Ant (Hymenoptera: Formicidae) Fauna of the Marine Port of Savannah, Garden City, Georgia (USA)[1]

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Abstract Seaports act as a critical interface between land and sea for the international transportation of goods and have played an important role in the introduction of exotic ant species worldwide. The objective of our survey was to catalog the ant species residing on and immediately adjacent to the Port of Savannah in Garden City, Georgia, USA. We assessed the ant fauna with pitfall traps, baits, active searching on trees, extraction from leaf litter, and destruction of coarse woody debris (rotting logs) along nine transects in wooded areas. We also collected ants along roadside habitat on and adjacent to Port of Savannah property. In total, we collected 1,300 samples in 2015 and 2016. Forty-five ant species representing 20 genera were cataloged, including 13 exotic species from 10 genera; 65,424 ants were collected during the study. The most diverse genera were *Strumigenys* (six species); *Crematogaster* and *Pheidole* (five species each); and *Camponotus* and *Solenopsis* (four species each). The tawny crazy ant, *Nylanderia fulva* Mayr, which was the most common ant collected (76% of all ants collected along nine transects in wooded areas), is reported here for the first time in Chatham County, Georgia and is the northernmost location from which it has been reported. Owing to the ubiquitous nature of the Formicidae, one or more ant species were present in 97.7% of the study's 1,300 samples.

Key Words seaport, Formicidae, invasive, *Nylanderia fulva*, *Strumigenys*

Seaports are a critical interface between land and sea for the international transportation of goods (Blonigen and Wilson 2006). Moreover, a seaport serves as a key node within international production and distribution networks (Carbone and Martino 2003). Approximately 80% of the world's trade is conducted by vessels traveling among seaports across the globe (United Nations Conference on Trade and Development 2015). A positive correlation between Gross Domestic Product and the importation of exotic species means that economic growth brought about by increasing international trade will also bring with it an increasing number of exotic species (Hulme 2009). Moreover, regions of the globe new to international trade ensure new source pools of potential exotic species, thereby maintaining the rate of introduction of alien species (Seebens et al. 2018). Not surprisingly, ports play an important role in their surrounding ecosystem, serving as an interface between

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ecology and economics and being focal points for the introduction of exotic species (Stohlgren and Schnase 2006).

As Suarez et al. (2005) have shown, port cities along the Gulf Coast of the United States have played an important role in the introduction of numerous exotic ant species into North America and include the red imported fire ant, *Solenopsis invicta* Buren, the Argentine ant, *Linepithema humile* Mayr, the tawny crazy ant, *Nylanderia fulva* Mayr, the bigheaded ant, *Pheidole megacephala* (F.), and its congener, *Pheidole obscurithorax* Naves. In a database of nearly 46,000 first records of 16,000 alien species, 26 species had more than 50 first records; two of the three most common first records were for ants—the crazy ant, *Paratrechina longicornis* (134 first records), and the big-headed ant, *Pheidole megacephala* (92 first records). A majority (58%) of species in the database were represented by a single first record. A first record constitutes the year of first detection of a species that later became established in a region (Seebens et al. 2018).

The Port of Savannah, in Garden City, Georgia is the fourth busiest maritime port in North America and has the greatest potential for future growth among the five busiest ports in the United States (G. Hammer, Georgia Port Authority, Garden City, GA, pers. comm.). Its location, approximately 30 km inland from the Atlantic coast on the Savannah River, would allow invading species to bypass potentially hostile coastal habitats. Monitoring the import and export of potentially disruptive plant and animal species into and from Georgia, and in particular the port of Savannah, is a difficult and ongoing task managed by the cooperative efforts of the Georgia Ports Authority and several government agencies including the USDA, the Georgia Department of Agriculture, the Georgia Forestry Commission, the U.S. Forest Service, and U.S. Customs and Border Protection. While these agencies monitor the cargo arriving at and leaving from the port, the habitable areas surrounding the port remain uninspected. The objective of this study was to catalog the ant species residing on and immediately adjacent to the Port of Savannah in Garden City, Georgia. The survey focused on wooded areas and roadsides, which are conducive to colonization by ants.

