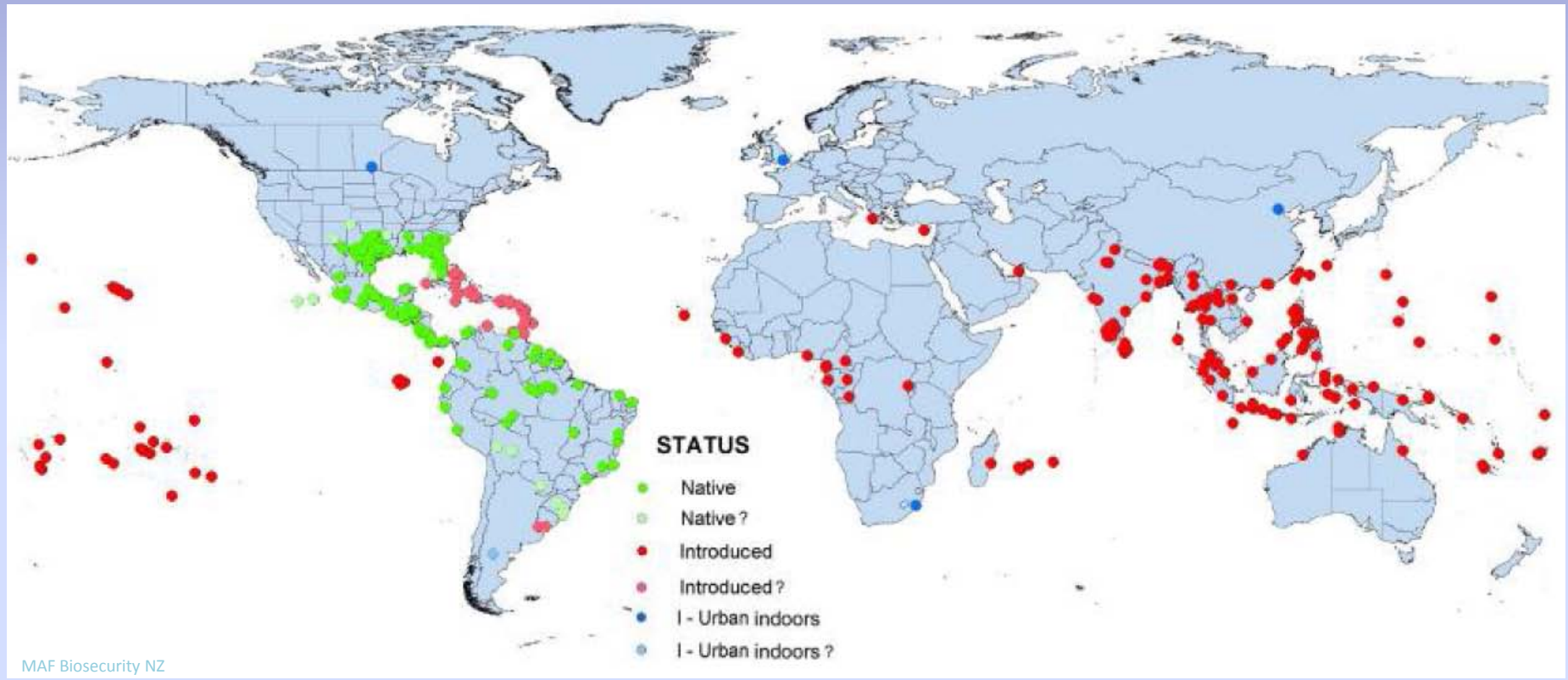
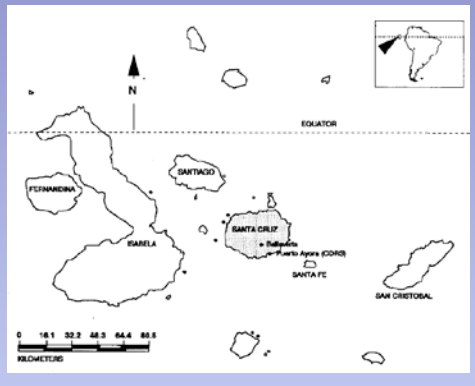
# Potential for biological control of the tropical fire ant *Solenopsis geminata* and lessons learned from fire ant biocontrol in Texas




Rob Plowes
Brackenridge Field Lab
University of Texas at Austin

# *S. geminata* in Galapagos

- Arrived over 100 years ago.
- Has spread to most islands.
- Polygyne form causes locally dense populations.
- Serious pest on tortoises and iguanas.
- Can coexist with *Wasmannia,* collectively impacting arthropod diversity.





ECUADOR, Galápagos:
Santa Cruz, Bellavista
S00°38'18.4" W090°25'44.6"
180m,07.i.2007, #HWH179
H. Herrera, Aspirador

# *S. geminata* in Hawaii

- No native ants - now has ~45 species
- *S. geminata* well established by the 1870‘s
- Novel interactions in newly  assembled ant communities
- Danger of other ants released from competition if *geminata* is controlled

# Impacts of invasive *S. geminata*

**Agricultural impacts**

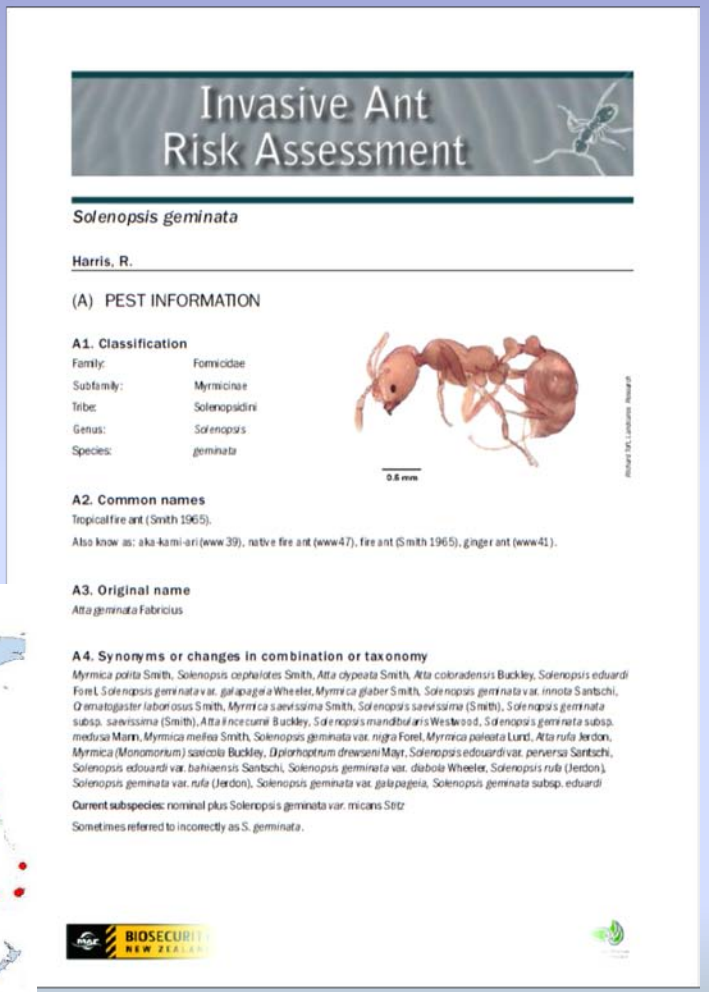
- Stings to farm workers and livestock
- Outbreaks of insects such as mealybugs and other crop pests.
- May result in increased plant diseases transmitted by such pests.
- *BUT:* Lewis (1912) described the beneficial impact of their feeding on pest insects.
- Can damage plastic tubing, irrigation systems.

**Conservation impacts**

- Impacts on native butterfly eggs and larvae (eg Guam).
- Potential to displace native ant populations.
- Consumes myrmecochorous seeds; and may ingest the elaisome without dispersing the seed.

# Organized responses: assessments, quarantines & containment

- Invasive Species Specialist Group (ISSG) of IUCN
- Pacific Invasive Ant Group 2004
  - to maintain effective quarantine systems
  - to assist with regionally coordinated eradication & containment efforts



Invasive Ant Risk Assessment

*Solenopsis geminata*

Harris, R.

(A) PEST INFORMATION

**A1. Classification**

| | |
|---|---|
| Family: | Formicidae |
| Subfamily: | Myrmicinae |
| Tribe: | Solenopsidini |
| Genus: | *Solenopsis* |
| Species: | *geminata* |

0.5 mm

**A2. Common names**

Tropical fire ant (Smith 1965).

Also know as: aka-kami-ari (www.39), native fire ant (www.47), fire ant (Smith 1965), ginger ant (www.41).

