Survey of Formicidae Attracted to Protein Baits on Georgia's Barrier Island Dunes

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Abstract - Although insects have been identified as valuable bioindicator species, insect diversity in coastal sand dunes is understudied. Our study presents the first survey focused on Georgia's barrier island ant assemblage. We surveyed the primary and secondary dunes of Cumberland, Little St. Simons, and Sapelo islands in the summers of 2016 and 2017 using protein baits to recruit scavenging ants that forage on dunes and beaches. We placed 4863 baits over the 2 sampling seasons; 2458 recruited ants. We documented 29 ant species, including 3 new records for the state: *Dorymyrmex reginicula*, *Pheidole navigans*, and *Solenopsis globularia*. Our survey provides a baseline for future projects to evaluate disturbance and ecosystem health on Georgia's barrier islands.

Introduction

Insects, generally, and ants, specifically, have been understudied on coastal sandy dunes and beaches. As recently as 1990, textbooks on coastal systems mention that insects fail to establish viable populations on beaches (Brown and McLachlan 1990). Research has, however, shown that beetles (Colombini et al. 2017) and ants (Chen et al. 2015) are capable of dwelling in both beach and dune habitats (Barboza et al. 2012). Insects have been suggested as bioindicators in coastal ecosystems (Gonzalez et al. 2014), particularly ants (Chen et al. 2015, Larrea et al. 2016), because they display microhabitat specialization and are easily collected with minimal ecological impact. Healthy ecosystems tend to have high ant species richness (Andersen and Majer 2004, Angulo 2016), a principle useful for investigating the state of island and coastal dune ecosystems. A baseline inventory of the organisms present in a system must be established in order to posit species as bioindicators, but only a handful of studies have investigated the presence of ants on dunes. Dune-dwelling ants have been shown to be a critical component of vertebrate food webs in Cape Cod (Timm and McGarigal 2013), and formicid diversity can be high in disturbed coastal areas that have undergone substantial development such as Nantucket Island (Ellison 2012). Chen et al.'s (2015) work in Mexico collected 121 species of ants in dune habitats, showcasing the potential for rich assemblages in coastal regions. However, no previous survey of ants in Georgia focused on coastal dunes.

Prior to establishing a baseline, examining ant functional groups can be a meaningful initial evaluation of an assemblage. Ant functional groups are useful for determining disturbance levels in ecosystems (Andersen 1995, Andersen and Majer 2004), and the genera comprising functional groups in North America are

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consistent with standards established on other continents (Andersen 1997). When species assemblages have yet to be documented, the diversity (or lack thereof) of encountered functional groups can offer a first glimpse into the robustness and health of an assemblage.

Two statewide and 3 regional surveys have examined ant diversity in Georgia. Wheeler (1913) reported 72 species, which was later reduced to 62 through taxonomic revisions; that list contains little information other than presence. A 2004 survey catalogued ground-dwelling ants in relation to Georgia's major land-resource areas, reporting 96 species (Ipser et al. 2004). The inland dunes along the Little Ohoopee River have also been surveyed, with 77 species collected (MacGown et al. 2009). An investigation of dune disturbance near Fort Benning, GA, encountered 47 ant species (Graham et al. 2008), while Hill and MacGown (2008) compared ant assemblages between inland sandy habitats.

The current survey adds to the knowledge of ants specific to the coastal dunes of Georgia's barrier island ecosystems. The objectives of our survey were to: (1) document the ant assemblage that would recruit to protein baits along the vegetation edge of primary sandy dunes, where shore-nesting vertebrates occur along the Georgia Coast and (2) monitor for invasive species, such as *Nylanderia fulva* (Mayr) (Tawny Crazy Ant), that have been documented in port cities along the Georgia coast.

Field-site Description

The barrier islands of the Georgia coast are considered some of the least developed islands along the entire Atlantic coast of the US (Bratton and Miller 1994). We surveyed Cumberland, Little St. Simons, and Sapelo islands during the summers of 2016 and 2017 (Fig. 1). Cumberland Island is a national park and wilderness area. Little St. Simons Island (LSSI) is a private island managed under the guidance of the Little St. Simons Ecological Advisory Council. Sapelo Island is managed through the Georgia Department of Natural Resources (DNR) and harbors both the Sapelo Island National Estuarine Research Reserve and the University of Georgia Marine Institute. All 3 islands are only accessible via boat or aircraft, but vary in degree of remoteness; LSSI is adjacent to the more developed St. Simons and Sea islands; Cumberland is within sight of commercially developed Amelia Island (to the south) and Kings Island Naval Base (to the west); and Sapelo is the most isolated from mainland development. Although all 3 islands have some degree of historic human habitation and land use, none have undergone major development characteristic of nearby islands connected by a bridge to the mainland.

