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Four decades of inland invasion by Formosan subterranean termite in Alabama: expansion associated with transportation infrastructure

Xing Ping Hu and Nobuaki Mizumoto*

Department of Entomology & Plant Pathology, Auburn University, Auburn, AL, 36849, USA
*: Correspondence: nzm0095@auburn.edu

ORCID: XPH: 0000-0002-2334-037X; NM: 0000-0002-6731-8684
Short title: Distribution of *C. formosanus* in Alabama

Abstract
Invasive termites pose ecological and economic concerns as both cellulose-destroying pests and ecosystem engineers. The Formosan subterranean termite, *Coptotermes formosanus* Shiraki, is listed among the world's worst invasive species and has established invasive populations across continents. Most studies have emphasized their transoceanic international dispersal and establishment in the coastal areas. However, inland expansion at the local and regional scales within the terrestrial landscape has rarely been tracked. Here, we show that expansion of *C. formosanus* is strongly associated with road transportation infrastructure, particularly the interstate highway system in Alabama, USA. We compiled 40 years of distribution records, primarily reported from the Alabama Cooperative Extension Service and the Alabama Pest Control Association. Since its first detection at the Port of Mobile in 1984, *C. formosanus* has been recorded in 32 of 67 counties, with an ongoing increase in detections. Our time-to-detection models indicated that climate, human population density, and the presence of interstate highways were associated with county-level *C. formosanus* infestation, whereas small roads or railway density were not. These results suggest that the spread has shifted from railroad-related infrastructure in the 80s and 90s, after incubation around the city with railroad stations. Our study illustrates a steady northward progression of the species' established range, highlighting the importance of continued monitoring of inland invasion pathways.

Keywords: Invasive species phenology, human-mediated dispersal (HMD), urban entomology

Introduction

The development of human transport networks not only supports social and economic activities but also facilitates the spread of alien species beyond their current distribution ranges (Capinha et al. 2015). Among invasive species, social insects often have a strong impact on native communities and the local economy, with a high proportion of the invasive insect species being social insects (Simberloff and Rejmanek 2019; IUCN 2026). The invasion process of social insects is often complex and species-dependent (Bertelsmeier et al. 2017; Bertelsmeier 2021); e.g., repeated introductions from the native range (Eyer et al. 2021), the bridgehead effect, i.e., a specific introduced area serving as a main source of secondary invasion (Blumenfeld and Vargo 2020; Blumenfeld et al. 2021), and hybridization between invasive and/or native species (Fournier and Aron 2021). Thus, it is essential to track the invasion process at both global and local scales to understand the biotic and abiotic factors affecting the expansion of anthropogenic distributions, helping predict and prevent future invasions.

The social insect species with the highest estimated economic costs globally is the termite *Coptotermes formosanus* Shiraki (Blattodea; Heterotermitidae), with annual costs of 30 billion US dollars (Bradshaw et al. 2016; Cuthbert et al. 2022). In addition to being a major structural pest (Rust and Su 2012; Evans et al. 2013), *C. formosanus* can infest and travel with mobile structures (Hu 2026) and affect urban and suburban forest ecosystems by infesting living trees (Evans et al. 2019; Evans 2021; Chouvenc and Brown 2025). Originating in eastern Asia, it has expanded its distribution by anthropogenic transport, especially in the USA, across Hawaii, the southeastern USA from Texas to North Carolina, and California (Blumenfeld et al. 2021), as well as a recent record in Israel (Scheffrahn et al. 2020). Its successful spread across the Pacific islands, the Florida Peninsula, and the Gulf Coast is clearly owing to its capacity for ship-borne introduction, with privately owned boats serving as key vectors for local and global colony dispersal (Scheffrahn and Crowe 2011; Scheffrahn 2023; Chouvenc 2025). Detailed distributional records from Florida State support this model in which maritime commerce facilitated repeated introductions and coastal footholds (Chouvenc 2026). However, once established in port cities, the mechanisms of inland spread across terrestrial landscapes remain under-quantified.

Alabama provides a tractable system for examining inland expansion following a single major coastal introduction. Alabama consists of 67 counties, of which only two have access to the Gulf Coast. The first *C. formosanus* detection was in 1984 at the Port of Mobile (Su and Scheffrah 1986), the only major port, suggesting that maritime introduction was the initial entry pathway. Over the subsequent four decades, *C. formosanus* has expanded its distribution in the terrestrial landscape northward (Sponsler et al. 1988; Stephen 2012). Given the limited natural dispersal distance of alates, human-mediated overland transport is likely to have contributed to this expansion (Messenger and Mullins 2005; Simms and Husseneder 2009; Mullins et al. 2015; Mizumoto 2026). Early observations suggested infested railway cross ties are the primary source of *C. formosanus* spread (Austin et al. 2008), yet the relative contributions of different transportation network systems remain untested in the inland spread of *C. formosanus* termites.

Here, we document and analyze 40 years of county-level detection records of *C. formosanus* in Alabama, compiled primarily from reports by the Alabama Cooperative Extension System and the Alabama Pest Control Association. Using time-to-detection modeling, we tested whether inland expansion is associated with climatic suitability, human population density, and transportation infrastructure, including interstate highways, secondary roads, and railways. Using the model, we evaluated the future detection risks for counties without records yet. Our results provide quantitative evidence for infrastructure-associated inland expansion of *C. formosanus*. Our findings underscore the importance of continuous monitoring of invasive termites beyond the initial detection and establishment in the coastal area.