**A3. Original name**

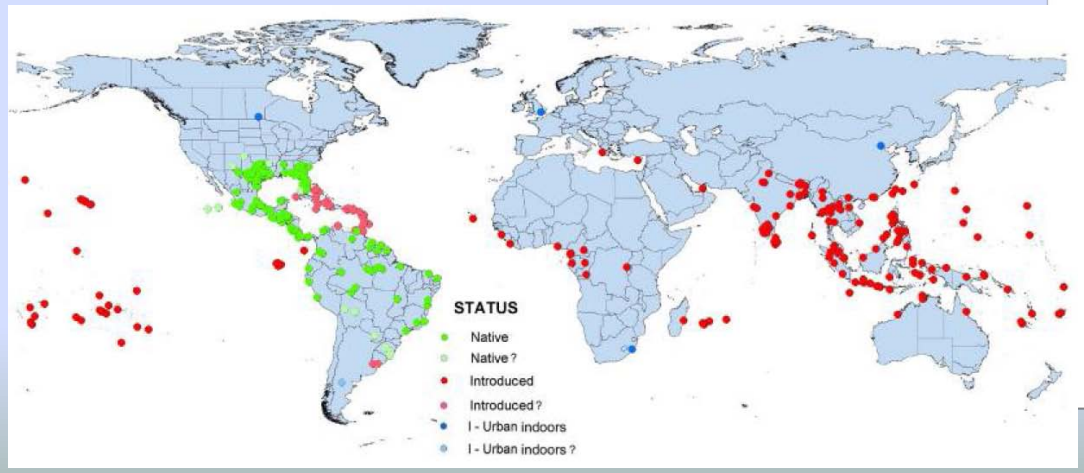
*Atta geminata* Fabricius

**A4. Synonyms or changes in combination or taxonomy**

*Myrmica polita* Smith, *Solenopsis cephalotes* Smith, *Atta clypeata* Smith, *Atta coloradensis* Buckley, *Solenopsis eduardi* Forel, *Solenopsis geminata* var. *galapagea* Wheeler, *Myrmica glaber* Smith, *Solenopsis geminata* var. *innota* Santschi, *Ormatogaster laboriosus* Smith, *Myrmica saevissima* Smith, *Solenopsis saevissima* (Smith), *Solenopsis geminata* subsp. *saevissima* (Smith), *Atta lincecumii* Buckley, *Solenopsis mandibularis* Westwood, *Solenopsis geminata* subsp. *medusa* Mann, *Myrmica mellea* Smith, *Solenopsis geminata* var. *nigra* Forel, *Myrmica paleata* Lund, *Atta rufa* Jerdon, *Myrmica (Monomorium) saxicola* Buckley, *Diplorhoptrum drewseni* Mayr, *Solenopsis edouardi* var. *perversa* Santschi, *Solenopsis edouardi* var. *bahiaensis* Santschi, *Solenopsis geminata* var. *diabola* Wheeler, *Solenopsis rufa* (Jerdon), *Solenopsis geminata* var. *rufa* (Jerdon), *Solenopsis geminata* var. *galapageia*, *Solenopsis geminata* subsp. *eduardi*

**Current subspecies:** nominal plus *Solenopsis geminata* var. *micans* Stitz

Sometimes referred to incorrectly as *S. germinata*.



**Goal**: to assemble a suite of self-sustained natural enemies.

Biocontrol agents may interact and work synergistically with environmental and competitive stressors.

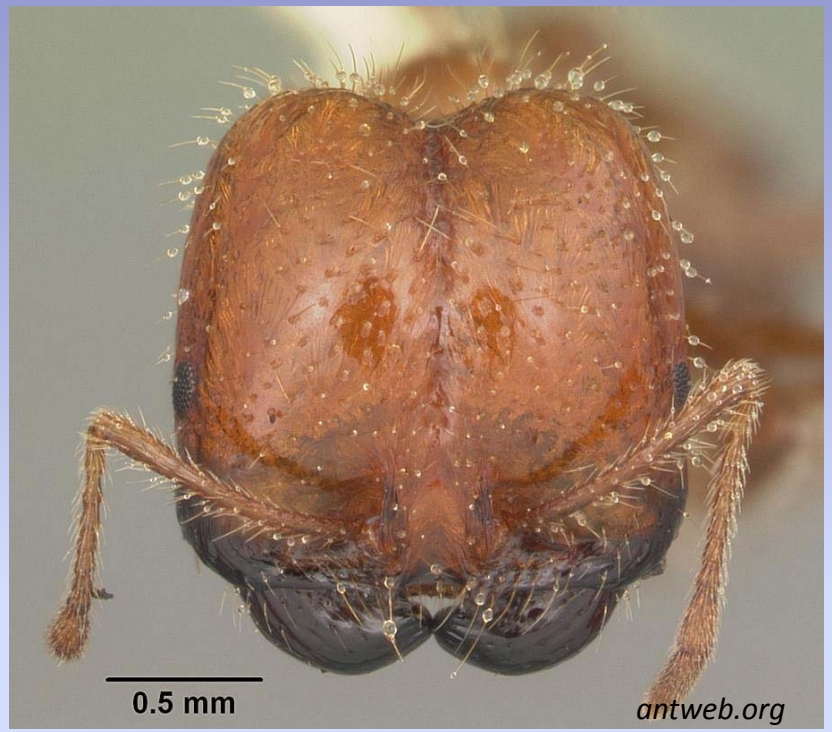
**Goal**: to assemble a suite of self-sustained natural enemies.

Biocontrol agents may interact and work synergistically with environmental and competitive stressors.

**How are social insect populations regulated?**
**- top down (predators, parasites, pathogens)**
**-bottom up (competition for env dependent resources)**

**Very few attempts at biocontrol in social insects.**
**Ongoing efforts with *Solenopsis invicta* - no clear results yet.**

## *S. geminata*




*Partly granivorous*

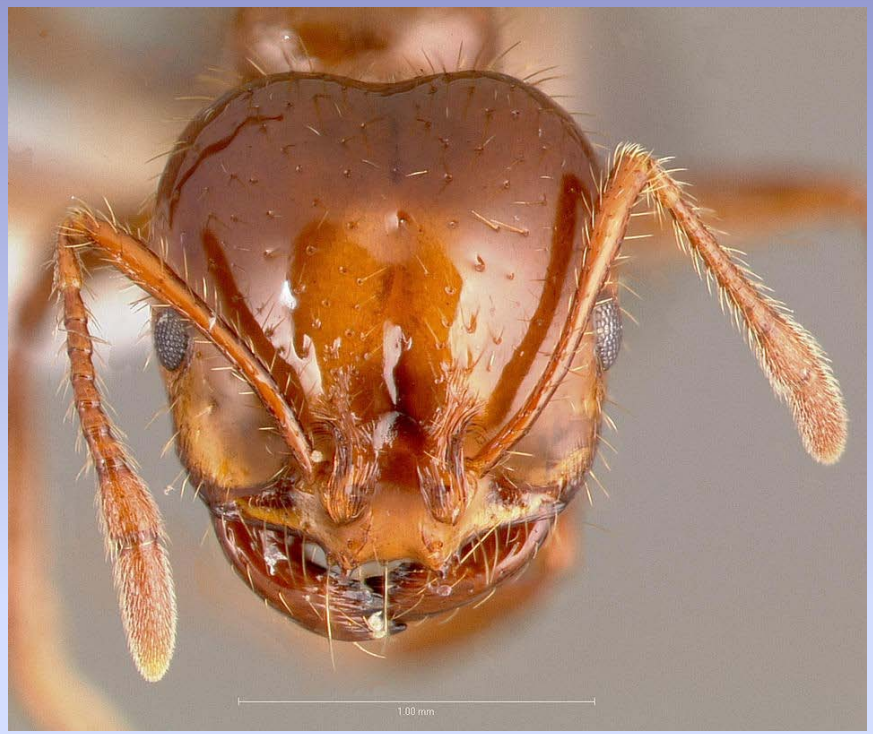
*Copes with sandy soils*

*Shade tolerant*

*Seasonally dormant*

*Tend honey dew insects*

## *S. invicta*



*Omnivorous*

*Avoids sandy soils*

*Avoids shade*

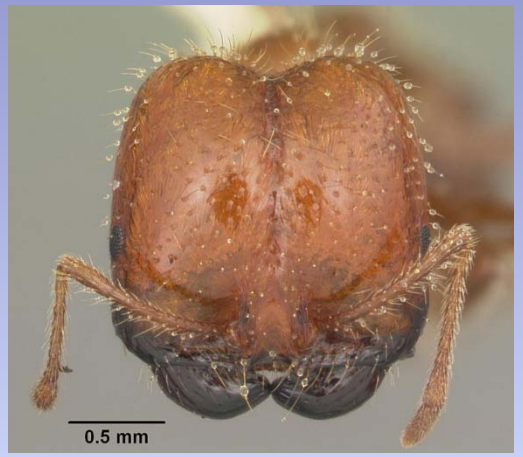
*Active whenever warm*

*Tend honey dew insects*

# Systematics of *Solenopsis geminata* group  Trager (1991), Pitts (2002)

**Geminata species group**

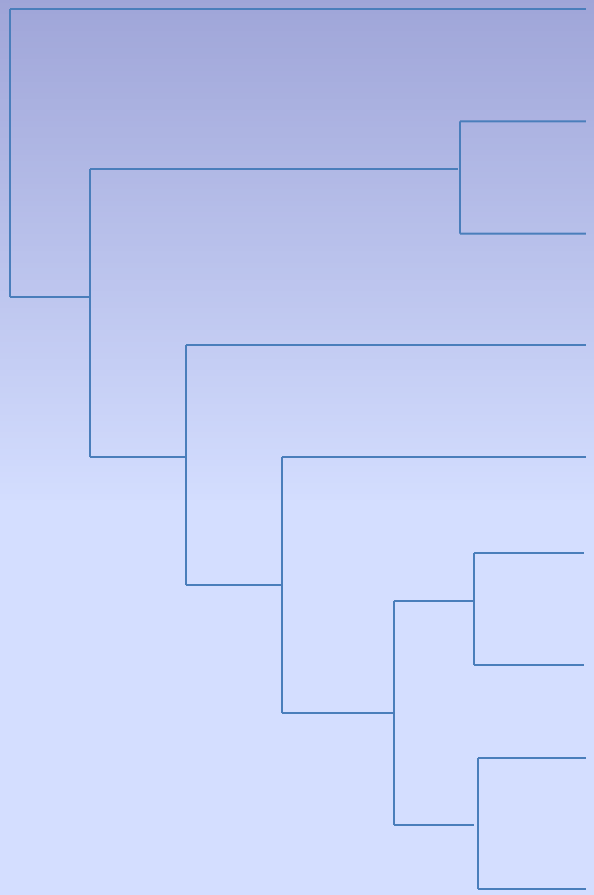
| | |
|---|---|
| Geminata subcomplex | |
| *S. geminata* | s US to n S.Am |
| Xyloni subcomplex | |
| *S. xyloni* | *s* US, n Mx |
| *S. amblychila* | *s*w US, n Mx |
| *S. aurea* | *s*w US, n Mx |
| Gayi subcomplex | |
| *S. gayi* | Chile, Peru |
| *S. bruesi* | Peru |