The islands included in this study contain central maritime-forest habitat, predominantly *Pinus* (pine) and *Quercus virginiana* Mill. (Live Oak), that transition to marsh–estuary (to the west), or dune–beach (to the east) habitats. Both Cumberland and Sapelo islands have well-studied geology and plant communities (e.g., Bratton and Miller 1994, Mallinger 2014, Stallins 2003). The plant species we commonly encountered on the dunes where ant collections took place are listed in Table 1, with grass identifications from Mallinger (2014).

Methods

We made ant collections on each island on the primary dune, which is the foremost dune in the beach-dune profile where vegetation first establishes, and secondary sandy dunes, which are adjacent to but inland of the primary dune (Psuty 2008). During the summers of 2016 and 2017, we surveyed dunes on Cumberland, Little St. Simons and Sapelo islands for ants that would recruit to hot-dog protein baits; preliminary trials indicated hot dogs were as effective as tuna fish and peanut butter for attracting ants, and more manageable to use. We sampled on Cumberland Island from 7 to 18 July in 2016 and 30 May to June in 2017, LSSI from 22 June

Figure 1. The barrier islands of the Georgia coast with the 3 surveyed islands indicated. The dunes of each island were surveyed in the summers of 2016 and 2017, coinciding with the sea turtle nesting season.

to 2 July in 2016 and 19 to 29 June in 2017, and Sapelo Island from 30 July to 4 August in 2016 and 21 to 30 July in 2017. Our plot design (Fig. 2) consisted of 21 traps along the vegetation edge of the primary dune parallel to the shoreline, with a transect of 3 traps running perpendicular to the shoreline into the dune interior every 50 m, for a total of 36 traps per plot during a sample period. We spaced traps 10 m apart, resulting in a 200 m x 30 m grid. We preferentially sampled the vegetation edge because it likely indicates safe nest-sites to beach-nesting vertebrates and the ants of interest in our study. The plot design allowed for investigating ant activity between the vegetation-edge boundary and the more densely vegetated

Table 1. Commonly encountered plant species on Georgia barrier island dunes where ants were collected.

Common name	Scientific name
Beach-tea Croton	*Croton punctatus* Jacq.
Bitter Panicgrass	*Panicum amarum* Ell.
Cabbage Palm	*Sabal palmetto* (Walt.) Lodd. Ex J.A. and J.H. Schultes
Camphorweed	*Heterotheca subaxillaris* (Lam.) Britton and Rusby
Cockspur Pricklypear	*Opuntia pusilla* (Haw.) Haw.
Eastern Prickly pear	*Opuntia humifusa* (Raf.) Raf.
Fiddleleaf Morning Glory	*Ipomoea stolonifera* (Cyrill.) J.F. Gmel.
Glasswort	*Salicornia* spp.
Narrowleaf Silkgrass	*Pityopsis graminifolia* (Michx.) Nutt.
Pennywort	*Hydrocotyle bonariensis* Lam.
Russian Thistle	*Kali tragus* (L.) Scop.
Sea-Oats	*Uniola paniculata* L.
Sea rocket	*Cakile* spp.
Seashore Dropseed	*Sporobolus virginicus* (L.) Kunth
Seaside Morning Glory	*Ipomoea pes-caprae* (L.) R. Br.
Spanish Bayonet	*Yucca aloifolia* L.
Wax Myrtle	*Myrica cerifera* L.

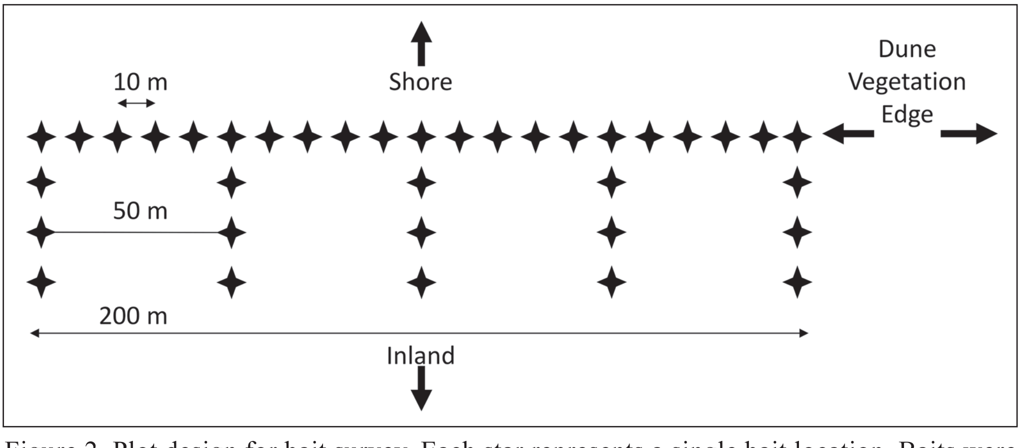

Figure 2. Plot design for bait survey. Each star represents a single bait location. Baits were placed every 10 m along the vegetation edge of the primary dune parallel to the shore. A transect perpendicular to the shore was placed in the dune interior every 50 m to make a 200 m x 30 m grid.

