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

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

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

**Geminata species group**

Geminata subcomplex

* S. *geminata  
  s US to n S.Am

Xyloni subcomplex

* S. xyloni  
  s US, n Mx
* S. amblychila  
  sw US, n Mx
* S. aurea  
  sw 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
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

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<th>tricuspis</th>
<th>curvatus</th>
<th>obtusus</th>
<th>litoralis</th>
<th>nocens</th>
<th>cultellatus</th>
<th>nuditernis</th>
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x - completed, o - ongoing, s - stopped  A - in Argentina
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. GILBERT¹


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*

- **list of images and labels:**
  - disneyi
  - arcuatus
  - cultellatus
  - laticarinatus
  - dentiger
  - kungae
  - 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*

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

Status of work on *geminata* parasitoids & pathogens

<table>
<thead>
<tr>
<th>Step</th>
<th>21 species</th>
<th>Kneallhazia</th>
<th>Burenella</th>
<th>Mattesia</th>
<th>Viruses</th>
<th>Fungi</th>
<th>Bacteria</th>
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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

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<th>Level</th>
<th>Description</th>
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<tr>
<td>Individual</td>
<td>direct mortality ~0.5% infection rate</td>
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<tr>
<td>Behavior</td>
<td>defense, alarm, reduced foraging</td>
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<tr>
<td>Colony</td>
<td>foraging by major workers inhibited</td>
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<tr>
<td>Population</td>
<td>generational time scale needed</td>
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<tr>
<td>Community</td>
<td>successional time scales, noisy data</td>
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*Interactions*  
*potential to vector pathogens*
Understanding colony dynamics

♂ alates    ♀ alates

nest activities 1-2 mths

major workers

minor workers

food

foraging activities 2-3 mths

pupae

larvae

fert eggs

unfert eggs

queen

growth rates worker size distribution

larval pheromone regulates egg production
Understanding colony dynamics

*Male alates*  
*Female alates*

**Major workers**  
**Minor workers**

**Pupae**  
**Larvae**

**Fert eggs**  
**Unfert eggs**

**Queen**

**Food**

**Foraging activities 2-3 mths**

**Nest activities 1-2 mths**

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

weather  soils  landuse/landcover

productivity

GIS & climate layers

food

Colony B

Colony A

flies

pathogens

competition
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
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University of Texas at Austin

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H Axen, B Brown, S Porter, D Oi, S Valles

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