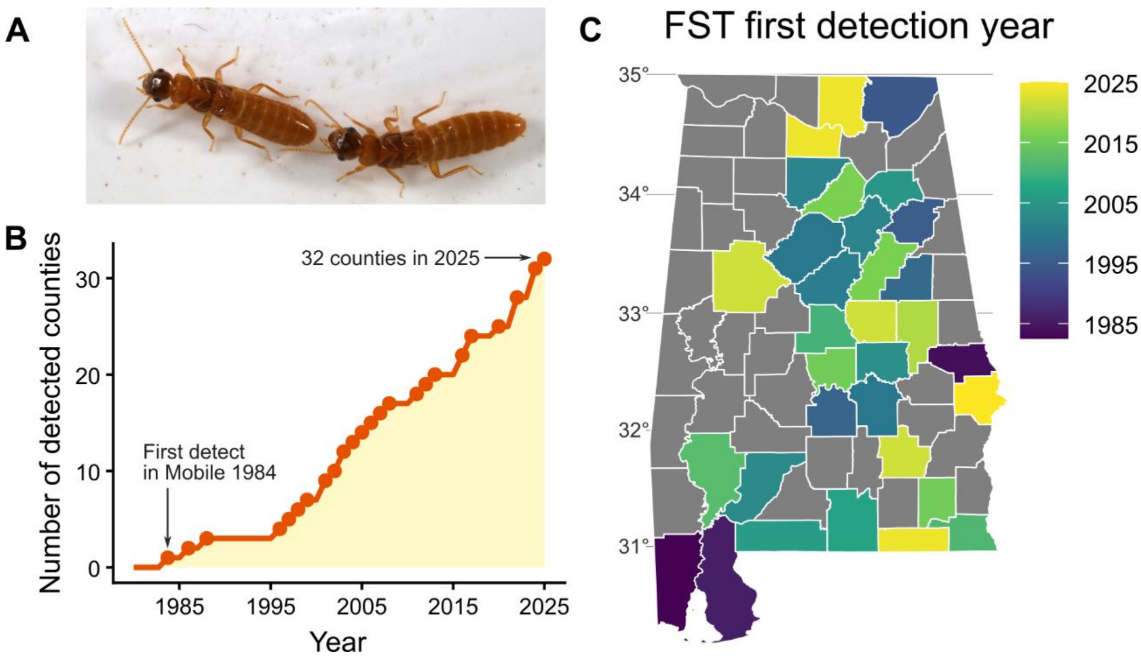

Figure 1. The expansion of the detection of *C. fomorsanus* termites in Alabama. (A) A mating pair of *C. formosanus* in tandem running, which is the most commonly observed form for the general public after the seasonal swarming flight. (B) Time development of the cumulative number of counties with *C. formosanus* detection. (C) County map of Alabama with the first detection year of Formosan subterranean termites (FST).

Materials and Methods

Data collection

All data were collected through multiple survey efforts, mostly via samples submitted to the authors or to the Auburn University Plant Diagnostic Laboratory by residents, professional pest control operators, and Extension agents in Alabama. Submitted samples were identified using dichotomous keys (Weesner 1965; Scheffrahn and Su 1994). To facilitate the submission, Alabama Cooperative Extension System initiated two series of Awareness educational programs: 1) a train-the-trainer program focused on educating county extension agents, who in turn made the information and educational materials available to clients of each county; 2) collaboration with Alabama Pest Control Association, focusing on pest management professionals. In addition, extension articles on termite biology and management methods were developed and disseminated to homeowners and residents across the state. In 2025, we also performed the distribution survey as part of the North American Termite Survey (NATS) by distributing the sticky traps for alate collections. In summary, intensive field collections were conducted in cooperation with county extension agents and pest management professionals in counties with records of *C. formosanus*.

Historical records of *C. formosanus* in Alabama were primarily maintained by Extension specialists, including specimens and field notes. However, voucher specimens are no longer accessible, and no centralized archive of voucher specimens exists before 2023. All records from published sources, Extension reports, and the authors' observations are summarized in the Appendix. And all locational information with metadata will be stored and shared by EDDMapS of *C. formosanus* (EDDMapS 2026), upon acceptance of the manuscript.

Most samples and records *of C. formosanus* termites are alates during seasonal mass dispersal events. In Alabama, it usually occurs from April to June, depending on latitude and temperature. The presence of alates is considered to represent an established infestation of *C.*

formosanus (Su and Scheffrah 1986). First detection events are typically associated with swarming dispersal flights that are attracted to urban lights near human property or even inside buildings. This leads to the seasonal surge of phone calls to the Extension agency (Appendix). Thus, the first detection year, based on reports from homeowners, pest control professionals, and Extension agencies, is considered to approximate the year the area was established, rather than temporal changes in sampling efforts.

Data analysis

To investigate the biotic and abiotic factors associated with the county-level first-detection year of *C. formosanus*, we used a Cox proportional hazards model (Reino et al. 2009). Setting 1984, the first report of *C. formosanus* in Alabama in Mobile, as a starting year, we measured the years until detection for every county. We treated the county without any records in 2025 as a censored observation. As factors potentially affecting the detection year, we included the latitude (proxy of climate), human population density (/km^2), the density of primary and secondary roads (/km^2), the density of railroads, and the presence of an Interstate highway (Fig. 2). County-level information of these variables was obtained using the "sf" package v1.0-24 (Pebesma 2018) and the "tigris" package v.2.2.1 (Walker 2016) in R. The information was based on 2024 data, except for railroads, which were based on 2011 data. The primary and secondary roads include the Federal interstate highway system, main arteries, usually in the U.S. highway, state highway, or county highway system, according to the Census Bureau (Walker 2016). All the variables were scaled using the z-value transformation. We used the coxph() function in the "survival" package (Therneau 2001) in R, without considering interactions between variables. Both covariates of any variables and the global model did not violate the assumption of the proportional hazards assumption, according to the function cox.zph() (all $P > 0.10$; global test $P = 0.40$). Pairwise correlations among variables also confirmed that most correlations were low to moderate (Spearman's $\rho < 0.45$), although population density and road density showed a strong positive correlation ($\rho \approx 0.81$). All analyses were performed using R v4.5.2 (R Core Team 2025).

