Alate Trap-Based Assessment of Formosan Subterranean Termite (Isoptera: Rhinotermitidae) Dispersal Flight Phenology Associated With an Urbanized Barrier Island Ecosystem

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Environ. Entomol. 43(4): 868–876 (2014); DOI: http://dx.doi.org/10.1603/EN13223

ABSTRACT During 2009, 2010, and 2011, the reproductive dispersal flight phenology of Formosan subterranean termites (*Coptotermes formosanus* Shiraki) was assessed on Galveston Island, TX, via LED light-based termite alate traps. In all three years, traps were deployed at sampling sites before the initiation of *C. formosanus* dispersal flights, and retrieved weekly until the cessation flights. In total, 45, 102, and 90 traps were deployed during 2009, 2010, and 2011, respectively. In all years, *C. formosanus* flights began during the second full week of May; however, peak dispersal flight activity occurred 2 wk earlier in 2009 and 2011 than in 2010. Significantly more alates were collected during the 2009 flight peak than in 2010 and 2011 despite the fact that greater than twice the number of traps were deployed in 2010 and 2011, versus 2009. Additionally, a greater percentage of traps collected *C. formosanus* alates in 2009 (71.1%) than in 2010 (38.2%) or 2011 (20.0%). A relatively inexpensive trap design (~US$25.00 per trap) was developed for this project. The traps used in this work yielded results that were similar to those of other researchers using a variety of different trap designs. It is hoped that these results will allow for more targeted surveillance of *C. formosanus* dispersal flights by residents and pest management professionals at this location and elsewhere.

KEY WORDS *Coptotermes formosanus*, alate, dispersal, invasive insect

The Formosan subterranean termite *Coptotermes formosanus* Shiraki (Isoptera: Rhinotermitidae) is an invasive termite species that currently occupies range in 15 states in the continental United States and Hawaii (Swain et al. 2011). These termites are endemic to mainland China (Kistner 1985) and the Island of Taiwan (formerly Formosa; Li et al. 2009), and it is believed that their introduction to the Hawaiian archipelago was the result of maritime activity originating from Taiwan, with subsequent introductions to the continental United States originating from Hawaii (Su and Scheffrahn 1998, Cabrera et al. 2000, Hawthorne et al. 2000, Howell et al. 2000, Scheffrahn et al. 2001, Jenkins et al. 2002, Puckett et al. 2012). However, Austin et al. (2006) suggested two distinct *C. formosanus* introductions to Hawaii, and then the continental United States, both originating from mainland China.

Since introduction into coastal Texas in the 1960s, the known range of *C. formosanus* has expanded, and these insects have been documented in 31 Texas counties (R. E. Gold, personal communication). While the ecological impacts of this invasive termite species are not fully understood, economic costs associated with control efforts, damage to, and repair of structures approach US$2 billion annually in the United States (Su 2003, Paudel et al. 2010). Strategies for control and remediation of *C. formosanus* include physical and chemical barriers to prevent termites from gaining access to structures, chemical treatment of infested soil and wood, and baits. Additionally, a great deal of research to assess the feasibility of biological controls (including nematodes, bacteria, fungi, and botanical extracts) for termites has been conducted (Chouvenc et al. 2011).

During dispersal flight periods, the maximum distances traveled by *C. formosanus* alates are typically shorter that 1 km (Messenger and Mullins 2005, Husseneder et al. 2006, Lax and Wiltz 2009). Thus, natural range expansion of *C. formosanus* would presumably proceed at a relatively slow pace if unassisted by humans. However, human-assisted movement of these termites in commerce-related goods has been well documented (Spink 1967, Lax and Wiltz 2009, Lee et al. 2009, Hochmair and Scheffrahn 2010). As a result, quarantine programs have been initiated in many states (including Texas) which attempt to curtail additional range expansion of this exotic insect pest. Such programs focus on prohibiting the movement of this invasive species (and others) from areas of known establishment, into areas where they have not been yet been demonstrated to occur. Quarantine efforts

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include education, monitoring, and inspection of materials that *C. formosanus* routinely use as harborage, as these materials enter regions in which *C. formosanus* have not been documented. However, relatively less attention has been paid to regions in which *C. formosanus* is well established. If viewed as a "source–sink" population dynamics scenario, such regions may be considered refugia for "source" populations, and thus should be considered vitally important to the overall quarantine and management of this pest.

