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Exotic spread of *Solenopsis invicta* Buren (Hymenoptera: Formicidae) beyond North America

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Abstract

The South America fire ant *Solenopsis invicta* Buren arrived in Mobile, Alabama by ship sometime before 1945. Since then, *S. invicta* has spread in North America across the southern US and northeastern Mexico. More recently, *S. invicta* has invaded the West Indies and parts of the Old World. Here, I examine this more recent exotic spread of *S. invicta* beyond North America, reporting new West Indian records and questioning some Asian records. In 1981, *S. invicta* was first found in the West Indies, on Puerto Rico. With my new records from Vieques, Aruba, and Jamaica, *S. invicta* is now known from 28 West Indian islands. In 2001, the first Old World populations of *S. invicta* were discovered in New Zealand and Australia. Nascent populations of *S. invicta* in New Zealand have been exterminated and Australia populations have been kept in check through intensive control efforts. Populations of *S. invicta* in Taiwan and China first found in 2003-2004, however, have spread broadly. Published reports of *S. invicta* from Malaysia and Singapore were based on misidentifications, presumably of the more widespread Neotropical fire ant, *Solenopsis geminata* (Fabricius). Reports of *S. invicta* from India and the Philippines seem questionable and need confirmation. Where *S. invicta* has invaded, it has displaced *S. geminata* in open habitats, leaving remnant *S. geminata* populations, primarily in forested areas. In working to limit the spread and impacts of fire ants, it will be important to differentiate among the species, and recognize their similarities and their differences.

Introduction

More than 100 years ago, Forel (1911) compiled a list of 15 tramp ant species, spread by human commerce, which had achieved or were in the process of achieving cosmopolitan distributions. Eight of these have become major ecological, agricultural, and/or household pests: *Anoplolepis gracilipes* (Smith), *Linepithema humile* (Mayr), *Monomorium destructor* (Jerdon), *Monomorium pharaonis* (L.), *Paratrechina longicornis* (Latreille), *Pheidole megacephala* (Fabricius), *Solenopsis geminata* (Fabricius), and *Tapinoma melanocephalum* (Fabricius) (Wetterer 2005, 2007, 2008, 2009a, b, 2011, Wetterer et al. 2009). Over the past 100 years, many additional ant species, not on Forel's (1911) list, have begun to spread around the world. The most notorious of these is the fire ant *Solenopsis invicta* Buren.

Solenopsis invicta is well known for its painful sting, which in humans causes a burning sensation, usually followed in a day or two by the appearance of a white pustule. The venom can cause severe allergic responses and result in secondary infections, sepsis, anaphylactic shock, and even death (Prahlow & Barnard 1998). *Solenopsis invicta* poses a threat to wildlife (Allen et al. 2004). For example, *S. invicta* attacks and kills hatchling sea turtles (Allen et al. 2001, Parris et al. 2002, Krahe et al. 2003, Krahe 2005).

Originally from the grasslands of South America, *S. invicta* arrived in North America by ship at the port of Mobile, Alabama apparently between 1933 and 1945 (Buren et al. 1974) and has spread across the southern US and northeastern Mexico, particularly in open disturbed areas, causing ecological and economic damage. Many studies have documented the current and potential range of *S. invicta* within

North America (e.g., Callcott & Collins 1996, Korzukhin et al. 2001). This dreaded ant is now spreading through the West Indies (Wetterer & Davis 2010) and has recently arrived in New Zealand, Australia, and parts of Asia (Chen et al. 2005, Zhang et al. 2007, Ascunce et al. 2011). Climate tolerance models predict that *S. invicta* should be able to successfully invade many additional regions in both the New World and Old World (Morrison et al. 2004, Sutherst & Maywald 2005). Here, I examine this recent exotic spread of *S. invicta* beyond North America, reporting new records for the West Indies and questioning some published records from Asia.

Methods

Using published and unpublished records, I documented the worldwide range of *S. invicta*. I obtained unpublished site records from museum specimens in the collections of Archbold Biological Station (ABS, identified by M. Deyrup) and the Museum of Comparative Zoology (MCZ, identified by S. Cover). In addition, I used on-line databases with collection information on specimens by Antweb (www.antweb.org), and the Global Biodiversity Information Facility (www.gbif.org).

Geographic coordinates for collection sites came from published references, specimen labels, maps, or geography web sites (e.g., earth.google.com, www.tageo.com, and www.fallingrain.com). If a site record listed a geographic region rather than a "point locale," and I had no other record for this region, I used the coordinates of the largest town within the region or, in the case of small islands and natural areas, the center of the region. I made one exception, for Peru. Trager (1991) and Pitts (2002) both listed *S. invicta* from Peru with no site, but Peru is a large country, so I mapped the record to Esperanza, the city in Peru closest to a known *S. invicta* population (in Brazil). Taber (2000) presented a range map with *S. invicta* only in this part of Peru. In total, I plotted >1600 site records for *S. invicta* (Fig. 1).