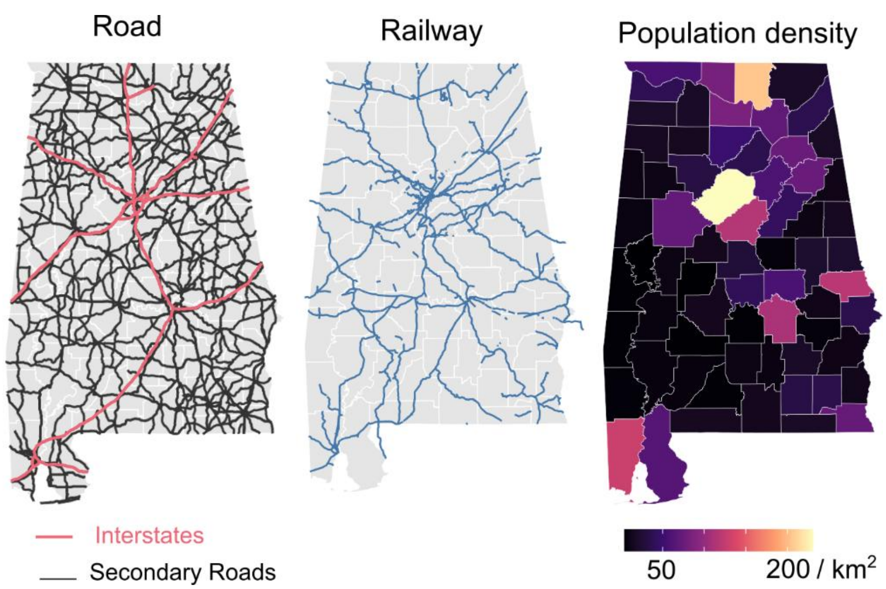

Figure 2. Human transportation infrastructure and population densities in Alabama as potential factors affecting the expansion of *C. formosanus*. We investigated the effects of road and railway density (km/km²) for each county, the presence of an Interstate highway, human population density, and latitude.

Results

The first confirmed *C. formosanus* infestation was identified from a termite collection in Mobile, made in 1984, and reported by (Su and Scheffrah 1986). Over the past 40 years, a collective effort has identified many *C. formosanus* infestations. As of 2025, the number of counties with verified *C. formosanus* infestations has increased to 32 (Fig. 1B). Jackson and Madison counties represent the northernmost inland range in Alabama (Fig. 1C), and thus, all counties in Alabama can potentially be infested by *C. formosanus*. The increase in the number of reported counties has not yet saturated (Fig. 1B).

Our Cox proportional hazard model estimated that the latitude, human population density, and the presence of Interstate highways (i.e., I-10, I-20, I-59, I-65, I-85, and their Auxiliary Highways) had significant effects on the early detection of *C. formosanus* in each county. The presence of the interstate highways had the largest effect on detection timing (Hazard ratio: HR = 2.65; 95% confidence interval: CI = 1.16-6.07; $\chi^2_1 = 5.31$, $P = 0.021$; Fig. 3), where counties with interstates were 2.65 times more likely to detect *C. formosanus* compared to counties without an interstate. Latitude also showed a large effect as the most significant factor (HR = 0.44; 95% CI = 0.28-0.69; $\chi^2_1 = 13.22$, $P < 0.001$; Fig. 3). Higher latitude reduced the hazard of detection by 56%. Finally, human population density significantly increased the hazard of detection (HR = 1.74; 95% CI = 1.12-2.71; $\chi^2_1 = 5.26$, $P = 0.022$, Fig. 3). On the other hand, we did not the significant effects of rail density (HR = 1.08; $\chi^2_1 = 0.12$, $P = 0.73$, Fig. 3) or road density (HR = 1.23; $\chi^2_1 = 0.64$, $P = 0.42$, Fig. 3).

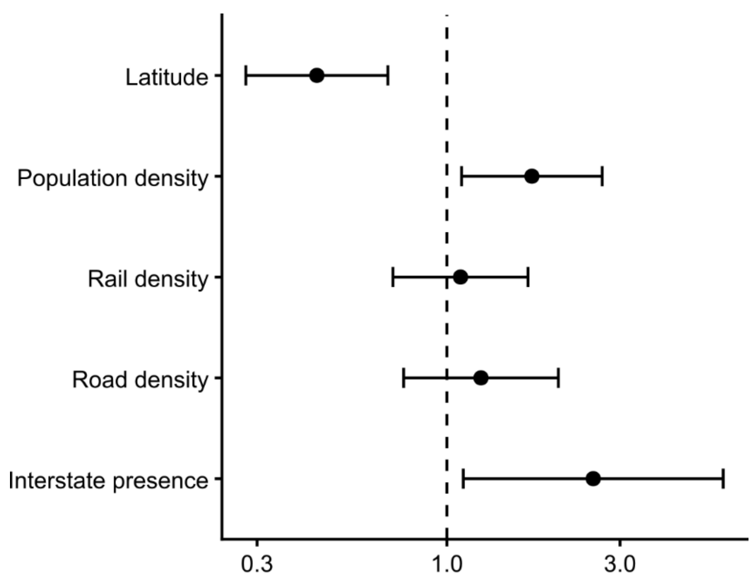

Figure 3. The forest plot of hazard ratios ± 95% CI from the Cox proportional hazards model for factors affecting county detection of *C. formosanus*. HR values > 1 indicate increased hazard.

Using the Cox proportional hazard model, we estimated the counties without *C. formosanus* records so far, but the highest risk of detection (Fig. 4). The 10 counties with the highest risks are as follows: Conecuh, Butler, Coffee, Macon, Sumter, Greene, Chambers, Limestone, Henry, and Crenshaw, where the probabilities of detecting *C. formosanus* in 2025 were from 77.1% (Conecuh) to 45.4% (Crenshaw).