Galveston Island, TX, is a 43-km barrier island along the upper Texas gulf coast (29° 18′ N, 94° 47′ W). Access to the island is restricted to two roadways and a ferry system. Thus, from an ecological perspective, the island represents a "semiclosed" system. It is unknown when *C. formosanus* was first documented on Galveston Island. However, the first discovery of *C. formosanus* in Texas occurred in 1956 when these termites were documented in Harris Co., TX (R. E. Gold, personal communication). Harris and Galveston County boundaries are contiguous. This discovery was followed by documentation of another population of *C. formosanus* from Orange Co., TX, in 1962 (Swain et al. 2011).

In September 2008, Galveston Island was the site of landfall of Hurricane Ike. The associated storm surge (>3 m), rainfall, and storm-associated winds resulted in tremendous damage to artificial structures and trees along the island (Williams 2010). The damage and subsequent reconstruction of residential and commercial buildings on the island allowed unprecedented observation of subterranean termite damage, much of which was the result of *C. formosanus.* We were allowed access to many of these structures during a tour of the island in February 2009, and were also afforded an opportunity to demonstrate to city officials the extent of the infestations and associated damage. These discussions led to our laboratory being given permission to approach Galveston Island property owners in an attempt to establish a *C. formosanus* surveillance program across the island.

We developed and deployed a novel sampling device to attract and collect *C. formosanus* alates at sampling sites. These traps were deployed before spring *C. formosanus* dispersal flights, monitored weekly throughout the flight season, and were removed at the conclusion of *C. formosanus* dispersal flights during the 2009, 2010, and 2011 sampling seasons. The *C. formosanus* alate capture data gathered during these three consecutive seasons of monitoring revealed highly resolved seasonal flight phenology trends. The traps (described in detail below) represent an inexpensive and efficient means of *C. formosanus* surveillance, and it is our hope that they will be considered for use by all involved in such monitoring.

Materials and Methods

Alate Traps. Traps were designed to incorporate components that attracted and ensnared responding *C. formosanus* alates, and that would allow the trap to be attached to vertical structures such as trees, utility poles, rain gutter downspouts, etc. The bases of the traps were constructed of a 30- by 30-cm square of 0.6-cm plywood board. All bases were protected from elements by applying Thompsons WaterSeal wood sealant (The Thompson's Co., Columbus, OH) before use. A 0.8-cm (inside diameter) hole was drilled in each corner of the board to accommodate 0.6-cm wide heavy-duty cable ties (Gardner Bender, Milwaukee, WI) for attachment to structures (Fig. 1). Next, four 0.3-cm holes were drilled at the top of the board to accommodate 0.2-cm wide light-duty cable ties (Gardner Bender) for attachment of a Hampton Bay solar LED spotlight (The Home Depot, Marietta, GA) to the base (Fig. 1). The solar panels on these traps charged four lithium phosphate 400 mAh batteries housed inside the unit, which were capable of supplying light over the course of one sampling season. These lights automatically illuminated during low-light conditions (from dusk until dawn). Next, Masterline 20- by 14-cm rodent glue boards (Univar, Austin, TX) were affixed to the plywood base underneath the lights with large binder clips (ACCO Brands, Inc., Lincolnshire, IL). The protective paper covering remained on glue boards until they were secured on structures. The cost of the traps included that of the LED lamp (US$21.57), the wooden base (US$0.25), cable ties (US$0.75), binder clips (US$0.80), and glue boards (US$0.20), or US$23.57 per trap.

Fig. 1. *C. formosanus* alate trap with Hampton Bay solar LED spotlight and attached to a utility pole.

Experimental Design. During March 2009, we began contacting property owners via email. These contacts were provided by Galveston Island, TX, homeowner's association membership rosters. Forty-five

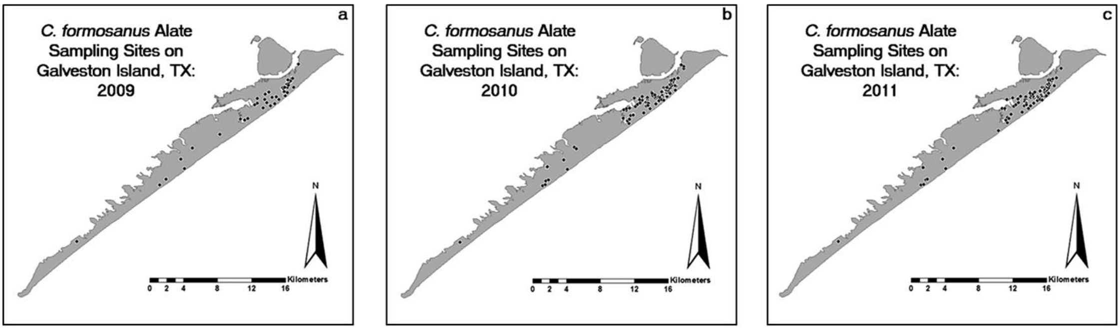

Fig. 2. (a–c) Location of *C. formosanus* alate trap placement (sampling sites) across Galveston Island, TX, during the 2009, 2010, and 2011 sampling seasons.