Materials and Methods

Site description. The Port of Savannah in Garden City, Georgia (N 32°08′00.00″, W 81°09′00.00″) is located approx. 30 km inland from the Atlantic Ocean on the west bank of the Savannah River. The property consists of a 3-km docking area for container vessels. Immediately adjacent to the docking area are large paved areas for container storage. Beyond this are several forested/green areas fragmented by paved and dirt roads and parking areas. Furthest west from the river is a large rail yard accompanied by more paved container storage.

Thirteen sampling sites within approx. 1 km^2 were chosen based on a preliminary visual assessment of port property. Nine sites located in wooded areas, both on and adjacent to the port, were selected for sampling along linear transects. Additionally, four sites located along paved and unpaved roadsides (300–780 m each, 2,310 m total) were selected to assess the ant community in this highly disturbed habitat (Fig. 1).

Fig. 1. Port of Savannah, Georgia, USA locations where ants were sampled in 2015 and 2016. Yellow lines indicate 90-m wooded transects where ants were sampled every 10 m by each of five sampling techniques—pitfall, extraction from leaf litter debris, bait, extraction from coarse woody debris, and active search on bark of a tree. White lines indicate roadside sampling by baiting and quadrat sampling.

Transect sampling in wooded areas. Forested fragments within the survey area were sampled with 1–3, 90-m transects. Each transect was sampled once during June or July 2015 and 2016. Sampling for ants was conducted with each of five methods: pitfall trapping, extraction of ants from leaf litter, standardized dissection of coarse woody debris, standardized active searching on tree trunks, and baiting. Sampling was conducted over 3 d to allow for 48 h of pitfall activity as described by Agosti and Alonso (2000). The first day consisted of placement of pitfall traps along three transects and the sampling of coarse woody debris, tree trunks, and baits on one transect. On the second day, ants were collected from coarse woody debris, tree trunks, and by bait samples from the two remaining transects. On the third day we collected leaf litter samples and removed pitfall traps. This 3-d protocol was repeated twice more to complete the sampling of all nine transects.

Ten pitfall traps were installed at 10-m intervals along each transect. A pitfall trap was a 9-dram plastic vial (BioQuip Products, Inc., Rancho Dominguez, CA) filled 2 cm with propylene glycol and the inside walls coated with 2.5 cm of PTFE fluoropolymer dispersion (Insect-a-Slip, BioQuip Products, Inc.) to prevent trapped ants from escaping. Propylene glycol acts as a preservative and does not readily evaporate when left in the field for several days. A small area was cleared of leaf litter and debris to expose the topsoil underneath. A hole, approx. 10 cm deep, was drilled with a cordless drill equipped with a 3.2-cm diameter auger bit (Bosch Tool Corp., Mount Prospect, IL). The traps were installed in the ground with the opened top flush with the soil. Traps were covered by a plastic plate, suspended approx. 5 cm above the ground, to prevent them from filling with rainwater. Traps remained in the ground for 48 h before they were collected.

Four additional sample types, each at least 5 m from each pitfall and each other, were collected at each station along each 90-m transect. Leaf litter samples were hand collected by filling a 3.8-L bag with leaf litter and the top layer of soil beneath the leaves from a single location. Bags were then placed in a cooler containing ice and returned to the laboratory (approx. 6 h after collection). In the laboratory, ants were extracted from litter by placing the samples in Berlese funnels where each remained for 1 wk.

Ants were collected from coarse woody debris (a partially rotted log approx. 5–10 cm diameter and no longer than 100 cm in length), dissected in a large white pan, and ants searched for by two people for 5 min (Fig. 2). Aspirated ants were transferred to and stored in snap cap vials containing 75% ethanol.

Trees, approx. 5–20 cm diameter at eye level, were selected and litter, debris, and vegetation removed from around the base. Each tree was visually searched for ants by two people for 5 min. Trees were searched from the ground associated with the root zone to approx. 2 m high. Flashlights were used to enhance visualization of ants. Ants were aspirated from the tree and transferred to and stored in snap cap vials containing 75% ethanol.

Baited traps were made by placing 1 cm of crushed Pecan Sandie cookies (Keebler Company, Battle Creek, MI) in 9-dram vials. Pecan Sandie cookies provide carbohydrates, fats, and proteins and is are common bait used when the sampling of ground-foraging ants is warranted (Ellison et al. 2007). A bait vial was upended, allowing the cookie to fall onto the vial's cap, and the vial was left on its side next to the cap on the ground. After 1 h, ants on the bait were aspirated and transferred to and stored in snap cap vials containing 75% ethanol.