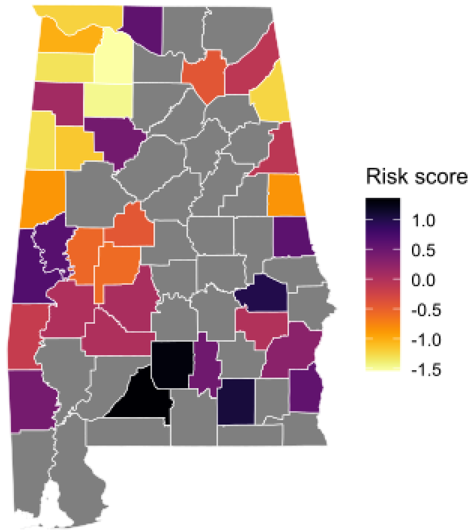

Figure 4. The risk scores for the Counties without *C. formosanus* records, estimated using the Cox proportional hazards model. The risk score corresponds to the linear predictor from the model calculated for each County.

Discussion

In Alabama, the distribution range of *C. formosanus* termites has been clearly expanding due to human-mediated transportation. The interstate highway system has the greatest effect on early detection, as well as on high human populations (Figs. 2 and 3). Railroads have often been considered a primary pathway for termite distribution expansion, where infested railway cross ties have served as the main source for the spread (Austin et al. 2008). We observed that several first detections of *C. formosanus* apparently were associated with these railway cross ties (Appendix). Similarly, in France, the distribution of invasive *Reticulitermes flavipes* is associated with the distances from railroads (Suppo et al. 2018; Perdereau et al. 2019). However, we did not detect significant effects of railroad density on county-level early detection of *C. formosanus*. This could be because, even if railroad ties were the primary infected materials in the past, they may not have been transported by rail but by road traffic. Instead, our results suggest that cars and trucks are the main modes of terrestrial expansion. In addition to previous railway cross ties, infested wood-based mulches, tree debris, or even non-cellulosic materials could serve as a carrier of *C. formosanus* colonies (Sun et al. 2006; Lee et al. 2009), typically careered by trucks. Furthermore, RV infestation can be a new source of vehicle-based transportation of colonies (Hu 2026). The Alabama highway system has also developed over the last 40 years, including 565 (since 1991) and 22 (since 2012), and future development can further form the terrestrial invasion processes (Eritja et al. 2017).

The temperature, approximated by the latitude in this study, is another primary factor for predicting early detection of *C. formosanus* (Figs. 1 and 3). Winter temperature is considered a limiting factor in the distribution of *C. formosanus*, with mean winter temperatures above 4°C and mean minimum temperatures above -5°C (Abe 1937; Mori 1987; Li 1991; Lee et al. 2021), typically restricted to within 35° of the equator (Su and Tamashiro 1987). Because of this, *C. formosanus* was estimated not to become established in northern Alabama (Appel and Sponsler 1989). Nevertheless, our records include many well-established infestations in the northern counties. For example, *C. formosanus* has been established in Cullman County since 2003 (Fig. 1; Appendix); the mean January 2003 temperature was 2.11 °C, and the lowest was -15.00 °C (Hu and Appel 2004), where urban structures should have provided a refuge during winter. With ongoing climate change, including rising temperatures and the urban heat island effect, the entire state of Alabama should be at risk of *C. formosanus* infestation (Fig. 4), as predicted by other global distribution models (Buczkowski and Bertelsmeier 2017; Duquesne and Fournier 2024).

Note that the records of first detection inevitably include lags relative to the true infestation in each county. The termite infestation process is generally cryptic and slow, with the colony developing within wooden materials without visible external signs. This cryptic nature makes it difficult to monitor the invasion process (Evans et al. 2013, 2019). The first reports are typically associated with the swarming flights of alates (Appendix), indicating the presence of already established colonies. Therefore, many other undetected counties could already have an infestation, waiting for the alate emergence. On the other hand, observational bias could be minimized for the first-detection year data. First detection always starts with the infested house, leading to a report to pest management professionals, Extension agencies, or state officials. Because the entire state of Alabama is at risk of *C. formosanus* infestations, it is essential to continue monitoring efforts, especially in counties with higher risk (Fig. 4). Our time-to-detection model could be applied to neighboring states, with little contact with coastal areas and wide-inland connections, such as Georgia, Mississippi, and Louisiana.

In conclusion, although transoceanic long-range dispersal and new establishment in coastal areas attract the most attention, the inland expansion of *C. formosanus* continues in the southeastern US. Florida has a strong development of termite distribution update systems that include *C. formosanus* (Chouvenc et al. 2022), while the records of other states have been sporadic or not up to date (Hathorne et al. 2000; Howell Jr et al. 2001; Jenkins et al. 2002; Lax and Wiltz 2009; Stephen 2012; Puckett et al. 2014; Evans et al. 2019; Guidry et al. 2024). In 2024, a working group, the North American Termite Survey (NATS) (NATS 2025), was initiated to produce an updated distribution map of *C. formosanus* in the United States using EDDMAPs (EDDMapS 2026). Such expansions of the monitoring efforts need to continue to be prepared for the drastic changes in potential risks at each state, as well as the invasion of additional species in the future.

Acknowledgment

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Data accessibility

The data and codes for this study are available in github.com/nobuaki-mzmt/FST-AL-distribution.

Appendix

County-by-county history of invasion records of Coptotermes formosanus

Listed below are the records of the *C. formosanus* (Formosan Subterranean termites, FST) spread in Alabama counties in chronological order. First record and subsequent significant records are listed. Note that the subsequent records are not a complete history of every single detection, rather selected records.

1. Mobile (1984)

First record: Alate sample collected in 1984, identified by Ray Beal. Voucher deposited at the USDA Forest Service, Gulfport. Documented by Su and Scheffrahn (1986).

Subsequent records:

- 1987-1989: alates subsequently identified from mosquito light traps at multiple locations by Appel and Sponsler (1989).
- 1995–1998: at least 39 homes and one subdivision in Mobile city were reported to be infested by pest management professionals (PMPs).
- 2002: 23 new incidents reported to Extension.
- Infestations have been reported every year since, with increasing numbers.

2. Lee (1986)

First record: Destructive damage discovered during renovation of the County Courthouse in 1986. First published record: alate swarming on 4 June 1987 at Auburn University campus, associated with railroad crossties on the ground (Sponsler et al. 1988).

