

**Review of dispersal distances and landing site behaviour of
Solenopsis invicta Buren, Red Imported Fire Ant (RIFA)**

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Summary

Project and Client

- A review of flight behaviour and queen landing site preferences of Red Imported Fire Ant (RIFA), *Solenopsis invicta* was undertaken for Biosecurity New Zealand by the University of Auckland in June 2008.

Objectives

- To review the international literature on the availability and quality of information on the flight behaviour and habitat preferences of RIFA.
- To identify knowledge gaps in terms of availability of specific and contextually applicable information.

Methods

- Information was obtained by: searching computer databases (CAB abstracts, Current Contents, OVID databases, Biological Abstracts, Science Citation Index, FORMIS) for relevant scientific papers, and technical reports; checking internet sites; cross-referencing; and contact with and querying of international ant researchers and biosecurity practitioners.

Results

- Major knowledge gaps were identified in the dispersal efficiency of polygynous heavy queens that seem to be the most likely candidate for long distance dispersal via nuptial flight.
- Dispersal distance estimates were also found to be not fully applicable to the polygynous colonies.
- Since dispersal is limited by energy reserves, the potential for polygynous queens to disperse long distances is less than that of monogynous queens.
- Non-mating swarming activity that may also be responsible for polygynous queen dispersal was also noted; however it is unlikely to result in long distance dispersal.
- RIFA alates are thought to be attracted to reflective surfaces, however the experimental basis for this is lacking.
- RIFA alates also prefer disturbed sites, and nesting spots are characterised by holes or crevices, suitable for nesting.

Conclusions

- The flight dispersal distance estimates are old and are not statistically robust.
- Polygynous heavy queens are the most likely queens to disperse distances comparable to monogynous queens. However, their capability as relates to individual nest founding is unknown. This is a considerable knowledge gap essential to this context since the RIFA colony at Whirinaki was polygynous.

- Landing site preferences are usually disturbance-related, although microhabitat specificities are unknown. The suitability of the immediate landing site is critical to successful founding.
- The visual cues that assist RIFA alates in selecting landing sites are essentially unknown, thereby underlining another important knowledge gap in RIFA biology.

Recommendations

- The dispersal distance estimates need to be applied with caution. The major knowledge gap on ability of heavy polygynous queens to found successfully after long distance dispersal needs to be addressed.
- Soil around local water bodies must be investigated during RIFA incursion (based on landing site preferences).
- On landing, RIFA queens inspect every available hole or crevice for nest founding suitability. A new method devised by Tschinkel and his colleagues could be applied to high-risk sites identified during incursions, based on the fore mentioned criteria. In this method, 4mm thick glass tubes containing anti-freeze are placed into the soil with rim at level with the soil. This will provide suitable holes for the queen to investigate and will eliminate any potential new nests.

1. Introduction

Biosecurity New Zealand is currently responding to the third incursion of Red Imported Fire Ant (RIFA); a nest was detected in 2006 on the property of Pan Pac Forest Products, Whirinaki, Napier. The colony was treated, extracted from the infestation site and studied. It was confirmed to be a polygynous colony with about 30,000 workers and was aged at about 2 years (Gunawardana, 2006). Following detection, an incursion response was initiated by MAFBNZ in June 2006. The immediate area around the colony and the surrounding area up to 2 km from the colony have been regularly surveyed for additional colonies and any that might have arisen from the nuptial flights in the preceding summers. There have been no further nests detected within the surveyed areas, in and around the infested site at Whirinaki. The surveillance methods included intensive pitfall trapping up to 200m from the nest site (since July 2006) and baited pottles throughout much of the delimited site (MAFBNZ, 2006). Slow-acting (insect growth regulators) and fast-acting (hydamethylnon-based) ant toxic baits were used to treat areas inaccessible to ground-based surveys in two high-risk sites in the Whirinaki area. These high-risk sites were identified based on the NIWA wind-plume modelling analysis (Turner et al., 2006) However, the wind plume model did not account for the flight capabilities of RIFA alates, instead relied on suitable pre-flight weather parameters and wind direction, to estimate the spread in different directions. In this review, the information available on the flight capabilities and dispersal by means of nuptial flights has been collated. Since the discovery of the two social forms, the monogynous and polygynous types-, most researchers have differentiated between the two kinds. However, in the older studies, the colony type has not been specified, therefore there is some doubt on the applicability of the information presented in those studies.

