corridors of suitable habitat should help mitigate the impact of the fragmentation of the island, and with densities of spiders often exceeding 100 per square metre, their abundance makes them amongst the most important predators in numerous ecosystems (Coleman & Crossley 1996). Density decreases of important predatory species, such as spiders, could have consequences for the ecosystems in which they are found. Despite the severely altered state of the island, the population of this species is reasonably healthy and is likely to remain stable for the foreseeable future. Conservation intervention in the form of the creation of corridors of suitable habitat and the restoration of degraded habitat should ensure the long term survival of a currently poorly researched species.

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