Subsequent records:

- 1990s–early 2000s: six infestations documented each decade. Infestations included living trees, structures, and railroad crossties.
- 2001: swarming at the courthouse and downtown Opelika.
- 2004: Renfro Opera-House in Opelika collapsed due to infestation, swarming from a pecan tree.
- 2005: heavy infestation in 5-year-old subdivisions.
- 2006: four historic buildings in downtown Opelika with interior swarming.
- 2007: Night-Club for sale was hunted due to swarming
- 2011: Auburn High School swarming from the ceiling (12 May); Structural inspection of the Courthouse revealed two of five roof trusses severely damaged, leading to closure of the second floor for restoration; the Opelika Termite Program Initiative started.
- 2025: 29 calls from Auburn residents, 43 from Opelika, and 50 from other cities reporting interior swarming.

Notes: One infestation between 2001 and 2003 was believed to have originated from construction timber obtained from Louisiana.

3. Baldwin (1988)

First record: Widespread alates captured in mosquito light traps, indicating established population; reported by Appel and Sponsler (1989).

Subsequent records:

- 2002: multiple public trees in Fairhope treated in collaboration with USDA Formosan Full-Stop researchers.
- 2003: Fairhope city launched a Formosan Termite Watch program using sticky traps at 109 locations; approximately 70% of sites were found to be infested.
- 2011: an educational program was requested by the city in response to extremely high activity.
- 2011–present: more than 20 cases reported per year.

4. Jackson (1996)

First record: Alates collected from a windowsill in Scottsboro, submitted by a PMP during an annual inspection. The house was approximately 150 m from a railroad track. One-year follow-up monitoring with in-ground wood stakes detected no termites in the soil.

Subsequent records:

- 2023 and 2025: two new infestations detected

Notes: Scottsboro is the northeasternmost city in Alabama, on the Tennessee border.

5. Calhoun (1997)

First record: Infestation reported by a PMP in Anniston. The property was landscaped with used railroad ties. Presence suspected for ~3 years prior based on a neighbor's observation of swarming without identification. Treatment performed in 1997 using baiting and soil treatment.

Subsequent records:

- 2002: five incidents (four houses, one tree) in Oxford city.
- 2011: live alates confirmed in the house of Dr. David Thornton (Jacksonville State University) over five days (20–25 May). Robbie Champion (Guaranty Pest Control) found no signs of termites in the crawlspace of the 2011 infestation despite alate presence; structure lacked obvious damage.
- 2015–present: steady increase in new infestations coinciding with rapid urban expansion.

6. Lowndes (1998)

First record: Sample submitted to Extension Service.

Subsequent records:

- 2001: dried alates sent by a homeowner; confirmed as FST. No site inspection was carried out.

Notes: Lowndes is adjacent to Montgomery County, where FST was discovered in 2001.

7. Clay (1999)

First record: Homeowner reported interior swarming to a PMP. Alate sample was sent to Extension for identification. The house was treated, and no termite activity was detected afterward.

Subsequent records:

- 2012: new incident in late May.
- 2015: infestation in the Delta City home was reported by homeowners, Marie and Charles Geeson (swarming on 20 June); inspection by Pat Markey (Orkin Pest Control Company) and the first author found damage in railroad tie pillars supporting a wooden deck; no termites were detected in the crawlspace or exterior foundation. A few alates found in the kitchen, attracted by the light.
- 2016: infestation of an oak tree in a residential yard (21 June).
- 2020–2024: additional infestations confirmed.

8. Montgomery (2001)

First record: Alate sample submitted by a homeowner through the Extension System; active mud tubes found on the exterior wall. House treated with baits by a PMP.

Subsequent records:

- 2002: second infestation ~3 miles from the first infestation in 2001, treated with liquid termiticide. Railroad tie damage was found at both sites without active termites.
- 2015, 2022, 2025: additional infestations confirmed in residential homes and tree stumps.

9. Jefferson (2001)

First record: Report from a PMP on 6 June 2001.

Subsequent records:

- 2002: six infestations confirmed from different cities; one house was severely damaged, requiring floor and wall replacement. The homeowner mentioned the presence of termite-infected railroad ties in the neighborhoods.

- 2006, 2011, 2012, 2019, 2021, 2024: additional confirmed specimens. 2012: homeowner in Birmingham (reported to Katelyn Kesheimer, Extension) confirmed interior swarming in a 3-story structure; first author conducted on-site inspection.

Notes: Jefferson County is experiencing rapid residential growth with rising FST reports.

10. Shelby (2002)

First record: Three FST complaints received by state inspectors in 2001–2002; all confirmed as FST and treated by PMPs.

Subsequent records: 2010, 2016 (Meadow Brook area, North Shelby County, off Highway 119), 2019, 2022, 2024.

11. Cullman (2003)

First record: Large interior swarm encountered on the evening of 13 June by homeowners returning from vacation; reported by their PMP to Extension the following day. Homeowner had installed railroad crossties bought 4 years prior for a retaining wall. Follow-up inspection found old damage in ties and active FST in two adjacent tree stumps; treated with Sentricon in late June 2003.The house was approximately 12 years old and located on the northern border of Cullman County.

Subsequent records: 2010, 2019, 2021, 2023, 2025.

Notes: Mean January 2003 air temperature at site: 2.11°C; minimum: −15°C.

12. St. Clair (2003)

First record: Alates observed flying around lights on the deck and porch of a pier-foundation mobile home in Odenville on 21 June; reported to a PMP. No active infestation found inside or outside of the house; follow-up inspection revealed two infested tree stumps nearby. No treatment applied.

Subsequent records: 2018, 2020, 2023.

13. Monroe (2004)

First record: Alates, soldiers, and workers confirmed in 2004. The homeowner had reported a swarm to a PMP in 2002, which was suggested to be FST without identification records. Two interior swarmings occurred in April 2003 at the same house, which subsequently received liquid treatment. The homeowner had purchased a truckload of railroad ties from Mobile in 1992 for landscape use.