Comparison of monogynous and polygynous colonies:

Monogynous and polygynous RIFA colonies can be differentiated between based on the number of queens and population structure of the nest. Monogyny refers to the possession by a colony of a single queen, polygyny to the possession of multiple queens (Hölldobler & Wilson, 1977). Besides this basic difference, a large number of differences in social structure and genetic

elements exist between the two kinds. Polygyny is an adaptive mechanism and polygynous colonies are thought to be more difficult to control than monogynous colonies of similar size (Glancey et al., 1987). They are also deemed to have an advantage in the recolonisation of a controlled area (Glancey et al., 1987). In monogynous colonies, queen control over sexual production is absolute and there is a very high degree of relatedness amongst the female nestmates (0.75) (Ross & Fletcher, 1985a). In polygynous colonies, however, there is significant structuring of populations. Mating occurring inside or near the natal nest, re-adoption of newly mated queens and budding as a mode of colony founding are some of the social aspects differentiating polygynous colonies from monogynous colonies (Keller & Ross, 1995; Ross & Fletcher, 1985a). Genetic studies, although not extensive, have to a degree supported these differences (Keller & Ross, 1995; Ross & Fletcher, 1985b).

The knowledge of the type of colony is important to estimate its reproductive potential and ability to spread. The queen(s) controls the production of sexuals in the colony. This phenomenon has been experimentally tested and also observed in the field (Vargo & Fletcher, 1986; Vargo & Fletcher, 1987). Monogynous colonies have far greater number of sexuals than polygynous colonies (Vargo & Fletcher, 1987). The number of sexuals in a colony is positively related to the number of participants in nuptial flights and therefore related to the tendency of dispersal.

The dispersal strategies of both monogynous and polygynous colonies will be compared in this report to decide on the applicability of the empirical data to either colony type.

Nesting site preferences: Micro-environmental factors may play an important role in the survival of the initial or claustral colony of RIFA. RIFA queens start a new colony by either haplometrosis (individually) or pleometrosis (joining new colonies) (Tschinkel & Howard, 1983). Pleometrosis is usually only an option after individual colony founding in RIFA and therefore not as relevant for initial incursions of RIFA. Individual colony founding is called claustral, meaning that the queen seals herself in a claustral chamber and rears the first brood on reserves stored in her body (Tschinkel, 1998). During this process of colony founding great amounts of body reserves are depleted. Claustral colony founding is a high-energy expenditure process (Tschinkel, 1993; Wheeler & Buck, 1996). Therefore the choice of micro-habitat for the nest-site must be critical to conserve energy reserves for colony founding and consequently

survival of the colony. It would affect polygynous queens to a greater extent, as they are less endowed with body reserves as compared to their monogynous counterparts (DeHeer et al., 1999).

Due to the importance of suitable sites (and their availability) to the success of new colonies, it is critical to know the factors that determine suitability of micro-habitats for colony founding. The visual/environmental cues that are available to the airborne female alates to base their landing site selection upon are therefore very important.

Therefore, information about flight dispersal distances and nest site preferences needs to be assessed for quality, and different estimates need to be compared to determine which are the most appropriate and accurate data sources. An assessment of knowledge gaps is also required.

2. Objectives and Scope

The aim of this report is to review the international literature on the following;

1) availability and quality of quantitative and qualitative data on the flight characteristics and flight behaviour of RIFA, *Solenopsis invicta* Buren, including the distribution of landing distances from the nest of queens from both polygyne and monogyne colonies following nuptial flights.