Roadside sampling. Baiting and quadrat sampling were used to catalog the ant fauna from four roadside habitats totaling 2,310 linear meters. The four sites selected surrounded the forested fragments described above. Each site was sampled once during June or July 2015 and 2016. Two of the sites were also sampled in October 2015 and March 2016. Along each roadside, bait and quadrat samples were alternated at 10–25-m intervals. Twenty bait samples and 20 quadrat samples were deployed at three of the four sites on each sampling date. However, the small size of the fourth site allowed for deployment of just 10 bait and 10 quadrat samples.

The baiting methodology described for collecting ants in the forested sites was also used for roadsides. All baiting trials were initiated prior to 0900 h. Baits were placed in a grassy area within 1 m of the road's edge. Quadrat sampling was

Fig. 2. At each station along each transect, ants were sampled from coarse woody debris by dissecting a partially rotted log. (A) Appearance of log prior to and (B) after dissection. Dissected logs were visually searched by two people for 5 min. Aspirated ants were transferred to and stored in snap cap vials containing 75% ethanol.

Fig. 3. Ants were collected from the sandy transition area along roadsides by placing a small quadrat (0.50 $\times$ 0.50 m) on the margin of the pavement and roadside. The area within the quadrat was searched for 5 min and ants aspirated and transferred to and stored in snap cap vials containing 75% ethanol.

conducted by random placement of a 0.50 $\times$ 0.50 m^2 area onto the sand and grass transition area flanking the road (Fig. 3). The area inside the quadrat was then searched, with the aid of a flashlight to help visualize the ants, for 5 min. Vegetation and grass were gently moved and/or removed to highlight ant occurrence. Ants were aspirated and transferred to and stored in snap cap vials containing 75% ethanol.

All ants were identified by B.M.G. using the key of MacGown (2017). Identifications were subsequently confirmed by D.B. (University of Illinois).

Results and Discussion

During this study we collected 65,424 ants, including 45 species from 20 genera, of which 13 were exotic species from 10 genera (Table 1). Fifteen genera were represented by 1–3 species (21 total species) while the remaining five genera were represented by 4–6 species (24 total species). The most diverse genera were *Strumigenys* (six species); *Crematogaster* and *Pheidole* (five species each); and *Camponotus* and *Solenopsis* (four species each). The most recent survey to include Chatham County was conducted by Ipser et al. (2004). In that survey, 27

Table 1. Ant species collected on and around the port of Savannah with collection method and habitat type noted. All identifications made based on MacGown (2017).

Species	Pitfall	Leaf Litter	Log	Tree	Bait	Quadrat	Wooded Transect	Roadside
Aphaenogaster carolinensis Wheeler**	+	+	+	+	+	−	+	−
Aphaenogaster fulva Roger**	+	+	+	+	+	+	+	+
Brachymyrmex depilis Emery	+	+	−	+	−	+	+	+
Brachymyrmex patagonicus Mayr*	−	−	+	+	+	+	+	+
Brachyponera chinensis (Emery)*,**	+	+	+	+	+	−	+	−
Camponotus castaneus (Latreille)	+	−	−	+	−	−	+	−
Camponotus floridanus (Buckley)	−	−	−	+	+	−	+	−
Camponotus pennsylvanicus (De Geer)**	+	−	−	+	+	+	+	+
Camponotus snellingi Bolton**	−	−	−	+	−	−	+	−
Cardiocondyla venustula Wheeler*,**	−	−	−	−	+	−	−	+
Cardiocondyla wroughtonii (Forel)*,**	−	−	−	−	−	+	−	+
Colobopsis impressa Roger**	+	+	+	+	−	−	+	−
Crematogaster ashmeadi Mayr	+	+	+	+	−	−	+	−
Crematogaster atkinsoni Wheeler**	−	−	+	−	−	−	+	−
Crematogaster minutissima Mayr**	+	+	+	+	−	−	+	−
Crematogaster pilosa Emery**	+	+	−	+	+	−	+	−
Crematogaster pinicola Deyrup & Cover**	+	−	+	+	+	−	+	−

Table 1. Continued.