Subsequent records: 2016, 2020

14. Elmore (2005)

First record: Homeowner submitted alate samples on 5 June 2005. Follow-up visit revealed severe damage to windows and numerous large exit holes in drywall.

Subsequent records:

- 2017: infestation of a dying oak on lakefront property near Alexander City, not near any urban area or major highway; confirmed by Dr. Charles Ray, who noted it was somewhat unusual given that most Alabama finds had been urban or highway-adjacent.
- 2020, 2021, 2024.

15. Etowah (2006)

First record: Sample submitted by a PMP.

Subsequent records: 2017, 2024.

16. Escambia (2007)

First record: Infestation in a 20–25-year-old ranch-style home north of Atmore. Samples included carton nests containing soldier heads.
Subsequent records: 2016, 2024.

17. Covington (2008)
First record: Collected by Mark's Aggressive Termite Control. Swarming in early June with no activity inside the structure; dead tree stumps in a neighbor's yard was indicated as a source.
Subsequent records: 2014, 2017, 2020.

18. Chilton (2011)
First record: PMP submitted alate sample that had swarmed inside a house to Charles Ray in June 2011.
Subsequent records: 2017, 2023.

19. Houston (2012)
First record: Tabor Pest Control (Mike and Jeff Tabor) in Dothan submitted a sample to the county office (Phillip Carter, AL A&M University) on 5 June; forwarded to Charles Ray on 9 June 2012. The sample included winged individuals and soldiers.
Subsequent records: 2016 (additional submission by Phillip Carter on behalf of Mike Tabor), 2019, 2024.

20. Clarke (2013)
First record: Jack Brewer (Lewis Pest Control, technical director) reported swarming evidence in Whatley in May. This was the first FST infestation for Lewis Pest Control outside the coastal counties (Mobile and Baldwin) in their traditional coverage area since 1963, across approximately 10,000 termite contracts. Sample collected on 23 May 2013 by Steven (Scooter) Williams (branch manager). The location was on Highway 84, approximately 100 miles inland from the Gulf of Mexico.
Subsequent records: 2020.

21. Autauga (2016)
First record: Samples from Booth City identified by Charles Ray on 17 June 2016, submitted by Steve Segrest.

22. Dale (2016)
First record: Soldier samples and damaged wood with workers submitted on 25 July 2016.

23. Blount (2017)
First record: Sample from City Warrior on 15 August 2017.
Subsequent records: 2018: alate collected from light trap at Highland Lake by Charles Ray (20 August).

24. Talladega (2017)
First record: Superior Pest Control reported swarming on 6 August from a living oak tree (~25–28 inches in diameter, 40 ft from the house) at Somerset Bed & Breakfast, Talladega. Swarming occurred at approximately 4:15 pm; the homeowner declined treatment of the tree.
Notes: This was the first recorded August swarming in Alabama; previous swarmings from this site had occurred in June.

25. Tallapoosa (2020)

First record: Alate specimen received from the county office on 23 June 2020.

26. Tuscaloosa (2022)

First record: Live interior swarming in a residential home. Samples submitted on 12 June by Denise Shirley on behalf of Scientific Pest Control of Tuscaloosa.

27. Pike (2022)

First record: Samples received from a PMP and an Extension agent in 2022.

28. Coosa (2022)

First record: Soldiers and alates submitted by a homeowner on 17 June 2022.

29. Geneva (2024)

First record: Damaged wood panels, soldiers, and workers received from a PMP on 8 May 2024.

30. Marshall (2024)

First record: Extension forwarded alates and an infested piece of wood from a house on 21 June 2024.

31. Morgan (2024)

First record: Cook's Pest Management reported an FST infestation that had damaged a 3-story building in July 2024. Colony treated with baiting at infestation sites and in surrounding landscaping.

32. Russell (2025)

First record: Sticky traps distributed as part of the NATS FST distribution survey; trap positioned near a light at the county Extension office, and alates were collected on 19 May 2025.

References

Abe Y (1937) On the distribution of the oriental termite, *Coptotermes formosanus* Shiraki, in Japan. Science Reports of the Tohoku Imperial University, Ser 4, Biology 11:12

Appel AG, Sponsler RC (1989) Formosan termites now in Alabama. Highlights of Agricultural Research 36:9

Austin JW, Glenn GJ, Gold RE (2008) Protecting Urban Infrastructure from Formosan Termite (Isoptera: Rhinotermitidae) Attack: A Case Study for United States Railroads. Sociobiology 51:231–248

Bertelsmeier C (2021) Globalization and the anthropogenic spread of invasive social insects. Current Opinion in Insect Science 46:16–23. https://doi.org/10.1016/j.cois.2021.01.006

Bertelsmeier C, Ollier S, Liebhold A, Keller L (2017) Recent human history governs global ant invasion dynamics. Nature Ecology & Evolution 1:0184. https://doi.org/10.1038/s41559-017-0184

Blumenfeld AJ, Eyer P-A, Husseneder C, et al (2021) Bridgehead effect and multiple introductions shape the global invasion history of a termite. Communications Biology 4:196. https://doi.org/10.1038/s42003-021-01725-x

Blumenfeld AJ, Vargo EL (2020) Geography, opportunity and bridgeheads facilitate termite invasions to the United States. Biological Invasions 22:3269–3282. https://doi.org/10.1007/s10530-020-02322-5

Bradshaw CJA, Leroy B, Bellard C, et al (2016) Massive yet grossly underestimated global costs of invasive insects. Nature Communications 7:12986. https://doi.org/10.1038/ncomms12986

Buczkowski G, Bertelsmeier C (2017) Invasive termites in a changing climate: A global perspective. Ecology and Evolution 7:974–985. https://doi.org/10.1002/ece3.2674

Capinha C, Essl F, Seebens H, et al (2015) The dispersal of alien species redefines biogeography in the Anthropocene. Science 348:1248–1251. https://doi.org/10.1126/science.aaa8913