2) availability and quality of information on landing site preferences of RIFA alate females.

The report will also make recommendations to Biosecurity New Zealand, as to knowledge gaps identified in the areas discussed above.

This report reviews only the flight characteristic and factors influencing flight distances directly in Section 4.1 and landing site preferences of RIFA based upon available information in Section 4.2. It does not review other means of dispersal, reproductive strategies or nest founding process of RIFA. Therefore, it does not include information on aspects of reproductive biology or distribution based on environmental factors. Only peer reviewed journals and websites of research organisations were included in the methods.

3. Methods

Information was obtained by: searching computer databases (CAB abstracts, Current Contents, OVID databases, Biological Abstracts, Science Citation Index, FORMIS) for relevant scientific papers, and technical reports; checking Internet sites of research organisations; cross-referencing; and contact with and querying of international ant researchers and biosecurity practitioners.

Information was gathered on:

- Flight range estimates of RIFA from different studies.
- Flight characteristics and behavioural differences between polygynous and monogynous queen types of RIFA.
- Observed patterns of habitat/nest selection choice of RIFA.

Information has been received from the following experts:

- Dr Charles Barr, Texas A & M University, Texas, USA
- Dr Shaun Forgie, Landcare Research Ltd., Auckland, New Zealand
- Disna Gunawardana, IDC, MAFBNZ, Auckland, New Zealand
- Dr. Walter R. Tschinkel, Florida State University, Florida, USA
- Dr. S. Bradleigh Vinson, Texas A & M University, Texas, USA
- Dr Darren Ward, Landcare Research Ltd., Auckland, New Zealand

4. Results

4.1, Flight characteristics and dispersal distance of RIFA alates

The most important means of dispersal for RIFA is via nuptial flights that also serve the two main functions for the persistence and survival of the species, namely, 1) mating opportunity and 2) genetic mixing. Nuptial flights form the stage for mating as the sexually mature alates of both sexes participate in nuptial flight. A nuptial flight generally occurs after a day or two of rainfall, with relative humidity greater than 80%, and temperature in the range of 21-33°C (Markin *et al.*, 1971; Milio *et al.*, 1988; Rhoades & Davis, 1967). A typical mating flight is characterised by 100-700 alates being released from the nest mounds. The alates climb to a higher area, either on the surface of the mound or nearby vegetation and take flight (Lofgren *et al.*, 1975). Males and females are both found in the dense nuptial flight clouds, though usually they are male biased (Markin *et al.*, 1971). Markin *et al.* (1971) found that 95% of the females descending from such a nuptial flight are mated, rapidly shed their wings and do not participate in a second flight. Nuptial flights also allow for a great chance of genetic mixing when alates from a number of mounds participate. Nuptial flights therefore have been recognised to play a very important role in the life cycle of most ant species (Lofgren *et al.*, 1975). Following is an account on the information available of the characteristics of nuptial flights of RIFA.

4.1.1, Nuptial flight frequency:

The most comprehensive information about the occurrence of nuptial flights of RIFA is from USA. There the nuptial flights are known to occur at any time of the year, if environmental conditions are favourable, with the most intense nuptial flights of RIFA occurring during the months of May, June and July (Markin *et al.*, 1971), with subsequent confirmation of this phenomenon in South Carolina (Bass & Hays, 1979). Nuptial flights generally occur during spring and early summer with the flights starting in the morning through midday in warm humid weather, usually after a heavy rainfall during the previous day (Tschinkel, 1993). Since most of this data comes from outside New Zealand, its applicability is debatable to New Zealand specific conditions. This is however beyond the scope of this report.

4.1.2, Nuptial flight energetics:

Nuptial flights are an energetically expensive activity. Glycogen has been implicated in fuelling the flight (Toom et al., 1976), and more recently carbohydrates have been found yet again as an important energy reserve for nuptial flights (Vogt et al., 2000).