**Saevissima species group**

| | |
|---|---|
| Saevissima subcomplex | |
| *S. invicta* | Br, Arg, Bol |
| *S. interrupta* | Arg, Bol |
| *S. macdonaghi* | Urug, Arg |
| *S. megergates* | se Br |
| *S. pythia* | Arg, Br |
| *S. quinquecuspsis* | Arg, Br |
| *S. richteri* | Arg, Br |
| *S. saevissima* | Amazonia |
| *S. weyrauchi* | Peru, Bol Andes |
| Electra subcomplex | |
| *S. electra* | Arg, Bol |
| *S. pusillignis* | Br |

# Phylogeny of *geminata* group



*xyloni outgroup*

Cent Am 1

Yucatan 2

Texas, n Mx 3

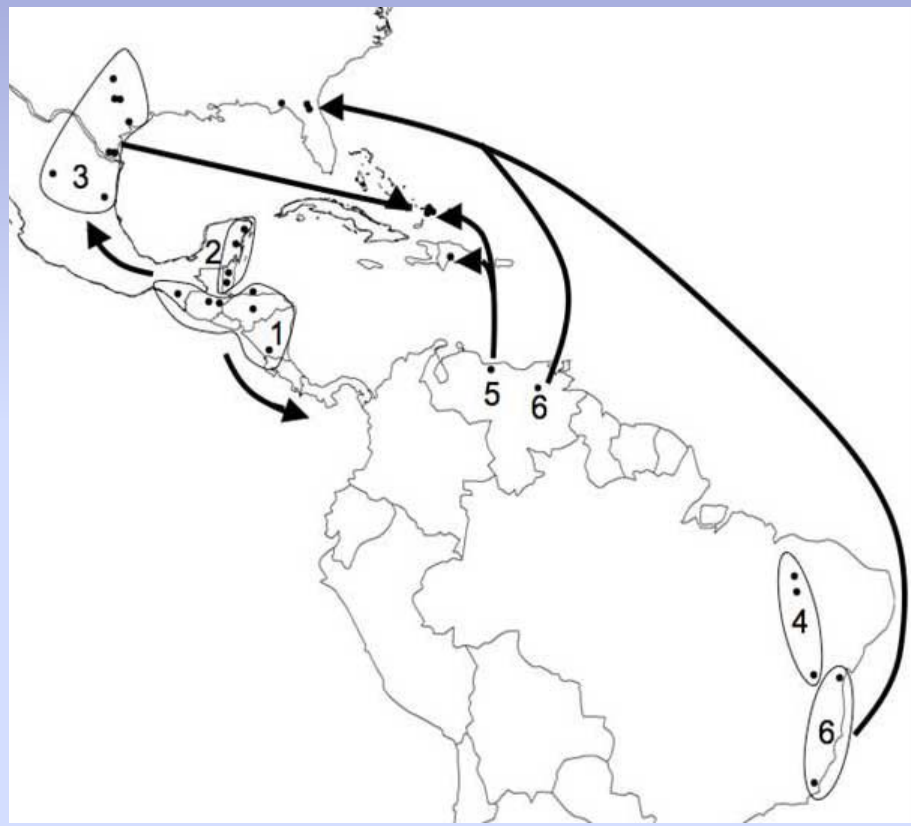
Brazil 4

Venezuela 5

Caribbean 5

Brazil, Venez 6

Florida 6




Branch lengths not scaled

**H. Axen** unpublished

# Progress with biocontrol in *invicta*

**Phorid flies**

6 species of *Pseudacteon* released

Initial 2 species now widely distributed

Microsatellite libraries developed for pop gen studies (UT)

**Microsporidian pathogens**

*Kneallhazia* now widely distributed across US

May have strong impacts at colony level

May be vectored by phorids

**Viruses**

SINV 1 widely distributed, but episodic virulence

**Other microbes and fungi**

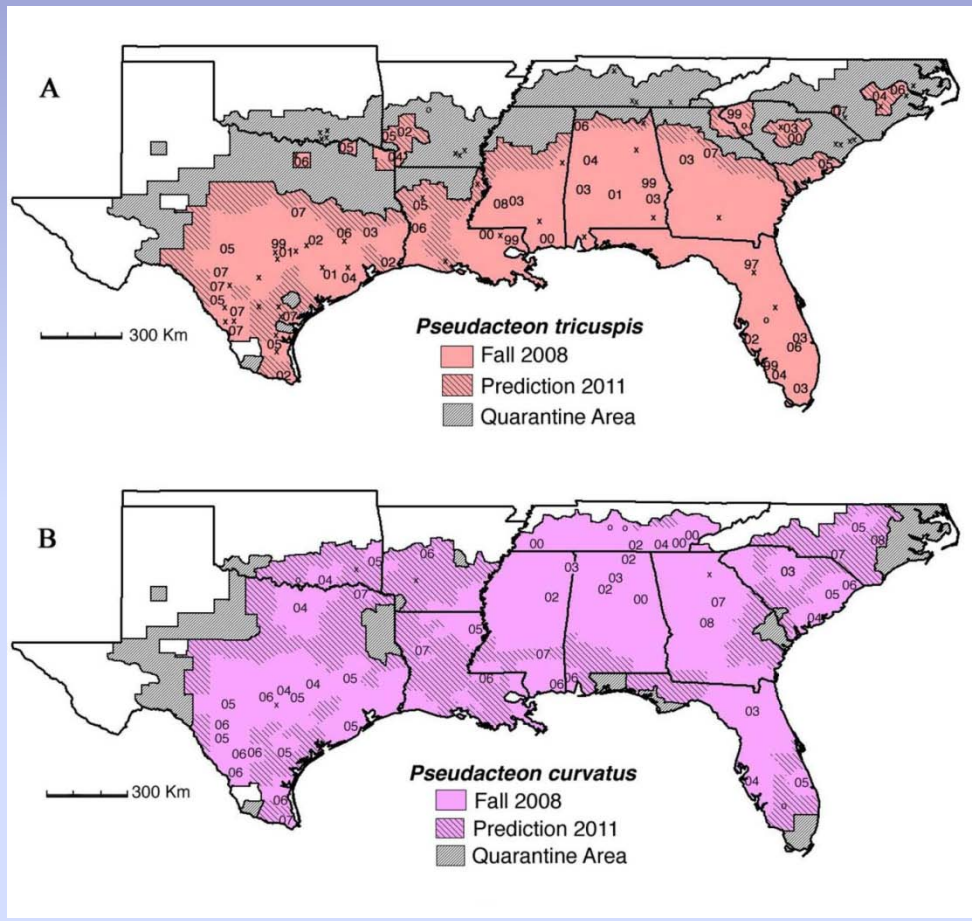
Studies ongoing of several fungi & bacteria