Chouvenc T (2025) Invasive termites and their growing global impact as major urban pests. Current Opinion in Insect Science 69:101368. https://doi.org/10.1016/j.cois.2025.101368

Chouvenc T (2026) Ongoing monitoring of the spread of 2 invasive subterranean termite species (*Coptotermes* Wasmann) in Florida (1990 to 2025). Journal of Economic Entomology toaf370. https://doi.org/10.1093/jee/toaf370

Chouvenc T, Brown A (2025) Minimizing the impact of invasive Coptotermes sp. (Heterotermitidae) on urban tree canopies using a recurrent inspection-elimination program. Journal of Economic Entomology 118:1868–1878. https://doi.org/10.1093/jee/toaf167

Chouvenc T, Scheffrahn RH, Buss L (2022) Termite species distribution in Florida and UF Termite Identification Services. EDIS 2022:ENY-2079/IN1360. https://doi.org/10.32473/edis-in1360-2022

Cuthbert RN, Diagne C, Haubrock PJ, et al (2022) Are the "100 of the world's worst" invasive species also the costliest? Biological Invasions 24:1895–1904. https://doi.org/10.1007/s10530-021-02568-7

Duquesne E, Fournier D (2024) Connectivity and climate change drive the global distribution of highly invasive termites. NeoBiota 92:281–314. https://doi.org/10.3897/neobiota.92.115411

EDDMapS (2026) formosan subterranean termite (*Coptotermes formosanus*). In: EDDMapS.org. https://www.eddmaps.org/distribution/uscounty.cfm?sub=4303. Accessed 9 Mar 2026

Eritja R, Palmer JRB, Roiz D, et al (2017) Direct Evidence of Adult Aedes albopictus Dispersal by Car. Scientific Reports 7:14399. https://doi.org/10.1038/s41598-017-12652-5

Evans TA (2021) Predicting ecological impacts of invasive termites. Current Opinion in Insect Science 46:88–94. https://doi.org/10.1016/j.cois.2021.03.003

Evans TA, Forschler BT, Kenneth Grace J (2013) Biology of invasive termites: A worldwide review. Annual Review of Entomology 58:455–474. https://doi.org/10.1146/annurev-ento-120811-153554

Evans TA, Forschler BT, Trettin CC (2019) Not just urban: The Formosan subterranean termite, *Coptotermes formosanus*, is invading forests in the Southeastern USA. Biological Invasions 21:1283–1294. https://doi.org/10.1007/s10530-018-1899-5

Eyer P, Blumenfeld AJ, Johnson LNL, et al (2021) Extensive human-mediated jump dispersal within and across the native and introduced ranges of the invasive termite *Reticulitermes flavipes*. Molecular Ecology 30:3948–3964. https://doi.org/10.1111/mec.16022

Fournier D, Aron S (2021) Hybridization and invasiveness in social insects — The good, the bad and the hybrid. Current Opinion in Insect Science 46:1–9. https://doi.org/10.1016/j.cois.2020.12.004

Guidry E, Janowiecki MA, Cottone CB, et al (2024) Statewide Survey Documenting New Records of the Formosan Subterranean Termite, *Coptotermes formosanus* (Blattodea: Rhinotermitidae), within Louisiana Parishes. Journal of Agricultural and Urban Entomology 40:1–6. https://doi.org/10.3954/JAUE24-03

Hathorne KT, Zungoli PA, Benson EP, Bridges WC (2000) The termite (Isoptera) fauna of South Carolina. Journal of Agricultural and Urban Entomology 17:219–229

Howell Jr HN, Gold RE, Glenn GJ (2001) Coptotermes Distribution in Texas (Isoptera: Rhinotermitidae). Sociobiology 37:687–698

Hu XP (2026) Defending your mobile home: protocol for Formosan termite control in RVs. Alabama Cooperative Extension System ANR-3220

Hu XP, Appel AG (2004) Seasonal Variation of Critical Thermal Limits and Temperature Tolerance in Formosan and Eastern Subterranean Termites (Isoptera: Rhinotermitidae). Environmental Entomology 33:197–205. https://doi.org/10.1603/0046-225X-33.2.197

IUCN (2026) SSC Invasive Species Specialist Group. Global Invasive Species Database. https://www.iucngisd.org/gisd/. Accessed 7 Mar 2026

Jenkins TM, Dean RE, Forschler BT (2002) DNA Technology, Interstate Commerce, and the Likely Origin of Formosan Subterranean Termite (Isoptera: Rhinotermitidae) Infestation in Atlanta, Georgia. Journal of Economic Entomology 95:381–389. https://doi.org/10.1603/0022-0493-95.2.381

Lax AR, Wiltz BA (2009) Swarming of the Formosan Subterranean Termite (Isoptera: Rhinotermitidae) in Southern Mississippi. Midsouth Entomologist 3:18–25

Lee KC, Sun J-Z, Zhu Y, Mallette EJ (2009) A Case Study of the Formosan Subterranean Termite, *Coptotermes formosanus* (Isoptera: Rhinotermitidae) Transported with a Non-Cellulosic Commercial Carrier in South Mississippi. Sociobiology 53:619–630

Lee S-B, Tong RL, Kim S-H, et al (2021) Potential Pest Status of the Formosan Subterranean Termite, *Coptotermes formosanus* Shiraki (Blattodea: Isoptera: Rhinotermitidae), in Response to Climate Change in the Korean Peninsula. Florida Entomologist 103:431–437. https://doi.org/10.1653/024.103.00403

Li Y-H (1991) The influence of temperature on the survival and activity of *Coptotermes formosanus* Shiraki. Acta Entomological Sinica 34:126–128. https://doi.org/10.16380/J.KCXB.1991.01.026

Messenger MT, Mullins AJ (2005) New flight distance recorded for *Coptotermes formosanus* (Isoptera: Rhinotermitidae). Florida Entomologist 88:99–100. https://doi.org/10.1653/0015-4040(2005)088%255B0099:NFDRFC%255D2.0.CO;2