properties were selected to serve as monitoring sites during the 2009 *C. formosanus* season (Fig. 2a). Selection criteria for properties included 1) a vertical structure to which a trap could be affixed, 2) assurance from the property owner that the trap would be constantly accessible through the entirety of the sampling season, and 3) presence of a secure and inconspicuous location where the trap was not likely to be tampered with by pedestrians. All traps were deployed during the first week of May in 2009. Traps were affixed to predetermined vertical structures, glue boards were marked with a unique numerical code identifying property locations, and the protective paper covering on glue boards was removed. Glue boards were replaced weekly and returned to the laboratory where *C. formosanus* alates were identified by wing characters (Scheffrahn and Su 1994) and counted. These procedures were repeated until all traps failed to collect any *C. formosanus* alates for a period of two consecutive weeks. The final collection of glue boards occurred on 15 July 2009. Afterwards, traps were removed and stored for use in subsequent sampling seasons.

The above described procedures were repeated in 2010 and 2011. However, a Galveston Island newspaper interview and subsequent publication of an article documenting our 2009 sampling effort resulted in the generation of increased interest in the project. As a result of this, the number of island residents who wished to become involved with the work increased dramatically. In 2010, 102 properties were used as sampling sites (Fig. 2b). Of these 102 properties, 33 were retained from 2009 and 69 properties were new to the study. The number of properties decreased to 90 in 2011 (Fig. 2c), resulting primarily from changes in property ownership between the 2010 and 2011 sampling seasons. The 90 properties used in 2011 consisted of 7 properties that were new to the study, 56 properties that were common between 2010 and 2011, and 27 properties that were used in all three years of the study. It is important to note that the majority of the additional properties added in 2010 and 2011 were located in the portion of the island with the highest human population density (see the cluster of sampling locations on the northeastern portion of Galveston Island in Fig. 2a–c). The final glue board collection dates in 2010 and 2011 were 25 June and 30 June, respectively. Additionally, all temperature data were gathered via weather-station database provided by Scholes International Airport (GLS), centrally located on Galveston Island.

Although traps were deployed and retrieved across the same periods during 2009, 2010, and 2011, they were not deployed and retrieved on identical calendar dates. To standardize these dates for statistical analysis, we simply numbered the weeks of the year, assigning number 1 to the first full week of January, and continued to number them sequentially through the sampling seasons. Termite flight data (mean number of alates and percent of traps that collected alates) were analyzed via Kruskal–Wallis χ^2 test for each week in which flights occurred to determine overall differences, and means were separated via Mann–Whitney *U* tests (values significantly different when $P \leq 0.05$). Temperature data were analyzed via analysis of variance (ANOVA) and Tukey's HSD post hoc means separation analysis (values significantly different when $P \leq 0.05$). The statistical procedures were separately conducted for each dependent variable, and SPSS v.19.0 (SPSS Inc. 2010, Chicago, IL) was used to perform these analyses. Additionally, *C. formosanus* flight initiation was modeled in relation to the following climatic variables: 1) mean temperature, 2) mean precipitation, 3) mean wind speed, and 4) mean humidity for trap collection weeks. Using a general linear model to fit the data from Week number 11 (8 wk before initiation of dispersal flights) to Week number 19 or number 21 (depending on the observed dispersal flight intensity peak for each sampling year), the ANOVA test was used to provide inferences about the explanatory climatic variables. Complete model regressions with all climatic variables (mean temperature, mean precipitation, mean wind speed, and mean humidity) and reduced model regressions (any combination of three or less variables) were analyzed. This analysis was conducted with SAS v. 9.3 (SAS Institute Inc. 2012). Voucher specimens of *C. formosanus* collected in this study were deposited in the Center for Urban and Structural Entomology insect collection at Texas A&M University.