Monogynous queens in different mating flights show a high degree of variability in live weights, dry weights and fat content (Vogt et al., 2000). Alates undertaking nuptial flights in May show the highest live weight, however, dry lean and fat measures increased with each monthly flight participants from May to June (Vogt et al., 2000). This suggests that later alates may have a better ability to search for nesting sites, due to higher fat storage that may persist for the founding period. Speed of female and male alates has been roughly estimated at 1-1.5 ms⁻¹ and 2 ms⁻¹ respectively (Vogt et al., 2000). Their average flight duration based on a simple energetics model is estimated at 45 minutes (Vogt et al., 2000), indicating that RIFA cannot be dispersed over very long distances without the aid of wind. Approximately 5 km is the estimated dispersal distance in the absence of wind; based on the assumption that exhaustion ends flight (Tschinkel, 2006). However, in a case of such maximised dispersal, no reserves would be left for colony founding. The long flights are limited by stored glycogen as post-flight females lose up to 60% of this glycogen supply (Toom et al., 1976). This data could be generalised for the monogynous and heavy polygynous queens based upon the weight measurements of the queens used in this study, however it is more likely that the queens were from a monogynous colony. This data can therefore not be used for the light or intermediate weight polygynous queens and is therefore not applicable to all the genotypic variants (discussed in section 4.1.4) of a polygynous colony.

4.1.3, Nuptial flight range:

A number of flight distance estimates for alate queens have been estimated in the literature for RIFA (see Table 4.1). Queens stay airborne only for about 30 minutes while males can stay airborne for hours, or even through the night (Tschinkel, 2006). Immediately after copulation, queens usually descend downwind directly to ground or may fly some distance before descending (Rhoades & Davis, 1967). Based on Markin and his co-workers' series of experiments (see Box 4.1) during the early 1970's a few estimates on the dispersal of queens from the parental nest via the nuptial flight have been recorded. In summary, the first experiment

concluded most of the newly mated queens flew up to a few 100 m from the natal nest while only a few were found up to 800 m away (Markin et al., 1971). But since no searches were made closer to the parental nest, there is no background recovery rate to compare the recaptures against. This experiment suggests that a great majority of the queens fly only a short distance before settling but there is also uncertainty about this possibility. Furthermore, it suggests that only about 3% of queens fly as far as 400m, while another subsequent experiment where reinvasion of a pre-cleared area was studied, suggests that 3% of the queens fly as far as 1.6km (Markin *et al.*, 1971). Another experiment on the collection of the alates from these reinvading young colonies suggested that 10-15% of newly mated queens fly up to 1.6km (Markin et al., 1972). Since no statistics other than totals were reported for these experiments, statistical comparison amongst these sets of experiments cannot be conducted and establishing the significance of the data is not possible. Therefore, these experiments give only rough estimates that can be summed up as the dispersal distance of majority of queens being up to 400m, while a few may fly up to 1.6 km or even more (Tschinkel, 2006). The height of female catches in the mating swarms also supports the low dispersal range estimates, as a very low proportion (2%) of females was captured at an altitudinal gradient from 60-100m (Markin et al., 1971). The male alates composed the volume of the typical mating swarm and extended higher up to 300 m, but the majority of the males were found in a dense layer concentrated between 60-150 m.

Having said that, records are available that indicate that over water female alates are able to fly or get blown across long distances, even up to 12-16 km away from the parental nest (Markin et al., 1971). This may be because the queen might be looking for visual cues of soil, in the absence of which it keeps on flying only to land dry, a great distance away from where it started (Tschinkel, 2006).

Table 4.1. Various estimates of dispersal distances, height, duration, colony type for nuptial flights of RIFA from the literature.