Mizumoto N (2026) Evaluating mate encounter and walking dispersal dynamics of termites using posture tracking and behavioral simulation. Journal of Pest Science 99:57. https://doi.org/10.1007/s10340-026-02023-3

Mori H (1987) The Formosan subterranean termite in Japan: its distribution, damage, and current and potential control measures. In: Biology and control of the Formosan subterranean termite: Proceedings of the International Symposium on the Formosan Subterranean Termite: 67th Meeting of the Pacific Branch, Entomological Society of America, Honolulu, Hawaii, 1985. College of Tropical Agriculture and Human Resources, University of Hawaii, Honolulu, Hawaii, pp 23–26

Mullins AJ, Messenger MT, Hochmair HH, et al (2015) Dispersal flights of the Formosan subterranean termite (Isoptera: Rhinotermitidae). Journal of Economic Entomology 108:707–719. https://doi.org/10.1093/jee/tov022

NATS (2025) The North American Termite Survey. https://termitesurvey.org/. Accessed 9 Mar 2026

Pebesma E (2018) Simple Features for R: Standardized Support for Spatial Vector Data. The R Journal 10:439–446. https://doi.org/10.32614/RJ-2018-009

Perdereau E, Baudouin G, Bankhead-Dronnet S, et al (2019) Invasion dynamics of a termite, *Reticulitermes flavipes*, at different spatial scales in France. Insects 10:30. https://doi.org/10.3390/insects10010030

Puckett RT, Espinoza EM, Gold RE (2014) Alate Trap-Based Assessment of Formosan Subterranean Termite (Isoptera: Rhinotermitidae) Dispersal Flight Phenology Associated With an Urbanized Barrier Island Ecosystem. Environmental Entomology 43:868–876. https://doi.org/10.1603/EN13223

R Core Team (2025) R: A language and environment for statistical computing.

Reino L, Moya-Laraño J, Cláudio Heitor A (2009) Using survival regression to study patterns of expansion of invasive species: will the common waxbill expand with global warming? Ecography 32:237–246. https://doi.org/10.1111/j.1600-0587.2008.05354.x

Rust MK, Su NY (2012) Managing social insects of urban importance. Annual Review of Entomology 57:355–375. https://doi.org/10.1146/annurev-ento-120710-100634

Scheffrahn RH (2023) Biogeography of *Coptotermes formosanus*. In: Su NY, Lee C-Y (eds) Biology and Management of the Formosan Subterranean Termite and Related Species. CABI, GB, pp 8–25

Scheffrahn RH, Bahder BW, Lu T (2020) *Coptotermes formosanus* (Blattodea: Rhinotermitidae) established in Israel and world distribution of a major termite pest. Check List 16:1537–1543. https://doi.org/10.15560/16.6.1537

Scheffrahn RH, Crowe W (2011) Ship-Borne Termite (Isoptera) Border Interceptions in Australia and Onboard Infestations in Florida, 1986–2009. Florida Entomologist 94:57–63. https://doi.org/10.1653/024.094.0108

Scheffrahn RH, Su N-Y (1994) Keys to soldier and winged adult termites (Isoptera) of Florida. The Florida Entomologist 77:460. https://doi.org/10.2307/3495700

Simberloff D, Rejmanek M (eds) (2019) 100 of the World's Worst Invasive Alien Species: A Selection From The Global Invasive Species Database. In: Encyclopedia of Biological Invasions. University of California Press, pp 715–716

Simms D, Husseneder C (2009) Assigning individual alates of the Formosan Subterranean termite (Isoptera: Rhinotermitidae) to their colonies of origin within the context of an area-wide management program. Sociobiology 53:631–650

Sponsler RC, Jordan KS, Appel AG (1988) New distribution record of the Formosan subterranean termite, *Coptotermes formosanus* (Isoptera, Rhinotermitidae), in Auburn, Alabama. Entomological news 99:87–89

Stephen CDR (2012) Alabama Rhinotermitidae: Nomenclature, Identification, Survey, and Phenology. Master's thesis, Auburn University

Su NY, Scheffrah RH (1986) The Formosan subterranean termite, *Coptotermes formosanus* (Isoptera: Rhinotermitidae), in the United States: 1970-1985. In: Proceedings of the National Conference on Urban Entomology. University of Maryland, College Park, pp 31–38

Su NY, Tamashiro M (1987) An Overview of the Formosan Subterranean Termite (Isoptera: Rhinotermitidae) in the World. In: Biology and control of the Formosan subterranean termite: Proceedings of the International Symposium on the Formosan Subterranean Termite: 67th Meeting of the Pacific Branch, Entomological Society of America, Honolulu, Hawaii, 1985. College of Tropical Agriculture and Human Resources, University of Hawaii, Honolulu, Hawaii, pp 3–14

Sun J-Z, Lockwood ME, Etheridge JL (2006) Evaluation of the Preferences of Dealates of *Coptotermes formosanus* (Isoptera: Rhinotermitidae) among Landscape Mulches. Sociobiology 48:1–16

Suppo C, Robinet C, Perdereau E, et al (2018) Potential spread of the invasive North American termite, Reticulitermes flavipes, and the impact of climate warming. Biological Invasions 20:905–922. https://doi.org/10.1007/s10530-017-1581-3

Therneau TM (2001) survival: Survival Analysis. 3.8-6

Walker K (2016) tigris: An R Package to Access and Work with Geographic Data from the US Census Bureau. The R Journal 8:231. https://doi.org/10.32614/RJ-2016-043

Weesner FM (1965) Termites of the United States, a handbook. National Pest Control Association, Elizabeth, New Jersey

Statements and Declarations

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Competing Interests

The authors declare no competing interests.

Author contributions

XPH: Conceptualization, Data curation, Investigation, Project administration, Validation, Writing – original draft, Writing – review & editing

N.M.: Conceptualization, Formal analysis, Investigation, Visualization, Writing – original draft, Writing – review & editing