- potential for augmentative biocontrol

Most bacteria too large to be ingested by ants

**Other organisms associated with invicta**

*Orasema* wasps, mites, nematodes

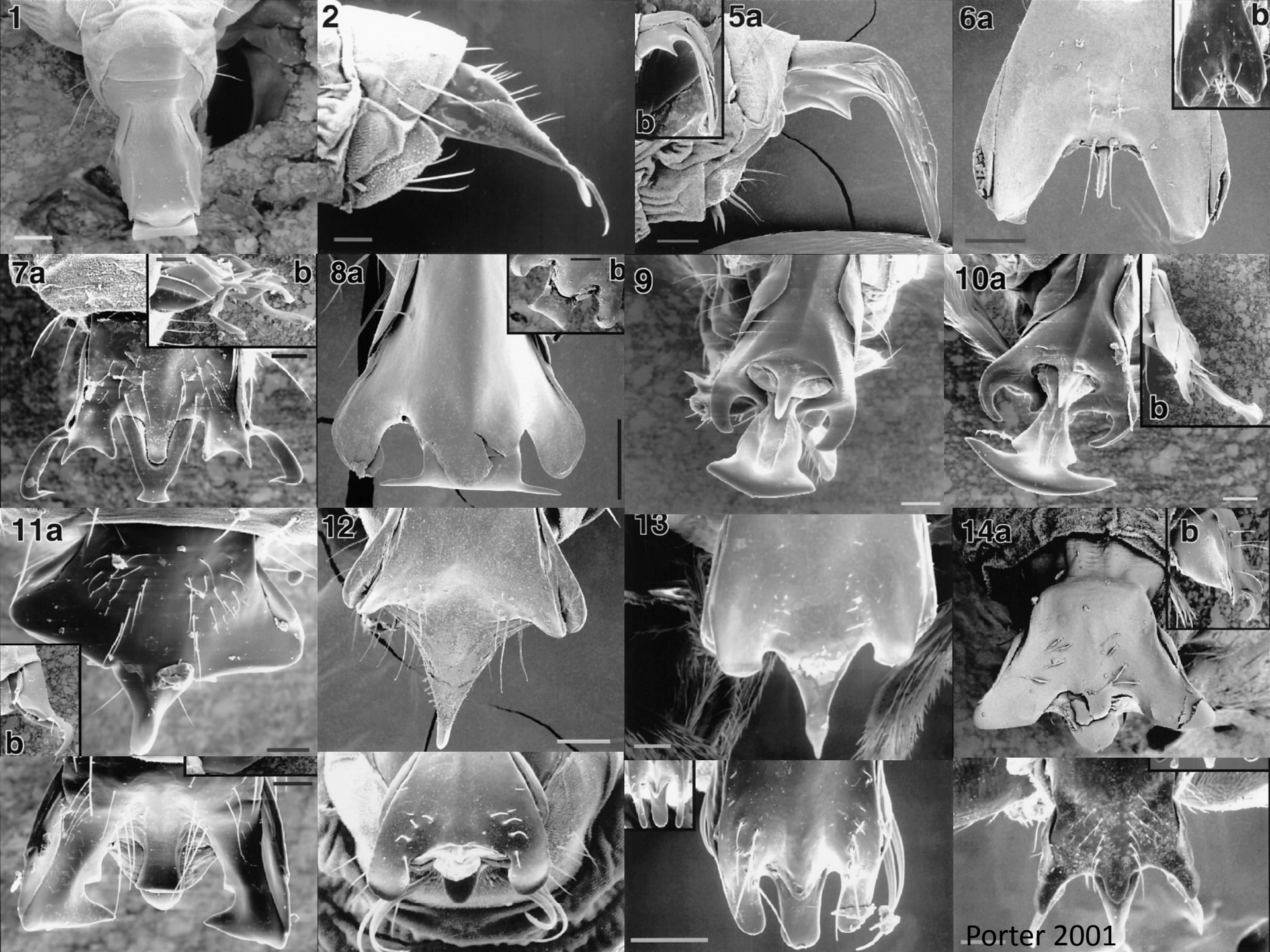



Callcott et al 2010

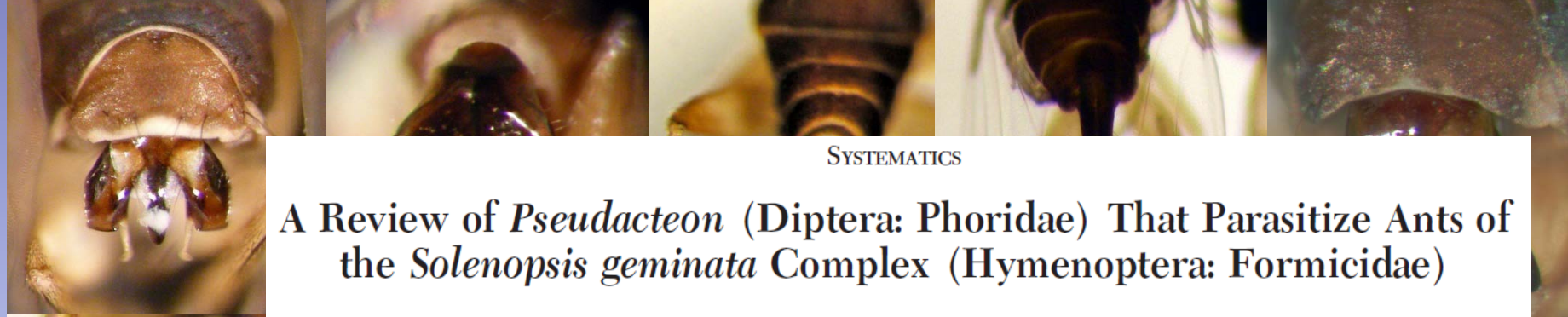
# Status of introductions of *invicta* phorids to North America

| | *tricuspis* | *curvatus* | *obtusus* | *litoralis* | *nocens* | *cultellatus* | *nudicornis* | *small obt* | *disneyi* | *15 other spp* |
|---|---|---|---|---|---|---|---|---|---|---|
| 1. Discovery | x | x | x | x | x | x | x | x | x | x |
| 2. Biological studies | x | x | x | x | x | x | x | x | x | o |
| 3. Importation | x | x | x | x | x | x | x | x | x | |
| 4. Lab Culture | x | x | x | x | x | x | A | A | A | |
| 5. Host Specifity Tests | x | x | x | x | x | x | x | x | | |
| 6. Release Permits | x | x | x | x | x | x | | | | |
| 7. Mass Rearing | x | x | x | s | s | x | | | | |
| 8. Field Release | x | x | x | x | o | o | | | | |
| 9. Establishment | x | x | x | x | o | | | | | |
| 10. Expansion | x | x | o | o | | | | | | |
| 11. Post-Release Tests | x | o | o | | | | | | | |
| 12. Target Impacts | o | o | o | | | | | | | |

x - completed, o - ongoing, s - stopped A - in Argentina




Porter 2001



SYSTEMATICS

# A Review of *Pseudacteon* (Diptera: Phoridae) That Parasitize Ants of the *Solenopsis geminata* Complex (Hymenoptera: Formicidae)

ROBERT M. PLOWES,[1,2] EDWARD G. LEBRUN,[1] BRIAN V. BROWN,[3] AND LAWRENCE E. GILBERT[1]

Ann. Entomol. Soc. Am. 102(6): 937–958 (2009)

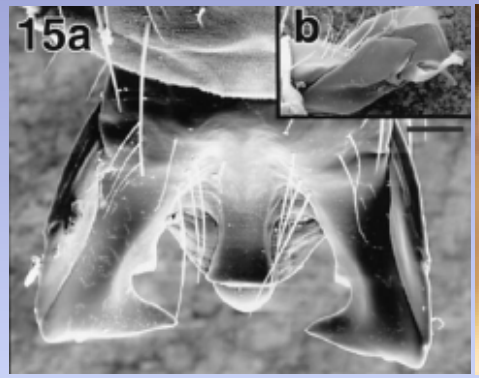
**ABSTRACT** Some phorid flies of the genus *Pseudacteon* Coquillett parasitize workers of *Solenopsis geminata* (F.) complex fire ants. The group is found to comprise at least 21 species of flies, of which 11 are new to science and described here: *P. amuletum*, *P. andinus*, *P. annulus*, *P. catarinae*, *P. deltoides*, *P. hippeus*, *P. kungae*, *P. laticarinatus*, *P. palomita*, *P. quinni*, and *P. robustus*. An identification key to the females is included. This expansion of known *Pseudacteon* species parasitizing the *S. geminata* complex makes it an interesting system for comparison with *Pseudacteon* flies that parasitize fire ants of the *S. saevissima* (Smith) complex.