Species	Pitfall	Leaf Litter	Log	Tree	Bait	Quadrat	Wooded Transect	Roadside
Cyphomyrmex rimosus (Spinola)*,**	+	+	+	+	+	+	+	+
Dorymyrmex bureni (Trager)**	–	–	–	–	–	+	–	+
Hypoponera opaciceps (Mayr)*	+	+	+	+	–	–	+	–
Hypoponera opacior (Forel)	+	+	+	+	–	+	+	+
Lasius alienus (Foerster)	+	+	+	+	+	–	+	–
Linepithema humile Mayr*,**	–	+	-	+	–	+	+	+
Monomorium minimum (Buckley)**	+	+	+	+	+	+	+	+
Myrmecina americana Emery**	–	+	–	–	–	–	+	–
Nylanderia concinna (Trager)**	+	+	+	+	+	–	+	–
Nylanderia faisonensis Forel	+	+	+	+	–	–	+	–
Nylanderia fulva Mayr*,**	+	+	+	+	+	+	+	+
Pheidole bilimeki Mayr**	–	–	+	–	–	–	+	–
Pheidole dentata Mayr	+	+	+	+	+	–	+	+
Pheidole dentigula Smith	+	+	+	+	+	–	+	–
Pheidole navigans Forel*,**	+	+	+	+	+	+	+	+
Pheidole obscurithorax Naves*,**	–	+	–	–	+	+	+	+
Pseudomyrmex ejectus (Smith)**	+	–	+	+	–	–	+	–
Solenopsis abdita Thompson**	+	+	+	+	+	–	+	–

Table 1. Continued.

Species	Pitfall	Leaf Litter	Log	Tree	Bait	Quadrat	Wooded Transect	Roadside
Solenopsis carolinensis Forel	–	–	–	+	–	–	+	–
Solenopsis invicta Buren*	+	+	+	+	+	+	+	+
Solenopsis picta Emery**	+	+	+	+	–	–	+	–
Strumigenys louisianae Roger	+	+	+	+	–	–	+	–
Strumigenys membranifera Emery*,**	–	+	–	–	–	–	+	–
Strumigenys ornata Mayr**	+	+	–	–	+	–	+	–
Strumigenys rostrata Emery **	+	+	+	–	–	–	+	–
Strumigenys silvestrii Emery*,**	–	+	–	–	–	–	+	–
Strumigenys talpa Weber**	–	+	–	–	–	–	+	–
Temnothorax curvispinosus Mayr	–	+	–	–	–	–	+	–

* Exotic species (MacGown 2017).
** Species new to Chatham County, Georgia (Ipser et al. 2004).
(+) Denotes a species collected by a sampling method or in a habitat; (–) denotes a species absent from a sampling method or habitat.

Table 2. Trapping statistics for the 2015–2016 ant survey at the Port of Savannah, Georgia, USA.

Trap Type	No. of Samples	No. of Ant Species Collected	No. of Samples Without Ants	Trapping Efficiency (%)*	Maximum No. Species in One Sample	Total No. Ants Collected
Pitfall	180	29	6	96.7	10	47,982
Leaf litter	180	32	2	98.9	10	7,902
Tree trunk	180	32	1	99.4	6	2,021
Logs	180	27	8	95.6	6	2,721
Baiting	380	21	9	97.6	6	2,984
Quadrat	200	14	4	98.0	6	1,814
Total	1,300	45	30	97.7 average		65,424

* % Trapping efficiency for each trap type = 100 − ([no. of samples without ants ÷ no. of samples] × 100).

species from Chatham County were noted, including 15 also collected in our survey. However, Ipser et al. (2004) focused on ground-dwelling species whereas our survey employed several sampling methods aimed at collecting ants from other habitats.

Our survey employed 1,300 samples over multiple sampling dates and time periods. Each collection method on each transect totaled 180 samples over the 2 yr for a combined 900 samples. Each collection method on the roadsides totaled 200 samples over the 2 yr for a combined 400 samples. In only 30 samples were no ants collected, 21 from wooded transects and 9 from roadsides. Owing to the ubiquitous nature of the Formicidae, ants were collected in 97.7% of samples (Table 2).

Among all sampling methods combined on the nine wooded transects, we collected 62,434 ants representing 42 species; 47,434 of the specimens (76%) were *N. fulva*. Both of the collection methods (bait and quadrat) combined on the roadsides collected 2,990 ants representing 16 species (Table 2). Pitfall trapping resulted in the collection of 29 species, leaf litter extraction 32 species, dissection of coarse woody debris 27 species, active searching on tree trunks 32 species, and baits 21 species; active search in roadside quadrats collected 14 species (Table 2). Baiting was conducted in wooded transects and on roadsides. Active search in quadrats was conducted only along roadsides, likely contributing to low species catch when compared to the other methods.