Table 1. Mean number of *C. formosanus* alates collected on traps during the 2009, 2010, and 2011 sampling seasons on Galveston Island, TX

	Mean no. of *C. formosanus* alates on traps					
	Week no. 19	Week no. 20	Week no. 21	Week no. 22	Week no. 23	Week no. 26
2009	4.18a	1.18a	0.55a	0.75a	0.09a	0.00b
2010	0.05c	0.21b	0.67a	0.22b	0.07a	0.13a
2011	0.43b	0.01c	0.00b	0.02c	0.00b	0.00b
P value	<0.01	<0.01	<0.01	<0.01	0.03	0.03
χ^2	22.79	46.11	28.01	29.10	7.02	6.70
df	2	2	2	2	2	2

Means followed by the same letter are not significantly different (Kruskal–Wallis; $P < 0.05$) and means separated using Mann–Whitney *U* test; $P < 0.05$ (SPSS for Windows, V. 19.0).

Results

Total Number of Alates Per Week. The first *C. formosanus* alate detection in 2009, 2010, and 2011 all occurred during Week number 19 (Table 1 and Figs. 3–5). Based on inspection of the total number of alates collected on all traps during weekly sampling events throughout the study, peak dispersal flight activity occurred during Week number 19 during 2009 and 2011, and during Week number 21 in 2010 (Fig. 3). Secondary flight intensity peaks occurred during Week number 22 in 2009 and 2011, and during Week number 26 in 2010 (Fig. 3). Alates were no longer detected after Week numbers 26, 27, and 23 in 2009, 2010, and 2011, respectively (Fig. 3). The total number of alates collected was 309, 155, and 42 in 2009, 2010, and 2011, respectively.

Mean Number of Alates Trapped Per Week. With regards to the mean number of alates trapped per week during the 2009, 2010, and 2011 sampling seasons, there were significant differences during Week numbers 19–23 and Week number 26 (Table 1 and Fig. 4). The mean number of alates collected during 2009 was significantly greater than that of 2010 and 2011 during Week number 19 ($\chi^2 = 22.79$; df = 2; $P < 0.01$), Week number 20 ($\chi^2 = 46.11$; df = 2; $P < 0.01$), and Week number 22 ($\chi^2 = 29.10$; df = 2; $P < 0.01$; Table 1 and Fig. 4). During Week numbers 21 and 23, the number of alates collected in 2009 and 2010 were significantly greater than those of 2011, but there was no significant difference between 2009 and 2010 ($\chi^2 = 28.01$; df = 2; $P < 0.01$ and $\chi^2 = 7.02$; df = 2; $P = 0.03$; respectively; Table 1 and Fig. 4). More alates were collected during Week number 26 of 2010 than in 2009 and 2011 ($\chi^2 = 6.70$; df = 2; $P = 0.03$; Table 1 and Fig. 4).

Mean Percent of Traps That Collected Alates. With respect to the percent of traps that collected at least one *C. formosanus* alate during each season, 71.11,

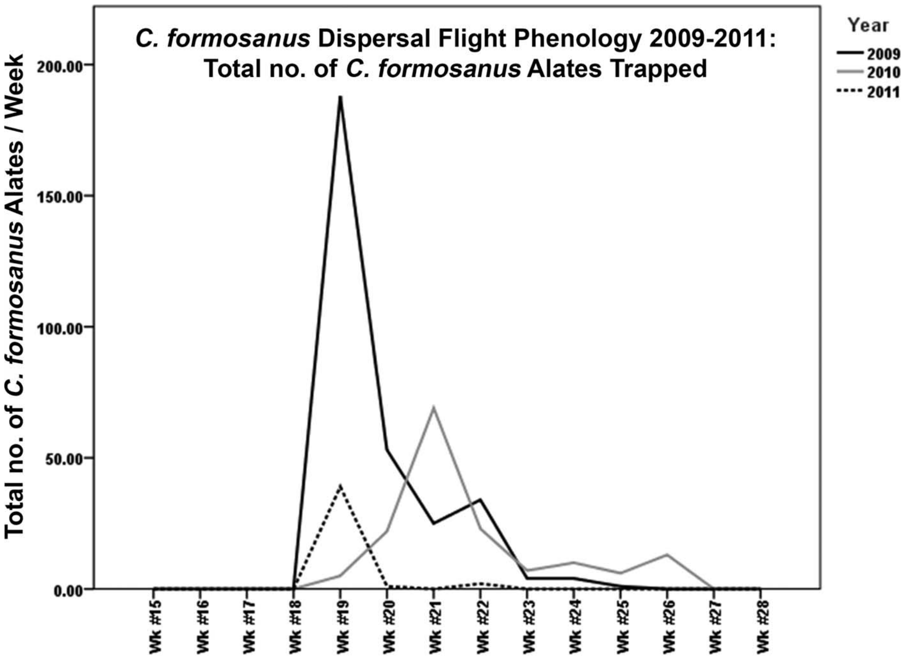

Fig. 3. Total number of *C. formosanus* alates collected on all traps during weekly sampling events throughout the 2009, 2010, and 2011 sampling seasons.