Estimates	Dispersal distance via nuptial flight	Height of nuptial flight	Duration of nuptial flight	Colony type/queens	References
1	100m-1.6km ¹	60-150m ²	30 mins, rarely 2 hours	most likely monogynous	Markin <i>et al.</i> , 1971
2	12-15 km ⁴	-	-	unknown, possibly monogynous	Markin <i>et al.</i> , 1971
2	5km ³	-	45 min	unknown	Vogt, 2000
3	-	-	20-30 min	unknown	Milio <i>et al.</i> , 1988
4	-	2-5 m	-	polygynous intermediate queens (99%)	DeHeer <i>et al.</i> , 1999

Comments

1. Summary range of dispersal distances from Markin and his colleagues' three experiments, see Box 4.1
2. Females only up to about 100m, only 2 females collected another 50 m higher
3. Assuming that exhaustion and depletion of energy resources end flight
4. Based on observation 2 see Box 4.1

Experiments of Markin and colleagues (from Markin et al., 1971)

Observational data: 1. On ground observations and aerial surveys using airplanes covering an altitudinal range of 2-1000fts, of flying alates following nuptial flights were conducted. Retractable nets lowered from the airplanes for 10 min intervals collected the flying alates at different heights.

2. Operators of charter boats were asked to report sightings of RIFA queens, and numerous sightings in water 3-5 miles away from shore were observed. Maximum distance recorded was from a single queen landing on a charter fishing boat 6 miles away from shore.

Experiment 1: RIFA colonies in a 12ha pasture were fed with bait containing fat soluble dye and within a four month period, about a quarter million alates had blue-dyed insides. These marked sexuals were captured following two nuptial flights downwind from the treated block. Newly descended queens were crushed to see if they contained the dye.

Experiment 2: Using insecticidal mirex bait, a square area of 8km by 8km was cleared 99% of its fire ant colonies. Disturbed areas (open fields and dirt roads) were searched for newly mated ants following three large mating flights from the surrounding colonies.

Experiment 3: By autumn the newly mated queens from the above experiment had formed observable mounds, and the survey was run again and the number of mounds at different distances from the treatment boundary was counted.

Box 4.1, Experiments and observational surveys done by Markin and colleagues from 1964-1968.

This dispersal data represents queens of the two overlapping kinds, long-distance dispersers and short-distance dispersers, the latter settling close to natal nest or getting re-adopted into it. But in the flight range experiments of Markin et al. (1971), the minimum distance of dispersal has not been documented. Markin et al., (1971) did not account for the effect of winds, and only a single mention of wind was made in their publication describing about 68 nuptial flight observations from 1964-1969. The experiments were not standardised against each other and yielded different estimates of dispersal distances.

Markin and his colleagues also did not specify the type of colonies, whether polygynous or monogynous, however this data has since been interpreted as containing a mixture of both (Tschinkel, 2006) since both colony types have been found in that region. Monogynous colonies are primarily long-distance dispersers: alates found colonies independent of each other, and if they land close to their natal nest are generally killed by workers of the natal nest (Tschinkel, 2006). Polygynous colonies consist of both short and long distance dispersers, with the variation in the dispersal strategies being governed by polymorphic forms of gene *Gp-9* (DeHeer et al., 1999). This information is based on the observation and genotyping of pre-flight, low flight and post flight queens of polygynous colonies. Heavy polygynous queens resembled monogynous queens in their nuptial flight behaviour and habitat preference (DeHeer *et al.*, 1999).

4.1.4, Flight patterns specific to polygynous colonies:

Polygynous queens usually have lower energy reserves and weaker flight capabilities when compared to monogynous queens (McInnes & Tschinkel, 1995). To add to this, dispersal polymorphism based on the weight categories of the newly produced queens has been well established due to the *Gp-9* gene locus (Keller & Ross, 1993, 1995). On the heavier end are the queens with the *Gp-9^{BB}* genotype, close in weight to their monogynous counterparts (ie. more energy reserves) and are therefore more likely to disperse and form individual colonies (Goodisman & Ross, 1999). One factor limiting the spread of *Gp-9^{BB}* queens is that most of them are killed by the workers before they leave the nest, however a few of them do leave and therefore have reproductive prospects and disperse away from the polygyne nest (Keller & Ross, 1993). In a laboratory-based study about 20% of the heavier polygynous queens (*Gp-9^{BB}* genotype) were found to have the potential to found individual colonies, however with lesser number of workers (Tschinkel, 2006). The proportion of heavy polygyne queens in a typical

polygynous colony however is unknown and therefore is it difficult to ascertain the effective potential spread by this class of polygynous queens.