Six species were collected by all sampling methods and from both habitat types: *Aphaenogaster fulva* Roger, *Cyphomyrmex rimosus* (Spinola), *Monomorium minimum* (Buckley), *Nylanderia fulva* Mayr, *Pheidole navigans* Forel, and *Solenopsis invicta* Buren. *Aphaenogaster fulva* and *M. minimum* are native species while the remaining four are exotic. *Nylanderia fulva* and *S. invicta* are invasive

Table 3. Number of ant species and exotic ant species in Georgia and adjacent states.*

State/Port	Total No. Ant Species	No. Exotic Ant Species	Exotic Ant Fauna (%)**
Port of Savannah	45	13	28.9
Alabama	173	28	16.2
Florida	230	65	28.3
Georgia	187	26	13.9
North Carolina	178	13	7.3
South Carolina	155	21	13.5
Tennessee	133	9	6.8

* Species numbers according to Joe MacGown's website "Ants (Formicidae) of the Southeastern United States"; https://mississippientomologicalmuseum.org.msstate.edu/Researchtaxapages/Formicidaehome.html.
** % Exotic ant fauna = (no. exotic ant species $\div$ total no. ant species) $\times$ 100.

species and are known to disrupt ant communities where they occur (LeBrun et al. 2013; Porter et al. 1988; Porter and Savignano 1990).

Nylanderia fulva is reported here for the first time in Chatham County, Georgia and is the northernmost expansion of the species on the east coast of the United States. In Georgia, *N. fulva* was previously reported from Dougherty and Lee counties (2013), Camden and Glynn counties (2014), and Brooks and Lowndes counties (2015) (MacGown 2017; D.R.S., pers. obs.). Its presence on an international seaport poses the question of whether it was transported to this location from another location within the United States or from elsewhere via the seaport. It also highlights the possibility of further transport aided by extensive container movement from the port to and from domestic and foreign locations. The potential for further human-aided dispersal of this species is magnified with its large and growing population on Port of Savannah property. In its introduced range, *N. fulva* has been shown to reduce overall arthropod diversity while favoring the proliferation of co-occurring exotic ant species, which tend to be small-bodied, over co-occurring native ant species. In addition, *N. fulva* displaces the red imported fire ant (LeBrun et al. 2013).

The estimated number of exotic ant species in Georgia is comparable to the number of exotic ant species in adjacent Gulf Coast states (MacGown 2017). Data from MacGown's website suggest an apparent trend of a decreasing number of exotic ant species with increasing distance from states with one or more commercial marine ports of entry (Table 3). The number of exotic ant species in states with one or more marine seaports may highlight the importance of these ports of entry as a means of exotic ant establishment. The large number of exotic species from Alabama, Florida, Georgia, and South Carolina may be explained by their association with moderate climates and warm oceans. These states are where habitats are amenable to establishment of exotic species from tropical regions and are impacted by the abundance of maritime ports of entry.

In recent years there have been a number of published studies aimed at delineating the role of ports responsible for the introduction of exotic ant species. Several port cities in Japan, for example, have a high ratio of exotic-to-native ant species (23% and 64% of the ant fauna), comparable to that at the Port of Savannah (28.9%) in relation to the state of Georgia (13.9%) (Table 3; Harada et al. 2013, 2014). The abundance of exotic ant species in port cities may decrease species richness of the ant community therein, paving the way for further invasion (LeBrun et al. 2013; Sunamura et al. 2007). The importance of monitoring these critical points of entry for invasive ant species has been highlighted by the repeated introduction of exotic species through these pathways (Hulme 2009; Sakamoto et al. 2016; Stohlgren and Schnase 2006; Suarez et al. 2005).

Our survey provides a detailed look into the state of the ant community associated with an international seaport in a moderate climate. International trade brings with it the risk of invasion by exotic ant species; this has attracted interest in the potential for future invasions and their impact in uninvaded areas (Bertelsmeier and Courchamp 2014). The analysis of the trade pathways being exploited by exotic ants warrants further study with a focus on ports as a critical point for interception and eradication (Ward et al. 2006).

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