# Some phorids may have an evolutionary record of host switching

**Host species:** *S. invicta* *S. geminata*

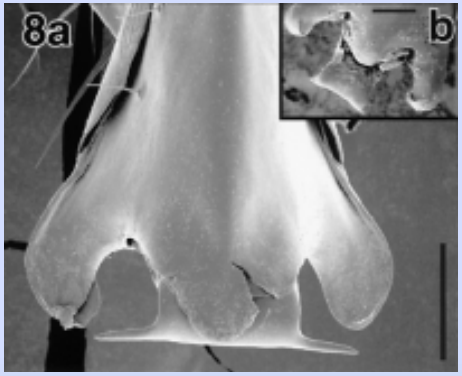

*disneyi*

*arcuatus*

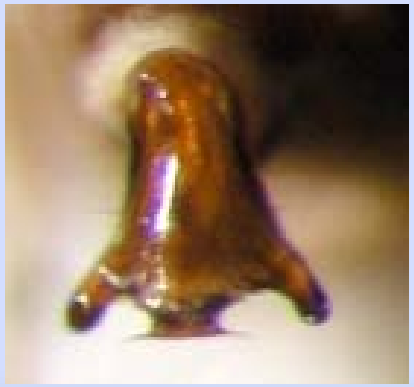



*dentiger*

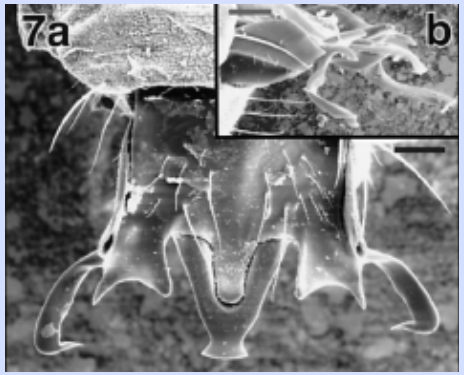
*kungae*



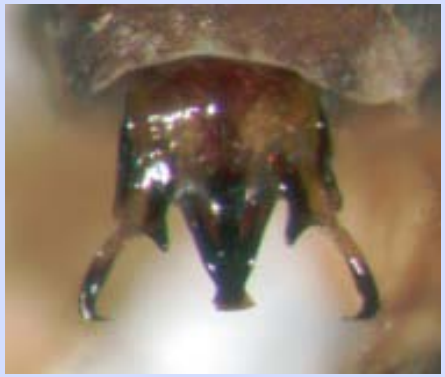

*cultellatus*



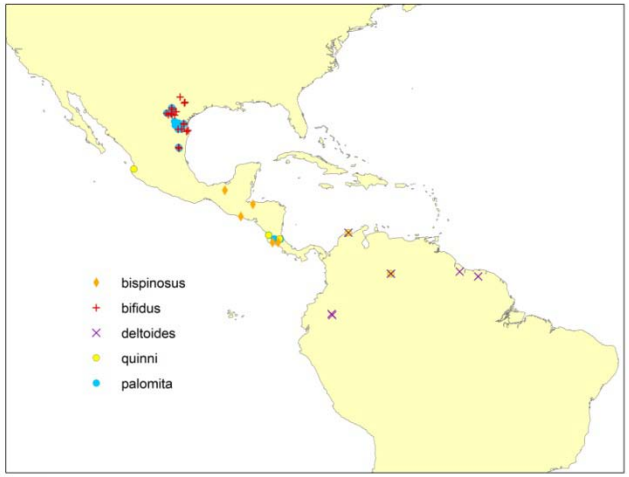
*laticarinatus*

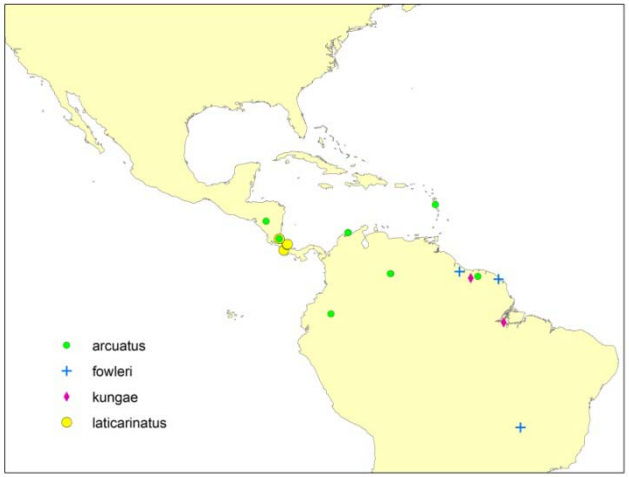


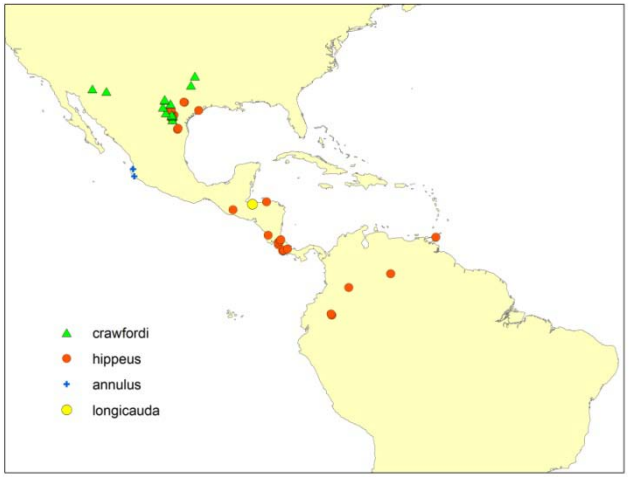

*fowleri*

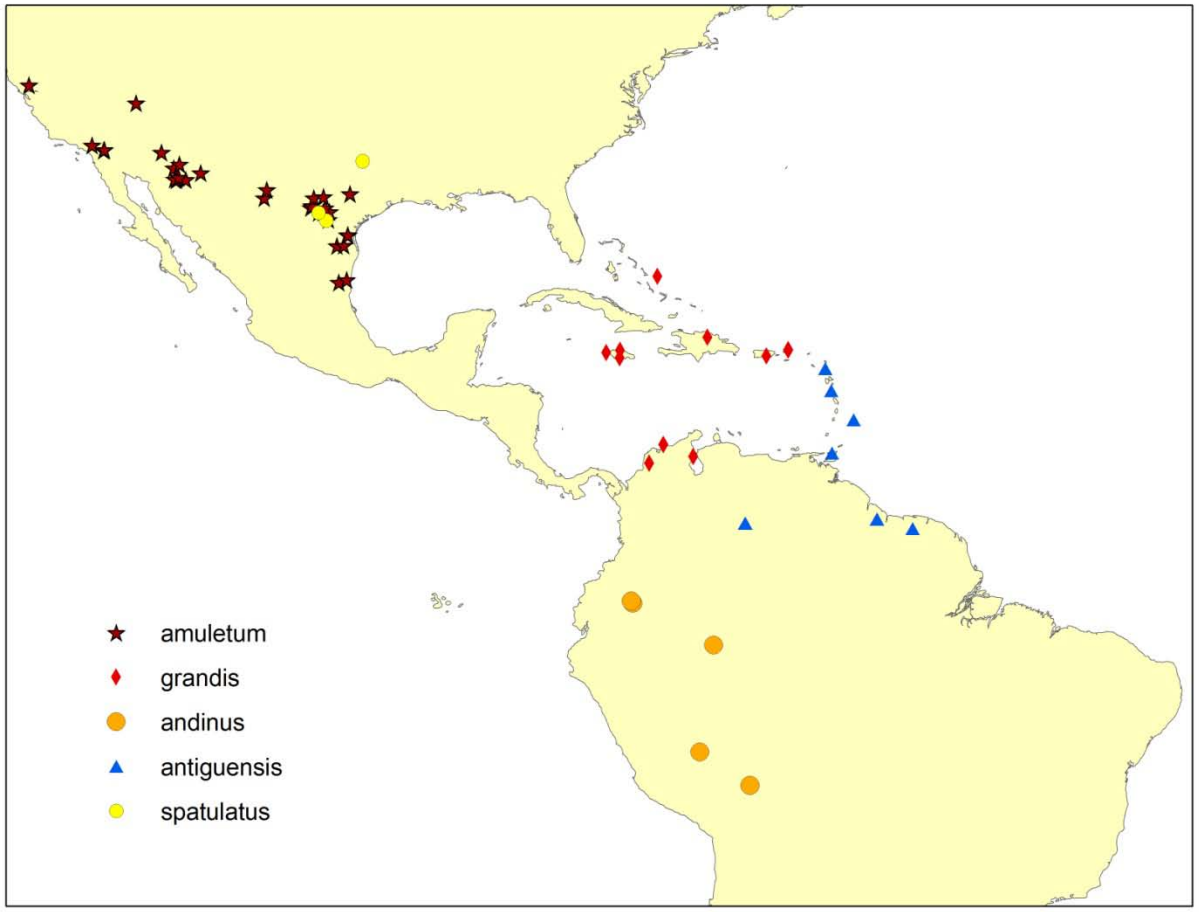


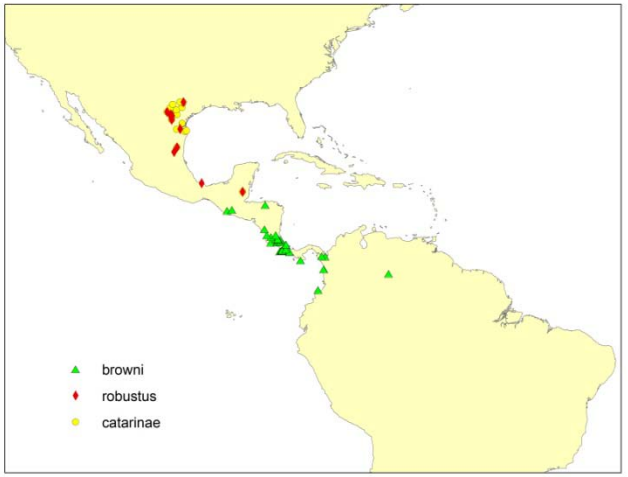
*nr.fowleri*



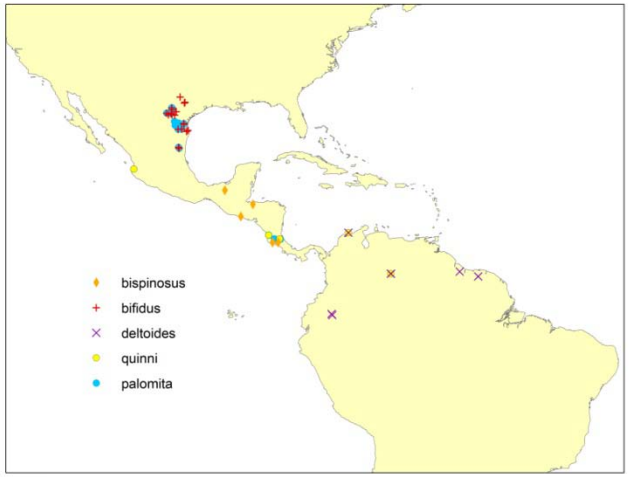



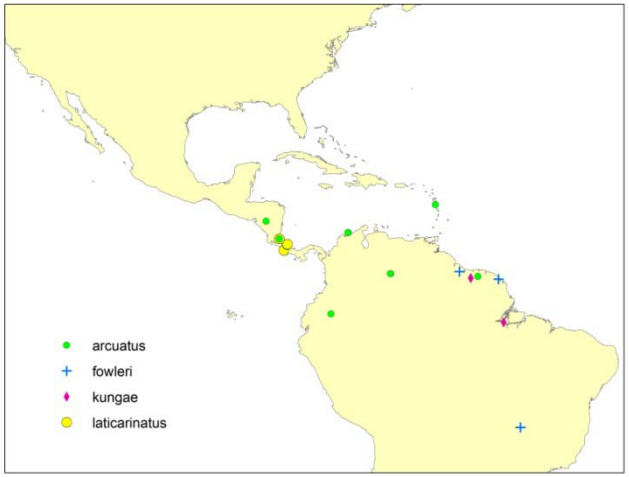



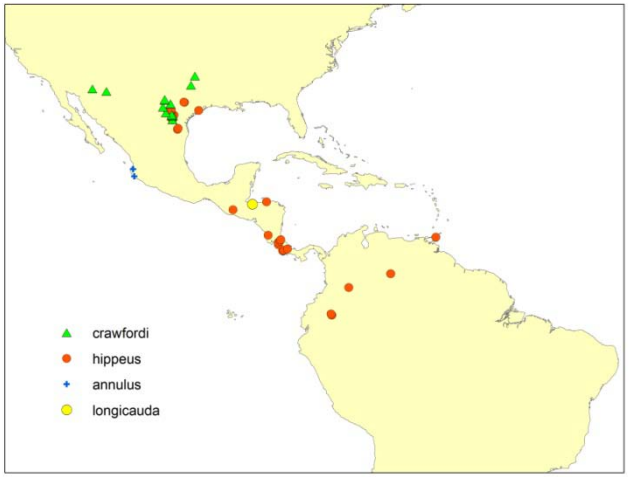



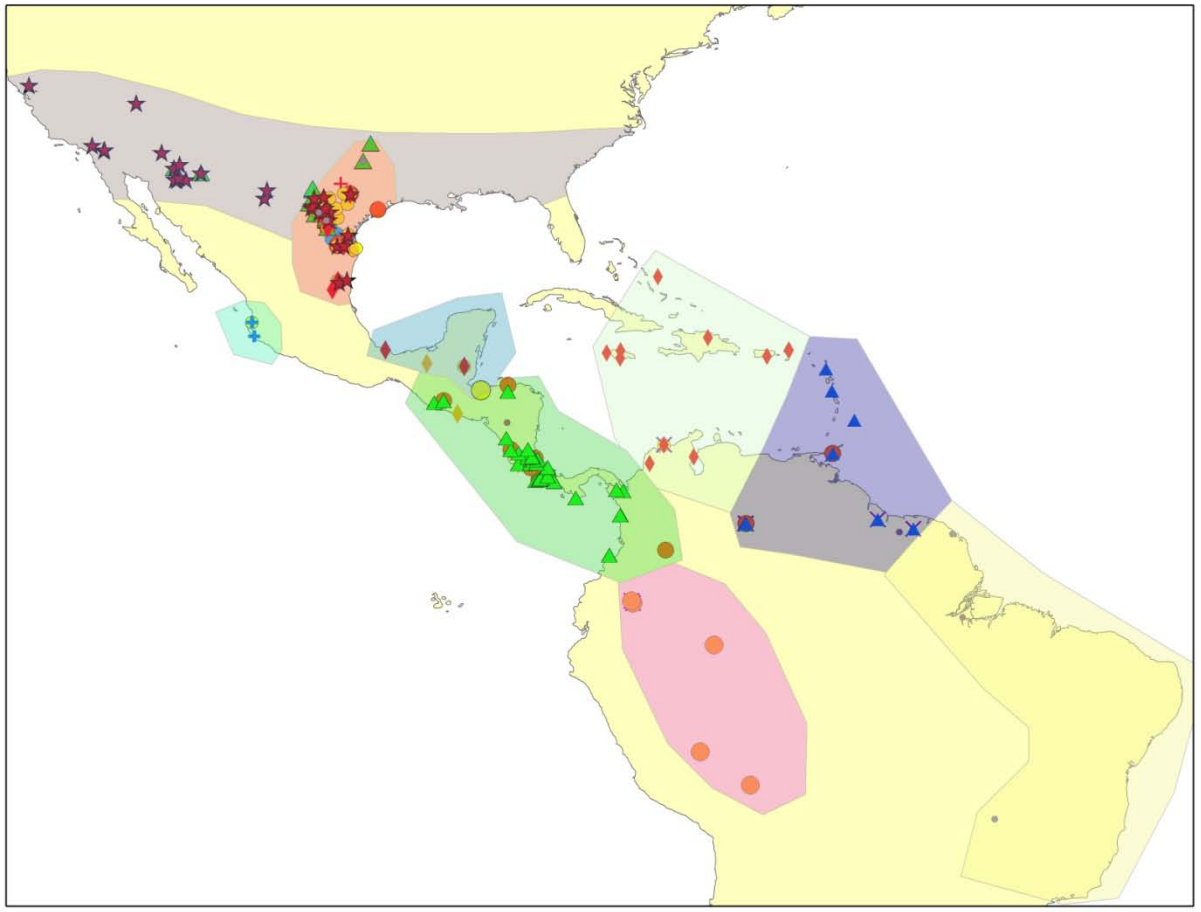



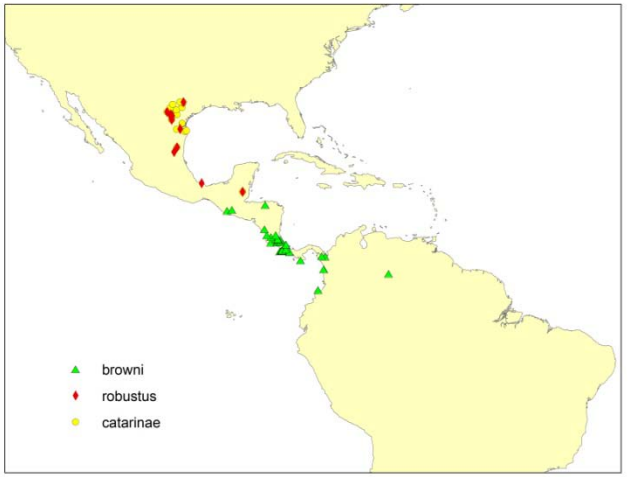

Biogeography of phorids on *S. geminata*



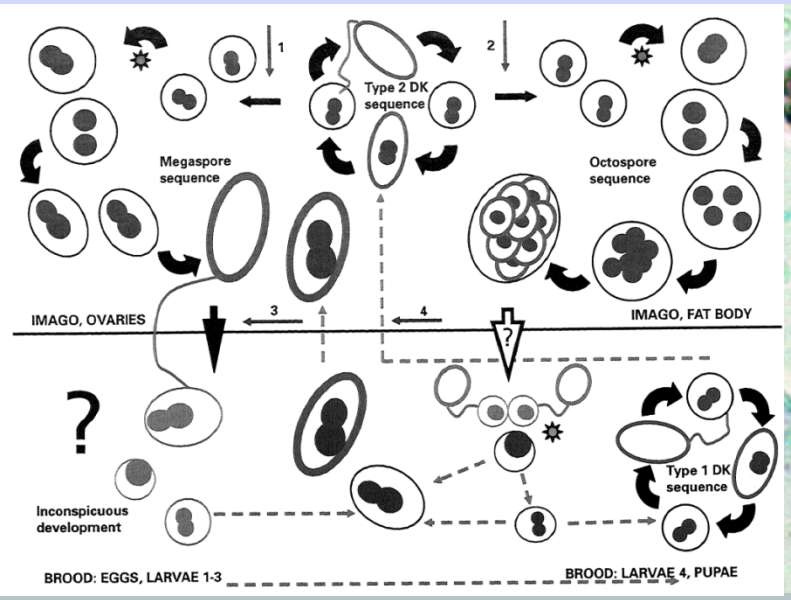





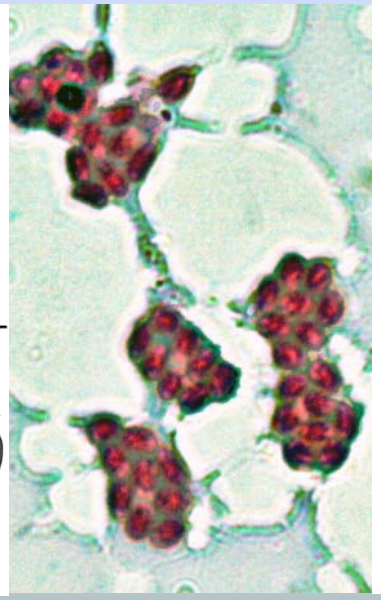

Support for Axen's work on *S. geminata* clades

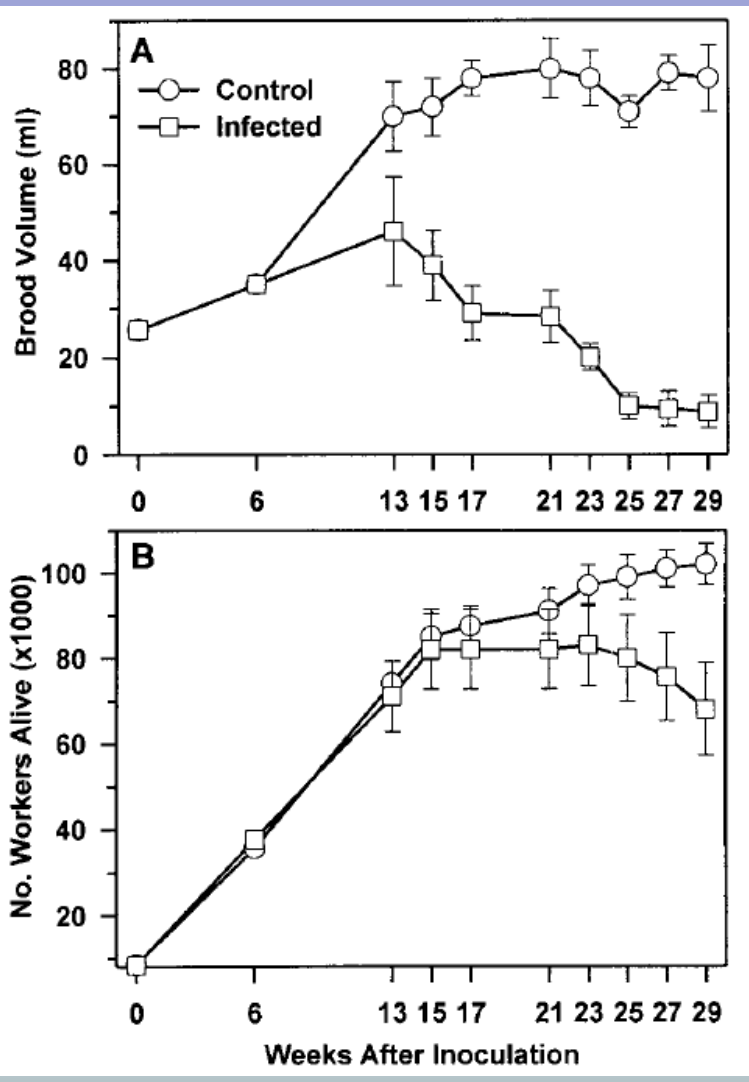
# Microsporidian pathogens

- Specialized parasitic fungi
- Complex life histories: single or multiple hosts, sexual & asexual reproduction.