However, the polygyne $Gp-9^{BB}$ queens have never been observed to found individual (haplometrotic) nests or found monogynous colonies (W.R. Tschinkel, pers, comm.). This yet remains to be proved but is likely to be true based on the fact that reproductive queens from a polygynous colony are almost exclusively $Gp-9^{Bb}$ (Goodisman *et al.*, 2000). The heavy queens are present close to monogynous areas, but generally get killed and therefore this adds to the list of factors hampering long distance spread of heavy polygynous queens. This factor is important because an open niche provided at an incursion site devoid of pre-existing monogynous colonies would allow the spread of heavy polygynous queens that may form up to a third of the queens descending after a nuptial flight to found nests (DeHeer *et al.*, 1999). Besides this, the realised dispersal of polygynous queens is based upon comparisons with estimates for monogynous queens. However, most RIFA researchers would agree that polygynous colonies are not long distance dispersers. In their native range, unaided by human facilitation, polygynous colonies only disperse tens of metres, and this includes dispersal by budding and nuptial flights (Mescher *et al.*, 2003). Polygynous queens are also more prone to physical barriers such as tall forests as the majority of polygyne queens are low fliers (as discussed above) (DeHeer *et al.*, 1999; Milks *et al.*, 2007). The realised spread of polygyne colonies via nuptial flight is only metres per year (W.R. Tschinkel, pers, comm.). The longer distance spread is via human mediated spread, which is beyond the scope of this report.

The lighter queens (with genotypes $Gp-9^{Bb}$ and $Gp-9^{bb}$) are less likely to disperse and more often mate near their natal nest and settle close to it (DeHeer *et al.*, 1999; Goodisman & Ross, 1999). Such dispersal is represented by the two small mounds found close to the larger mound at the infestation site at Whirinaki (Gunawardana, 2006).

4.1.5, Non-mating swarms:

Polygynous queens have also been reported to form low-flying (2m high) dense swarms nearly devoid of males (0.5% male alates) (Goodisman *et al.*, 2000). These females have completed their mating before forming these female biased swarms (Goodisman *et al.*, 2000). It is suggested that these swarms represent post mating dispersal strategies or facilitate nest site selection (Barr, C., pers. comm.). However, comparisons of the *mtDNA* haplotype distributions of these alates

revealed that the queens had not dispersed more than a few hundred metres from natal nests (Goodisman et al., 2000).

Based on this information it can be inferred that compared to monogynous colonies, the dispersal of polygynous colonies is lesser. Therefore the surveillance radius of 2 km around the polygynous nest at the Whirinaki site appears to be appropriate. However, since most of these estimates are based on fairly old studies and almost no recent studies have been conducted to verify the former data, there is a considerable doubt on its applicability. The monogynous field-based dispersal distance data of less than 2km to a certain extent is applicable to the heavy polygynous queens, if the proportion of them in a typical polygynous colony was known. The absence of this data in addition to the fact that no polygynous heavy queens have been reported to found a monogynous nest, decreases the importance of the heavy polygynous queens as a candidate for long-distance dispersal and identifies a major knowledge gap. Therefore experimental confirmation of the ability of polygynous heavy queens to disperse long distances and quantification of their ability to found a successful nest following such dispersal are the key questions that need to be addressed. Another factor that may play an important role in the applicability of the 1970s data is the effect of global climate change. Global climate change has inflicted not only higher temperatures but also altered wind patterns and seasonal rhythms (Houghton *et al.*, 2001; Wigley & Raper, 1992). Therefore the data on the flight patterns of RIFA collected almost 40 years ago may not fit as closely in to the weather regimes of today. The general trend that the polygynous queen dispersal efficiency is overall lesser than that of the monogynous queens, may be well applied to this context, although full confidence in the dispersal distances of monogynous queens is lacking.