Results

I collected *Solenopsis invicta* in the southeastern US and on West Indian islands (vouchers deposited in Harvard University's Museum of Comparative Zoology). I documented *S. invicta* records from 28 West Indian islands (Table 1), including its first records from Vieques (seven sites: Colonia Lujan, trees by pasture, 18.116N, 65.440W, 13 October 2005; Montealta, forest patch, 18.143N, 65.454W, 13 October 2005; west of Puerto Martineau, Route 200 at 4 km mark, 18.141N, 65.479W, 18 October 2005; east of airport, Route 200 at 5 km mark, 18.137N, 65.487W, 18 October 2005; pier turn-off, Route 200, 18.130N, 65.513W, 18 October 2005; Mosquito Pier, *Acacia* near end, 18.148N, 65.513W, 7 June 2006; Santa Maria, baseball field, 18.154, 65.432W, 8 June 2006), Aruba (two sites: Malmok, Tierra del Sol Golf Course, 12.607N, 70.043W, 3 August 2007; Oranjestad, Divi Village Golf Course, 12.538N, 70.058W, 3 August 2007), and Jamaica (one site: Cinnamon Hill, Cinnamon Hill Golf Course, 18.517N, 77.813W, 20 December 2010).

The ISSG (2010) website reported records of *S. invicta* from three of the Cayman Islands (Table 1), citing "Burton, 2003 in Varnham, 2006," though Varnham (2006) gives no specific island records. F. Burton (pers. comm.) could not recall the original source of the *S. invicta* records, however, in 2008, I collected *S. invicta* on Grand Cayman. It would be useful to confirm records from Cayman Brac and Little Cayman.

For published Old World records of *S. invicta*, site records and species identity are well documented for exotic populations in New Zealand, Australia, Taiwan, and China (Table 2). There have been three successive populations of *S. invicta* discovered in New Zealand, and each has been successfully exterminated (MAF Biosecurity 2010).

I was unable to verify reports of *S. invicta* from Malaysia, Singapore, India, and the Philippines (Na & Lee 2001, Rajagopal et al. 2005, Vanderwoude et al. 2006, Sarty 2007, Kuo 2008, Wikipedia 2012).

An and Lee (2001) reported *S. invicta* from Malaysia, Sarty (2007) listed *S. invicta* from Singapore, and Vanderwoude et al. (2006) mentioned *S. invicta* from both Malaysia and Singapore. I e-mailed C.Y Lee, M. Sarty, and C. Vanderwoude asking about the bases of these records. C.Y. Lee (pers. comm.) wrote: "*S. invicta* is not found in Malaysia and Singapore so far. It was a mistake in identification in the Na & Lee (2001) paper." C. Vanderwoude (pers. comm.) sent me copies of Na & Lee (2001) and Sarty (2007) and wrote "I'm scratching around for a better ref for RIFA [*S. invicta*] in Singapore but can't seem to lay my hands on it."

Rajagopal et al. (2005) surveyed ants in Sattur Taluk, Tamil Nadu, India, reporting *S. invicta* from all three habitats studied: riverine, cultivated, and industrial areas. It seems improbable to find high saturation of *S. invicta* in this one small area, but no *S. invicta* anywhere else in India. I e-mailed T. Rajagopal and R. Gadagkar (whom Rajagopal et al. 2005 credited with ant identification). R. Gadagkar (pers. comm.) replied: "I have now confirmed from my colleague Dr. Thresiamma Varghese that she did identify some ant specimens for Rajagopal et al but *Solenopsis invicta* was certainly not one of them."

Kuo (2008) listed *S. invicta* from the Philippines and Wikipedia (2012) included a report of *S. invicta* in the Philippines, which has been paraphrased on many other web sites: "There have also been reports of colonies in metro Manila and the Province of Cavite in the Philippines since July 2005; however, since early 2007, they have spread now as far as the Bicol Region." I could not find an e-mail contact for K.C. Kuo, nor the source of the Wikipedia reports,

Table 1. Earliest known records of Solenopsis invicta from West Indian islands. MCZ = Museum of Comparative Zoology. + = no previously published records.