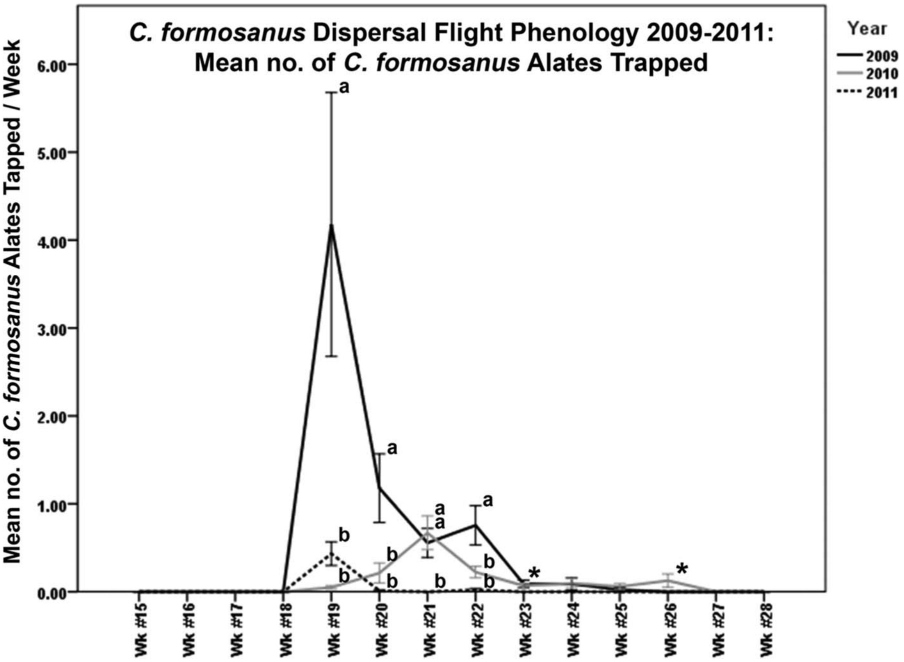

Fig. 4. Mean ± SE *C. formosanus* alates collected on all traps during weekly sampling events throughout the 2009, 2010, and 2011 sampling seasons. Note: Asterisk denotes significant differences, but not enough space to denote with letters (see Table 1).

38.23, and 20.00% of traps collected alates in 2009, 2010, and 2011, respectively. Regarding the mean percent of traps that collected *C. formosanus* alates during this same time period, there were significant differences during Week numbers 19–23 and Week number 26 (Table 2 and Fig. 5). The mean percent of traps that collected *C. formosanus* alates during 2009 was significantly greater than that of 2010 and 2011 during Week number 19 (χ^2 = 20.50; df = 2; P = < 0.01), Week number 20 (χ^2 = 45.12; df = 2; P = < 0.01), and Week number 22 (χ^2 = 28.53; df = 2; P = < 0.01; Table 2 and Fig. 5). During Week numbers 21 and 23, the percent of traps that collected *C. formosanus* alates in 2009 and 2010 was significantly greater than that of 2011, but there was no significant difference between 2009 and 2010 (χ^2 = 28.25; df = 2; $P < 0.01$ and χ^2 = 7.05; df = 2; P = 0.03; respectively; Table 2 and Fig. 5). A greater percent of traps collected alates during Week number 26 of 2010 than in 2009 and 2011 (χ^2 = 6.67; df = 2; P = 0.04; Table 2 and Fig. 5).