4.2, Landing site preferences:

The female alates participating in nuptial flights are a finite package of energy and resources (Toom et al., 1976; Tschinkel, 1993). These resources are used up during the mating flight, finding the right site for laying the claustral brood and rearing the first set of workers or minims (Toom et al., 1976; Tschinkel, 1993). As the newly mated queens resume their descent from the nuptial flight swarms, they could either fly for longer and disperse away from natal nest and still find a suitable moist site (moist to conserve the energy to be spent on the digging effort); or they

could land as quickly as possible, with ample resources to found the colony but with reduced dispersal distance. Both options would have advantages and disadvantages. Either way the main aim would be to conserve adequate energy for rearing a successful brood. Investing in site selection to enable successful founding of the claustral colony would therefore be very advantageous. The newly mated queens utilise the downwind direction for this reason, as 89% of newly formed colonies were observed to be on the leeward side of the natal mound (Rhoades & Davis, 1967).

4.2.1, Site selection:

It has been much implicated that newly mated queens choose their nest founding site while still in descent (Tschinkel, 2006). The range of an aerial search is much greater than on foot once the queen has landed and a number of visual cues would be available to the female alates while airborne (Tschinkel, 2006). The workers, and possibly alates, are known to be able to see in ultraviolet (Milio et al., 1988). Another aspect indicating site selection behaviour is the attraction of female alates to reflective surfaces (Milio et al., 1988; Tschinkel, 2006). However, this behaviour is mostly anecdotal or observational (W.R. Tschinkel, pers, comm.). The only documented observation of this behaviour of RIFA deemed as an adaptation to be able to settle near water bodies (Bhatkar, 1990), was a study conducted by Vinson and Greenberg in 1986. They found that plastic tubs covered with aluminium foil or containing water collected more queens from nuptial flights than tubs covered with dark cloth or containing soil (Vinson & Greenberg, 1986). The major knowledge gap in this field has been realised by a number of RIFA researchers, and future studies are being planned (W.R. Tschinkel, pers, comm.). Tschinkel and colleagues have devised a new methodology to address these questions. By seeding the bare ground with 4 mm close-ended glass tubes containing anti-freeze, descending RIFA alates can be collected, at the point when they are searching for a nest spot (discussed below) (W.R. Tschinkel, pers, comm.). Comparing the density of RIFA alates in such tubes placed in contrasting sites surrounding the area of a mating swarm, can give at least a confirmation of the site selection behaviour of newly mated queens. This method is in the field testing stage, as of now, but shows hope for future studies of RIFA dispersal and behaviour.

4.2.2, Habitat selection:

RIFA are known to be selectively attracted to mesic habitats with a high water table (Kemp *et al.*, 2000). RIFA are ruderal species and seek out disturbed areas (W.R. Tschinkel, pers, comm.). They are usually most abundant in partially vegetated, ecologically disturbed habitats such as road sides, dirt roads, soil depots (King *et al.*, 2008), recently disturbed land and are also quite often attracted to human associated sites, such as parking lots, swimming pools and other unsuitable sites (Tschinkel, 2006). These sites are unsuitable for nesting in most cases, except unless they find crevices or openings to found the claustral colony. RIFA also occur in greater densities on grazing lawns, while roadbeds are preferred over pastures (Milks *et al.*, 2007). In general, queens and nests are strongly associated with slightly higher grounds, usually for protection from rainwash areas and puddles (Tschinkel & Howard, 1983). One of the reasons for colonies being limited to more disturbed areas could be due to factors other than queen choice (Plowes *et al.*, 2007). RIFA may be informed through sensory cues such as olfaction. For example, RIFA are repelled by odoriferous Old World bluestem pasture grass (*Bothriochloa bladhii*) (Sternberg *et al.*, 2006). However the effect of soil chemistry has not yet been studied for RIFA (Milks *et al.*, 2007).