- *Kneallhazia* has a major impact on colony growth
- May be vectored by phorid flies (Oi et al 2008)




Sokolova & Fuxa 2008






Williams et al 1999

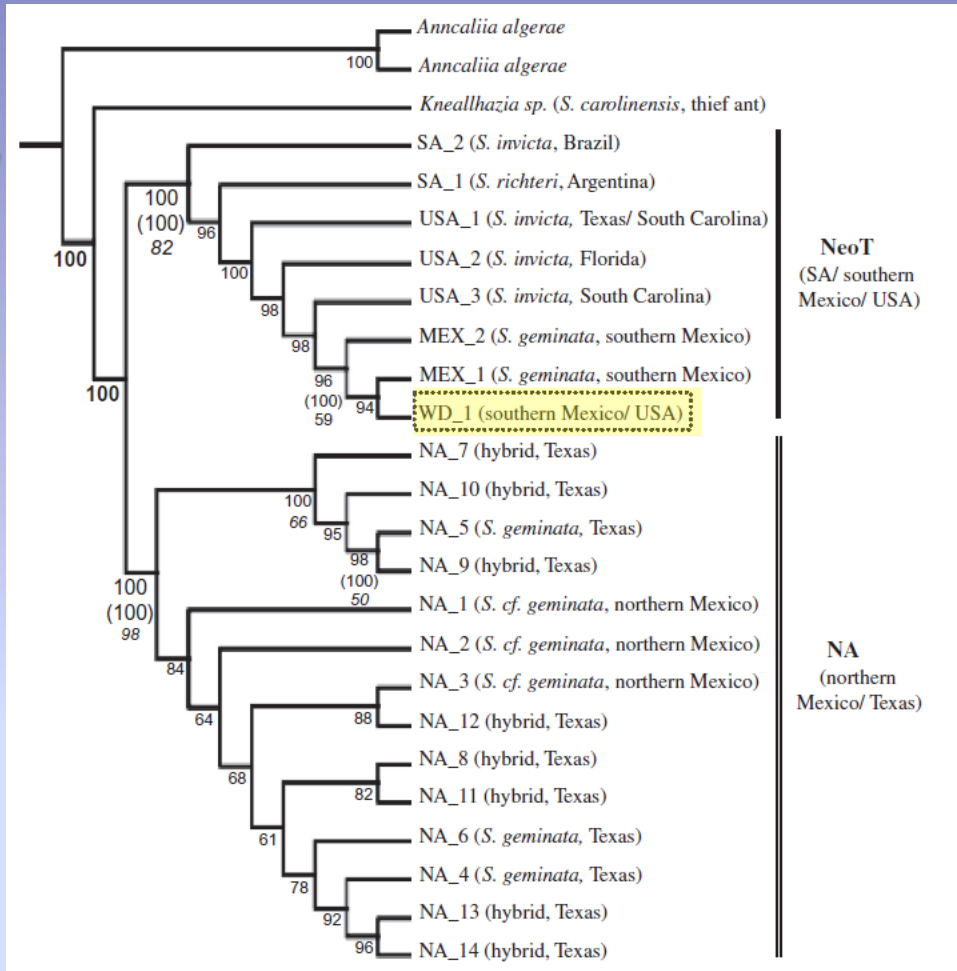
# *Kneallhazia* in *S. geminata*

Neotropical clade:

shared by *invicta & geminata*

North Am clade:

restricted to *xyloni & geminata*




**Molecular diversity of the microsporidium *Kneallhazia solenopsae* reveals an expanded host range among fire ants in North America**

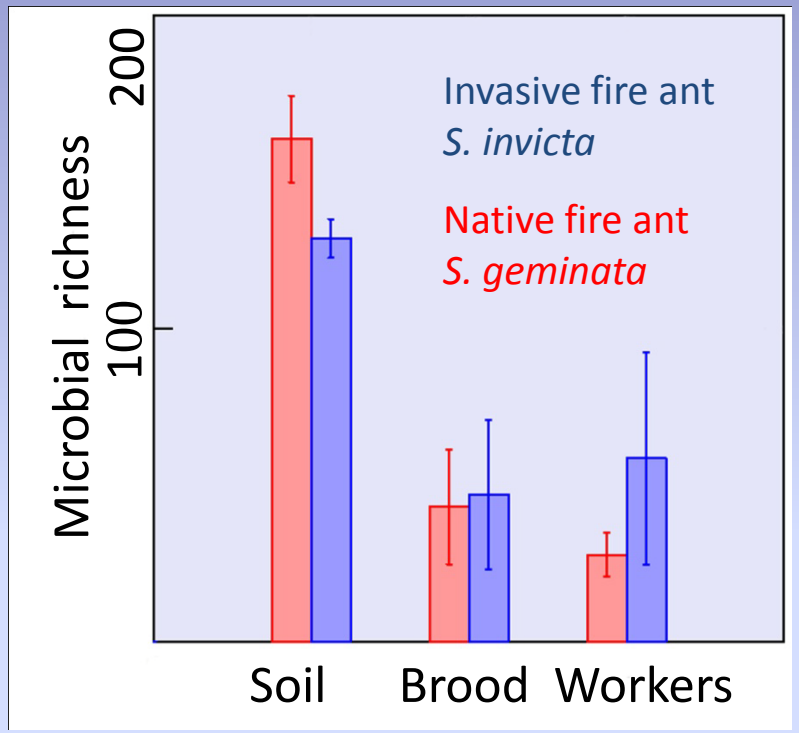
*Journal of Invertebrate Pathology, In Press*

M. S. Ascunce, S. M. Valles, D. H. Oi, D. Shoemaker, R. Plowes, L. Gilbert, E. G. LeBrun, H. Sánchez-Arroyo and S. Sanchez-Peña

# Microbial screens

- 454 Pyrosequencing & Unifrac analysis
- Detects all microbes, not just those culturable
- Gives names and abundances

- Compare native & invasive species
- Probes for symbionts & pathogens




**Bacterial communities in *Solenopsis invicta* and *Solenopsis geminata* ant colonies characterized by 16S-amplicon 454 pyrosequencing**

H. D. Ishak, R.M. Plowes, K. Kellner, R. Sen, E. Meyer, D. A. Estrada, S. E. Dowd and U. G. Mueller