dune interior. In order to sample ants but prevent attracting problematic vertebrate scavengers, we collected traps 3 h after we placed them. We collected morning (06:00–09:00), mid-day (12:00–15:00), and early evening (18:00–21:00) samples at each plot. We sampled 21 plots in 2016 (10 at Cumberland Island, 6 at LSSI, and 5 at Sapelo Island); in 2017, we sampled 10 plots per time period at each island. In addition, collaborators with the Georgia Sea Turtle Cooperative collected ants during the 2016 and 2017 sea turtle nesting season and provided 166 samples collected from sea turtle nests.

We identified ant species using an online key (http://mississippientomologicalmuseum.org.msstate.edu/Researchtaxapages/Formicidaepages/Identification.Keys.htm) developed and maintained by J. MacGown (Department of Entomology and Plant Pathology, Mississippi State University, MS), *Ants of Florida* (Deyrup 2016), and the collection at the University of Georgia Museum of Natural History. We also identified thief ants in the genus *Solenopsis* using Pacheco and Mackay (2013). E. Richard Hoebeke (Georgia Museum of Natural History, University of Georgia, Athens, GA), Ben Gochnour (Department of Entomology, University of Georgia, Athens, GA), and Doug Booher (Field Museum, Chicago, IL) assisted in confirming identifications.

Results

Fifty percent (2458 out of 4863) of the 2016 and 2017 trap placements provided evidence of recruitment activity. We collected 28 ant species through bait sampling, and collaborators on Wassaw Island collected an additional species (Table 2). We deposited voucher specimens at the Georgia Museum of Natural History at the University of Georgia.

Six species—*Solenopsis invicta*, *Forelius pruinosus*, *Pheidole morrisii*, *Dorymyrmex bureni*, *Pheidole bilimeki*, and *Solenopsis globularia*—comprised the majority of the collected assemblage, combining for 94.51% of total incidence abundance in 2016 and 90.95% of total incidence abundance in 2017. Sapelo Island had the greatest diversity, with 23 species, followed by Cumberland Island with 20 species and LSSI with 11 species. The most frequently encountered (incidence abundance) species was *S. invicta* on LSSI and *D. bureni* on Cumberland and Sapelo islands. The most numerous (total individual abundance) species was *S. invicta* on Cumberland Island and LSSI and *F. pruinosus* on Sapelo Island.

We collected 8 of the 9 functional groups developed by Andersen (1995, 1997). The collected groups were Dominant Dolichoderinae, Subordinate Camponotini, Hot Climate Specialists, Cold Climate Specialists, Tropical Climate Specialists, Cryptic Species, Opportunists, and Generalized Myrmicinae (Table 2).

Discussion

Four of the species collected are new or recently encountered published records for the state. *Cardiocondyla venustula* was first collected in Georgia in 2015 (Gochnour 2017). *Solenopsis globularia* is a new record for the state but commonly occurs in sandy soils in Florida (Deyrup 2016). No prior published record of *Pheidole navigans* exists for Georgia, however it has likely been present on both the coastal islands and inland sandhills for some time (J. MacGown's online key) as specimens collected in the US and initially identified as *Pheidole moerens* Wheeler are now all considered likely to be *Pheidole navigans* (Sarnat et al. 2015).

Table 2. List of ant species collected while surveying the primary dunes. Islands/areas where each species was encountered are indicated by first letter: C = Cumberland Island, L = Little St. Simons Island, S = Sapelo Island, and T = sea turtle nests. The state invasive status for each species is indicated by N = native or E = exotic (as defined by MacGown et al. (2009) and Economo and Guénard's antmaps.org (Janicki et al. 2016). * indicates recent record, ** incidates new record. Functional-group classifications are from Andersen (1997). Abbreviations for functional groups are: CCS = Cold Climate Specialists, CS = Cryptic Species, DD = Dominant Dolichoderinae, GM = Generalized Myrmicinae, HCS = Hot Climate Specialists, OPP = Opportunists, SC = Subordinate Camponotini, and TCS = Tropical Climate Specialists. Species also found in the Ohoopee dune survey (MacGown et al. 2009) are marked Y for yes.