Earliest record	
Puerto Rico	1981 (Buren 1982)
St Croix, USVI	1988 (Wetterer & Snelling 2006)
Trinidad	1991 (G.L. White, pers. comm.): several sites
San Salvador, Bahamas	1993 (Deyrup 1994)
New Providence, Bahamas	1995 (Deyrup *et al*. 1998)
North Andros, Bahamas	1996 (Deyrup *et al*. 1998)
Guana Island, BVI	1996 (Davis *et al*. 2001)
Gorda Cay, Bahamas	1997 (Davis *et al*. 2001)
Antigua	2000 (Davis *et al*. 2001)
Abaco, Bahamas	2000 (Davis *et al*. 2001)
Grand Bahama, Bahamas	2000 (Davis *et al*. 2001)
Providenciales, TCI	2001 (Davis *et al*. 2001)
Grand Cayman	≤2003 (ISSG 2010)
Cayman Brac	≤2003 (ISSG 2010)
Little Cayman	≤2003 (ISSG 2010)
Berry Islands, Bahamas	2005 (Wetterer & Snelling 2006)
St Thomas, USVI	2005 (Wetterer & Snelling 2006)
St John, USVI	2005 (Wetterer & Snelling 2006)
Tortola, BVI	2005 (Wetterer & Snelling 2006)
+Vieques, PR	2005 (J.K. Wetterer, MCZ): Colonia Lujan
Anguilla	2006 (Wetterer & Davis 2010)
St Martin	2006 (Wetterer & Davis 2010)
Barbuda	2007 (Wetterer & Davis 2010)
Montserrat	2007 (Wetterer & Davis 2010)
St Kitts	2007 (Wetterer & Davis 2010)
Nevis	2007 (Wetterer & Davis 2010)
+Aruba	2007 (J.K. Wetterer, MCZ): Tierra del Sol golf course
+Jamaica	2010 (J.K. Wetterer, MCZ): Cinnamon Hill golf course

Table 2. Earliest known records of *Solenopsis invicta* from the Old World. * = needs confirmation.

Earliest record	
New Zealand	2001 (Harris 2001)
Australia	2001 (Nattrass & Vanderwoude 2001)
*India	2001-2002 (Rajagopal *et al*. 2005)
Taiwan	2003 (Chen *et al*. 2005)
Guangdong Province, China	2004 (Zeng *et al*. 2005)
Hong Kong	2004 (Zeng *et al*. 2005)
Fujian Province, China	2005 (Zhang *et al*. 2007)
Guangxi Province, China	2005 (Zhang *et al*. 2007)
Hunan Province, China	2005 (Zhang *et al*. 2007)
Macau	2005 (Zhang *et al*. 2007)
*Philippines	2005 (Kuo 2008)

which were posted anonymously from two IP addresses in Houston, Texas. G. Alpert and D. General do not include *S. invicta* on their list of ants of the Philippines on antweb.org. D. General (pers. comm.), who worked with *S. invicta* for six years in Arkansas, has been actively searching for *S. invicta* in the Philippines, but so far has not found any. Although I cannot be certain, it seems likely that reports of *S. invicta* from India and the Philippines were based on misidentifications.

Discussion

Sometime before 1945, *S. invicta* arrived in Alabama from South America. *Solenopsis invicta* has since become widespread across the southern US and into northeastern Mexico, with scattered indoor records in more temperate areas (Fig. 1).

Starting about 1980, *S. invicta* began spreading through the West Indies, with the earliest records from Puerto Rico and the US Virgin Islands (Table 1, Wetterer & Snelling 2006). *Solenopsis invicta* is now known from 28 West Indian islands (Table 1). The most recent first records, from Aruba and Jamaica, all come from golf courses. Cinnamon Hill golf course in Jamaica, where I found *S. invicta,* imports sod from Florida. Such importation of sod from Florida may be an important mode of spreading *S. invicta* in the West Indies.

Solenopsis invicta was first recorded in the Old World in 2001 (Nattrass & Vanderwoude 2001, Harris 2001). Nascent populations of *S. invicta* have been exterminated in

New Zealand (MAF Biosecurity 2010) and have been largely kept in check in Australia through intensive control efforts (Vanderwoude et al. 2004). However, *S. invicta* populations in Taiwan and China, first identified in 2003 and 2004 respectively, have spread broadly (Fig. 1, Table 2). Lu et al. (2008) estimated that, based on its geographic spread, *S. invicta* first arrived in China around 1995. There seems to be no geographic or climatic barriers to prevent *S. invicta* from spreading throughout tropical and subtropical Asia (Morrison et al. 2004, Sutherst & Maywald 2005).