# Status of work on *geminata* parasitoids & pathogens

| | *21 species* | *Kneallhazia* | *Burenella* | *Mattesia* | *Viruses* | *Fungi* | *Bacteria* | *Orasema* | *Mites* |
|---|---|---|---|---|---|---|---|---|---|
| 1. Discovery | x | x | x | x | o | o | o | o | o |
| 2. Biological studies | o | o | o | o | | | | | |
| 3. Importation | US | US | US | US | US | US | US | US | US |
| 4. Lab Culture | o | o | | | | | | | |
| 5. Host Specifity Tests | | | | | | | | | |
| 6. Release Permits | | | | | | | | | |
| 7. Mass Rearing | | | | | | | | | |
| 8. Field Release | | | | | | | | | |
| 9. Establishment | | | | | | | | | |
| 10. Expansion | | | | | | | | | |
| 11. Post-Release Tests | | | | | | | | | |
| 12. Target Impacts | | | | | | | | | |

x - completed, o – ongoing, US – occurs in USA

# Opportunities and challenges with *S. geminata*

**The next steps ….**

- surveys of invasive and source populations to determine origins
- evaluate niche partitioning by *geminata* phorids
- additional studies of pathogen specificity, transmission and virulence
- thorough screening of microbiomes in source and invasive populations
- seek a better understanding of ant immune systems and defenses