Species	Island	Status (native/exotic)	Functional group	Found in Ohoopee Dune survey?
Aphaenogaster flemingi Smith	C, S	N	OPP	
Brachymyrmex depilis Emery	C, S	N	CS	Y
Brachymyrmex patagonicus Mayr	C	E	CS	Y
Camponotus floridanus (Buckley)	C, S, T	N	SC	Y
Cardiocondyla venustula Wheeler	C, S	E*	OPP	
Crematogaster laeviuscula Mayr	S	N	GM	
Crematogaster pilosa Emery	L, S	N	GM	
Crematogaster pinicola Deyrup and Cover	L, S	N	GM	Y
Cyphomyrmex sp.	C	E	TCS	Y
Dorymyrmex bossutus (Trager)	T	N	OPP	
Dorymyrmex bureni (Trager)	C, L, S, T	N	OPP	Y
[A]*Dorymyrmex reginicula* (Trager)	L, S, T	N**	OPP	
Forelius pruinosus (Roger)	C, L, S, T	N	DD	Y
Lasius neoniger Emery	S	N	CCS	
[D]*Monomorium minimum* (Buckley)	L	N	GM	
Nylanderia concinna (Trager)	C, L	N	OPP	
Pheidole adrianoi Naves	C, S	N	GM	Y
[C]*Pheidole bilimeki* Mayr	C, L, S, T	N	GM	Y
Pheidole dentata Mayr	C	N	GM	Y
Pheidole metallescens Emery	C, S	N	GM	Y
Pheidole morrisii Forel	C, L, S, T	N	GM	Y
[B]*Pheidole navigans* Forel	C, S	E**	GM	
Pogonomyrmex badius (Latreille)	C, S, T	N	HCS	Y
Solenopsis abdita Thompson	C, S	N	CS	Y
Solenopsis geminata (Fabricius)	S, T	N	HCS	
Solenopsis globularia (Smith)	C, L, S, T	N,**	CS	
Solenopsis invicta Buren	C, L, S, T	E	HCS	Y
Solenopsis molesta Emery	S	N	CS	
Solenopsis pergandei Forel	C, S, T	N	CS	Y

[A]Could have previously been reported as *D. insanus*.
[B]Could have been previously reported as *P. moerens*.
[C]Reported as *Pheidole floridana*, which is now only confirmed from Miami, FL (MacGown online key).
[D]Without a queen to confirm identification, possibly *M. viridium*, as workers are almost identical to those of *M. minimum* (MacGown et al. 2009).

Dorymyrmex reginicula is a new published record that may have previously been reported as *Dorymyrmex insanus* (Buckley) (D. Booher, pers. comm.).

There are similarities bordering on trends between our collected assemblage and the other surveys that have investigated dune-dwelling ants. Our results are consistent with coastal dune surveys that infrequently collected the majority of species but recorded several abundant species (e.g., Chen et al. 2015, Ellison 2012). The assemblage collected in our study is similar to that reported from the Ohoopee River Dunes (MacGown et al. 2009), where 16 of our 29 species co-occur (Table 2) and all genera we collected were found. However, the conspicuous lack of species such as *Nylanderia phantasma* (Trager), frequently encountered at night on the Ohoopee dunes but absent from our study, indicates night sampling as a meaningful first step to future research on Georgia's barrier islands. The Ohoopee dunes are remnants from a more ancient Georgia coastline but now lay inland and are part of a freshwater system representing a close analog to the coastal dunes we surveyed. The Ohoopee study employed a broad array of sampling techniques and collected 77 species (MacGowan 2009). Conversely, our study's choice of employing only bait sampling to target ants that would potentially recruit to a vertebrate nest still provided 29 ant species. The overlap in assemblages between the 2 surveys implies the dune ecosystems of Georgia's barrier islands harbor a diverse ant assemblage worth further exploration.

The assemblage we collected contained genera from 8 of the 9 North American ant functional groups (Table 2) developed by Andersen (1997). That approach to ant classification was established in Australia (Andersen 1995), where it has been used to evaluate habitat disturbance (Andersen and Majer 2004). Those functional groups, formed at the generic level, appear to be consistent between North America and Australia (Andersen 1997). While the classification scheme is not as well suited for determining disturbance in arid or sparsely vegetated environments (Hoffmann and Andersen 2003), it is useful for analyzing ant communities. Our targeted baiting approach collected most of those functional groups (Andersen 1997), implying that ant assemblages on Georgia's barrier islands are ecologically robust.

The presence of new records like *S. globularia* and regionally endemic species like *Pheidole adrianoi*, a species only found in Georgia, Alabama, and Florida, indicates the potential of Georgia's barrier islands to harbor unique insect fauna while providing ideal habitat to ant species suited to mainland coastal habitats. The presence of newly encountered exotic species also highlights the need for monitoring of these protected areas for potential introductions of community-altering invasive species. Our work, as the first in-depth examination of ants along the Georgia coast, provides a baseline for identifying formicide bioindicators in future habitat-assessment studies.

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