Published reports of *S. invicta* from Malaysia and Singapore were based on misidentifications (see above), presumably of the much more widespread fire ant, *Solenopsis geminata* (Fabricius), which invaded Asia from South

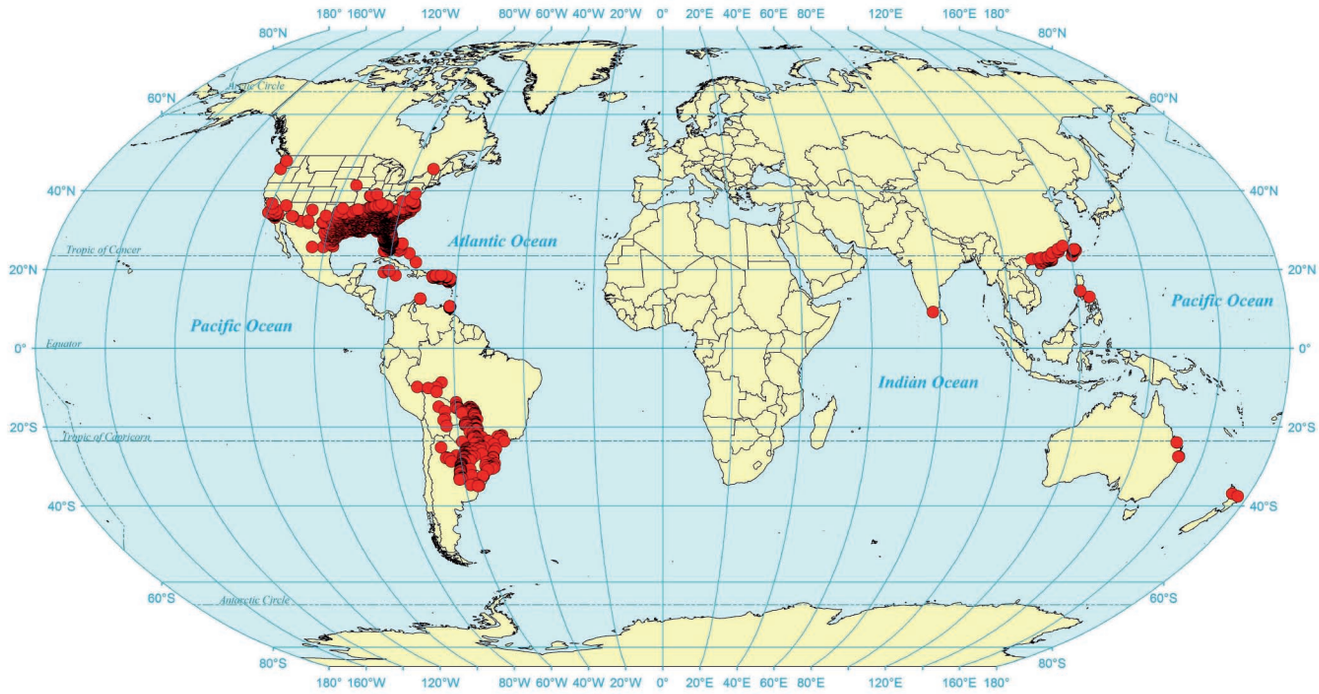

Figure 1. Worldwide distribution records of *Solenopsis invicta*. Records from India and the Philippines are questionable and need to be confirmed (see text).

America more than 160 years ago (Jerdon 1851). Reports of *S. invicta* from India (Rajagopal et al. 2005) and the Philippines (Kuo 2008) are questionable. It would be prudent to try to confirm whether or not *S. invicta* has actually invaded these countries.

Ascunce et al. (2011) analyzed DNA from *S. invicta* populations in Australia, Taiwan, and China and found they all originated from exotic *S. invicta* populations in the US. It seems most likely that *S. invicta* populations in the West Indies also originated in the US, imported on plant products, such as grass sod grown in Florida.

Despite its continued spread, *S. invicta* is still much less widespread globally than is *S. geminata* (see Wetterer 2011). When *S. invicta* invades, it typically displaces *S. geminata*, particularly in habitats preferred by both species: open, grassy areas. As a result, *S. geminata* has largely disappeared from much of its former exotic range in North America (Wojcik et al. 1976). In Florida, Porter (1992) found *S. geminata* at 83% of roadside sites where *S. invicta* were absent, but only 7% of sites where *S. invicta* was present. Models predict that *S. invicta* should be able to invade many tropical and subtropical regions now occupied by S. geminata (Morrison et al. 2004, Sutherst & Maywald 2005). In working to mitigate the spread and negative impact of *S. invicta, S. geminata*, and other fire ants around the world, it will be important to distinguish between these ants, and recognize both their similarities and their differences.

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