# Opportunities and challenges with *S. geminata*

**Challenges …..**

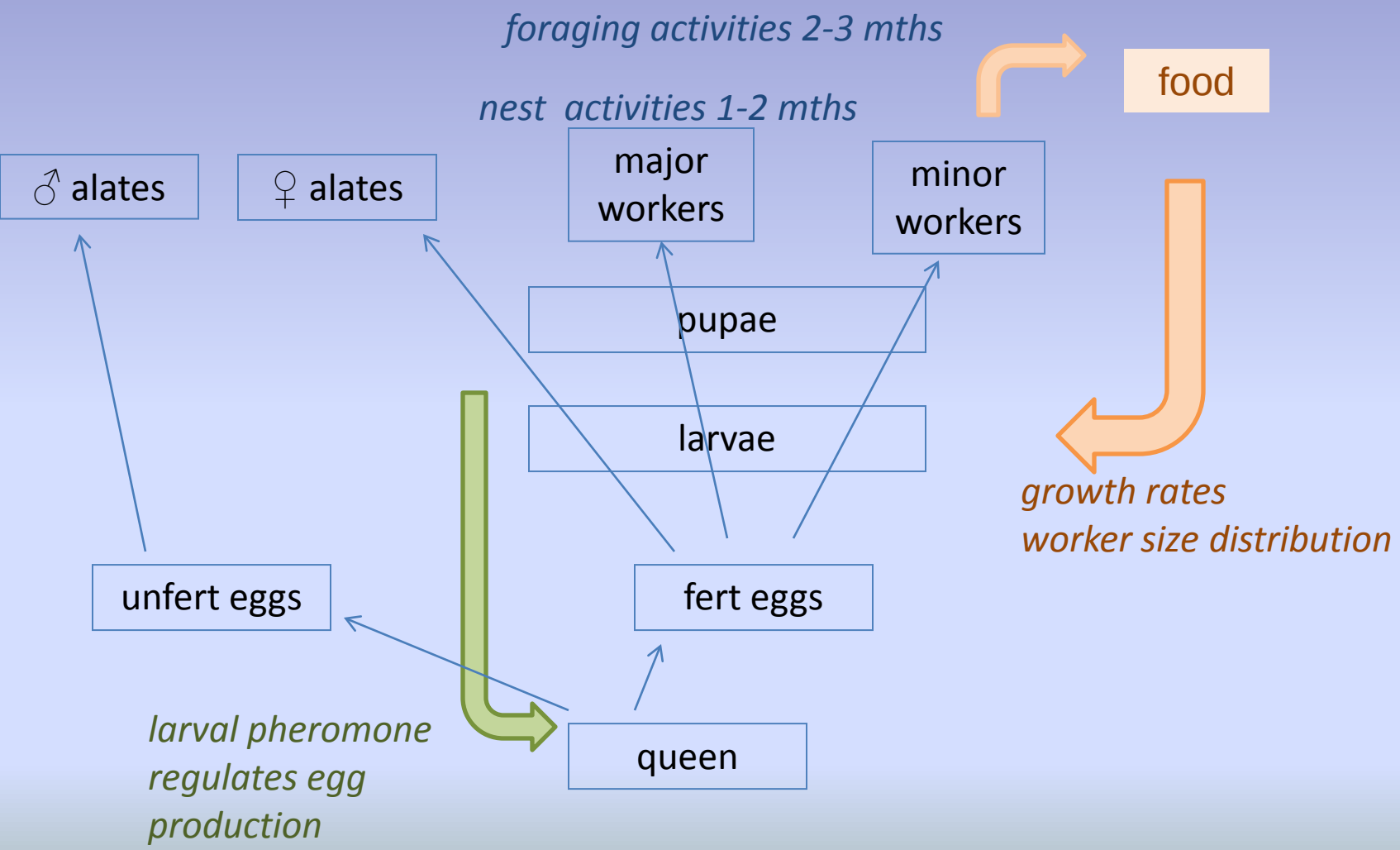
- developing cultures of parasitoids and pathogens
- host specificity testing of candidate BCA's in multiple countries
- evaluating  the most critical islands/ countries
- size of island ant populations relevant to establishment of BCA's
- permitting, coordination and funding in numerous countries

# Impacts of phorids on fire ants

**Levels of ecological organization**

| | |
|---|---|
| **Individual** | direct mortality ~0.5% infection rate |
| **Behavior** | defense, alarm, reduced foraging |
| **Colony** | foraging by major workers inhibited |
| **Population** | generational time scale needed |
| **Community** | successional time scales, noisy data |
| ***Interactions*** | *potential to vector pathogens* |

# Understanding colony dynamics



# Understanding colony dynamics

*foraging activities 2-3 mths*

*nest activities 1-2 mths*

food

♂ alates

♀ alates

major workers

minor workers

pupae

larvae

unfert eggs

fert eggs

queen

direct mortality <3%

Indirect effect

Vectoring ?

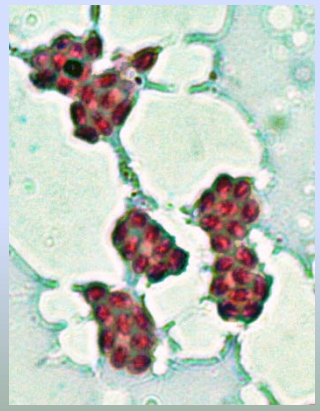
*growth rates*

*worker size distribution*

*mortality*

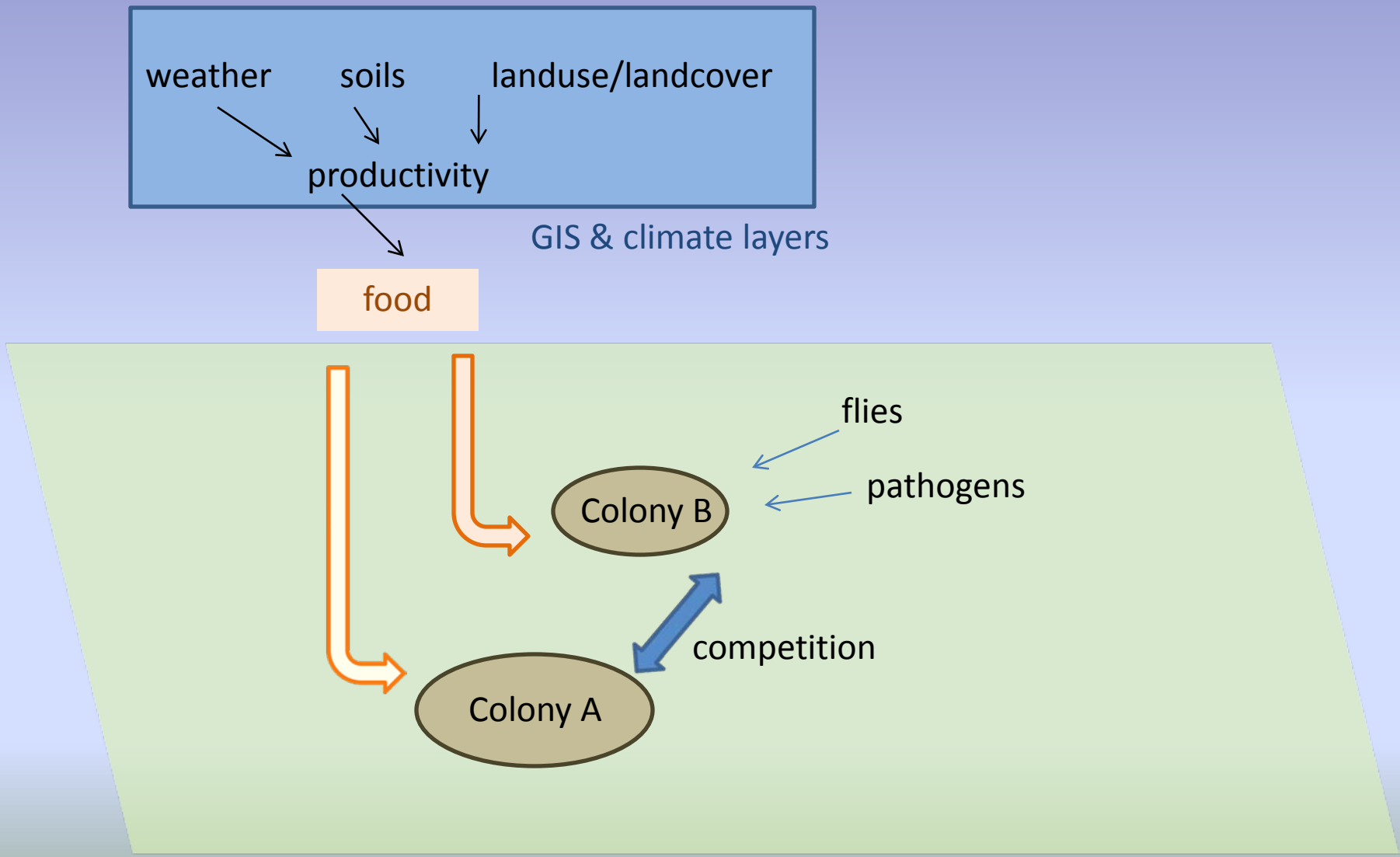
*egg production*

*larval pheromone regulates egg production*



# Fire ant population model

UT Austin & Agrilife Beaumont



# Lessons learned from *S. invicta*

- no silver bullets,  BC impacts diffuse, complex and long term
- will need a suite of potential BCA's
- consider parasitoids as disease vectors
- need to match ant host types with biotypes and genotypes
- complex impact studies & modeling
- new molecular tools:  phylogenetics, markers, 454P surveys

# *Acknowledgements*

Funding:
Lee & Ramona Bass Foundation
Helen C. Kleberg and Robert J. Kleberg Foundation
State of Texas fire ant initiative
University of Texas at Austin

Collaborators:
L Gilbert, E LeBrun, P Folgarait, U Mueller, H Ishak, D Estrada, H Axen, B Brown, S Porter, D Oi, S Valles

Photo credits:
L Gilbert, J Abbott, S Porter, A Wild