Polygynous queens and habitat selection: Heavy Gp^{BB} polygyne queens prefer dispersal to open, disturbed habitat patches, as do monogyne queens (DeHeer *et al.*, 1999). Lighter Gp^{Bb} queens have a mixed dispersal strategy: some remain near the natal nest and others disperse to open, disturbed areas like the heavy queens (DeHeer *et al.*, 1999). Light Gp^{bb} do not seem to have the energy for mating flights in large numbers (DeHeer *et al.*, 1999). The polygynous queens rarely nest in heavily vegetated areas and forests, but are most adapted to make use of disturbed soil and open fields (King *et al.*, 2008).

4.2.3, Post-landing behaviour:

A) Search for a suitable nesting site: As the newly mated queen lands on the ground, it inspects all available holes in the soil for suitability. On foot the queen travels only about 2-50 m (Tschinkel, 1998). If a suitable hole is not found fairly soon the queen starts to dig a hole. Within 40 mins of landing 50% of landed queens are underground. The founding chamber is rarely more than 2-3 m from the landing spot (Tschinkel, 1998).

B) *Habitat saturation*: Queens from polygyne nests have a preference for soils uncontaminated with colonies of other ants such as *Pheidole dentata* (Kaspari & Vargo, 1994). And 80% of the time, queens also avoid soil where other polygyne RIFA colonies are present (Tschinkel, 2006). Both choices tend to increase the probability of queen survival. Newly mated queens that land in territories of mature colonies are killed on discovery, so that the chances of successful founding in occupied habitat are very low (Tschinkel, 1998). This has useful implications such that if the area where the searches have been done is small and has a large mature colony, chances are slim that another colony would have formed in close vicinity of that area. The further you go the greater the chances of finding a newly found colony, up to a certain dispersal limit (see dispersal distance).

A great deal of information on visual cues available to RIFA alates is lacking. This is critical as the lack of appropriate habitat, which is probably ascertained using visual cues, can lead to further dispersal of RIFA when airborne, as over water bodies RIFA may fly even up to 12-14km (Markin *et al.*, 1971). Knowledge of disturbed areas in high risk sites may also be useful for intensive searching for likely nesting spots such as holes in the ground or crevices. The hole dug by the queen itself would be more cryptic and harder to find. But considering that a polygynous queen has low energy reserves, it would prefer to use available holes rather than digging one itself. However, the experimental evidence for such possible behavioural adaptation is also lacking.

5. Conclusions

The flight dispersal distance estimates for RIFA queens are old and are not statistically robust. Polygynous heavy queens are the most likely queens to disperse distances comparable to monogynous queens. However, their capability as it relates to individual nest founding is unknown. This is a considerable knowledge gap essential to this context since the RIFA colony at Whirinaki was polygynous. Landing site preferences are usually disturbance-related, although microhabitat specificities are unknown. The suitability of the immediate landing site is critical to successful founding. The visual cues that assist RIFA alates in selecting landing sites are essentially unknown, thereby underlining another important knowledge gap in RIFA biology.

6. Recommendations

- The dispersal distance estimates need to be applied with caution. The major knowledge gap on ability of heavy polygynous queens to found successfully after long distance dispersal needs to be addressed.
- Soil around local water bodies must be investigated during RIFA incursion (based on landing site preferences).
- On landing, RIFA queens inspect every available hole or crevice for nest founding suitability. A new method devised by Tschinkel and his colleagues could be applied to high-risk sites identified during incursions, based on the fore mentioned criteria. In this method, 4mm thick glass tubes containing anti-freeze are placed into the soil with rim at level with the soil. This will provide suitable holes for the queen to investigate and will eliminate any potential new nests.

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