Temperature. The mean temperature for 2011 was significantly greater than that of 2009 and 2010 at this sampling location (F = 2.94; df = 2,1,085; P = 0.05; Fig. 6A). Regarding the months before the initiation of *C. formosanus* dispersal flights during each year, there were significant differences between the mean monthly maximum temperatures in 2009, 2010, and 2011. The maximum January and February temperature during 2009 was significantly greater than that of 2010 and 2011 (January—F = 6.98; df = 2,90; $P < 0.01$; February—F = 13.21; df = 2,81; $P < 0.01$; Fig. 6A). The maximum March temperatures during 2009 and 2011 were significantly greater than that of 2010 (F = 6.39; df = 2,90; $P < 0.01$), but were significantly different from each other. The maximum April temperature during 2011 was significantly greater than those of

Table 2. Mean percentage of traps that collected *C. formosanus* alates during the 2009, 2010, and 2011 sampling seasons on Galveston Island, TX

	Mean % of traps that collected *C. formosanus* alates					
	Week no. 19	Week no. 20	Week no. 21	Week no. 22	Week no. 23	Week no. 26
2009	33.33a	40.00a	26.67a	35.55a	8.88a	0.00ab
2010	18.89bc	8.74b	26.21a	13.59b	5.82a	4.85a
2011	4.85c	1.11c	0.00b	2.22c	0.00b	0.00ab
P value	<0.01	<0.01	<0.01	<0.01	0.03	0.04
χ^2	20.50	45.12	28.25	28.53	7.05	6.67
df	2	2	2	2	2	2

Means followed by the same letter are not significantly different (Kruskal–Wallis; $P < 0.05$) and means separated using Mann–Whitney U test; $P < 0.05$ (SPSS for Windows, V. 19.0).

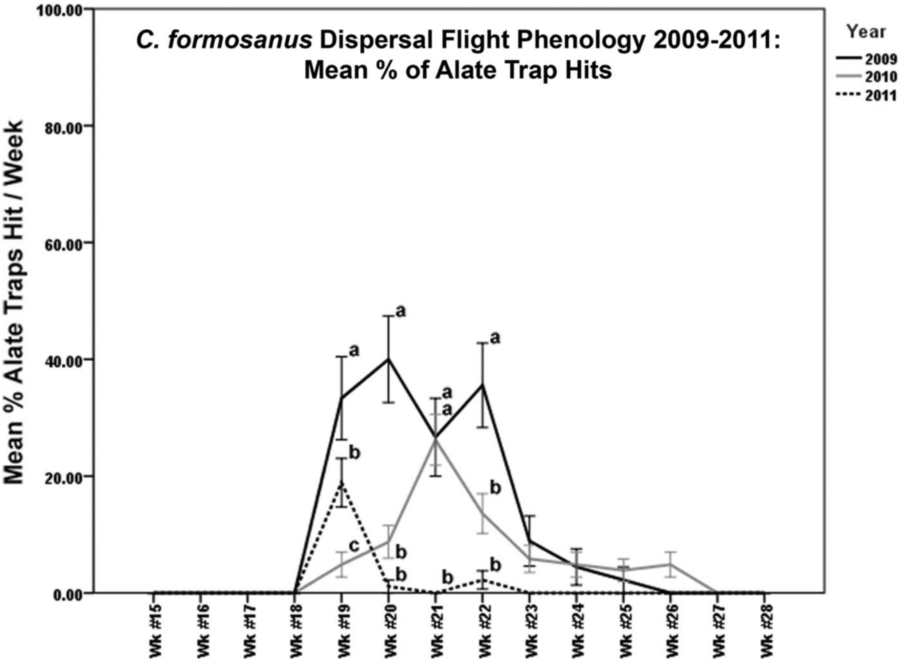

Fig. 5. Mean ± SE percent of traps that collected *C. formosanus* alates during weekly sampling events throughout the 2009, 2010, and 2011 sampling seasons.

2009 and 2010 ($F = 13.08$; df = 2,86; $P < 0.01$; Fig. 6A). Finally, there were no significant differences between the mean maximum temperatures during May of 2009, 2010, and 2011 ($F = 1.58$; df = 2,90; $P = 0.21$; Fig. 6A).

Precipitation. ANOVA failed to reveal significant differences ($F = 1.06$; df = 2,1092; $P = 0.35$) between mean annual precipitation at this site during the three years of the trial. Additional ANOVA performed to identify differences in mean monthly precipitation likewise failed to reveal significant differences at any discrete monthly period. Cumulative precipitation before flight periods was similar during each sampling year, and total cumulative annual precipitation was decreased in 2011, relative to 2009 and 2010, which were nearly identical (Fig. 6B). Acute rain events lasting between 1 and 2 d were recorded within 24 h of, or during, sampling weeks that recorded the initiation of dispersal flights during each sampling year.

Climate and Dispersal Flight Initiation. As a complete model (all four climatic variables), a linear re-

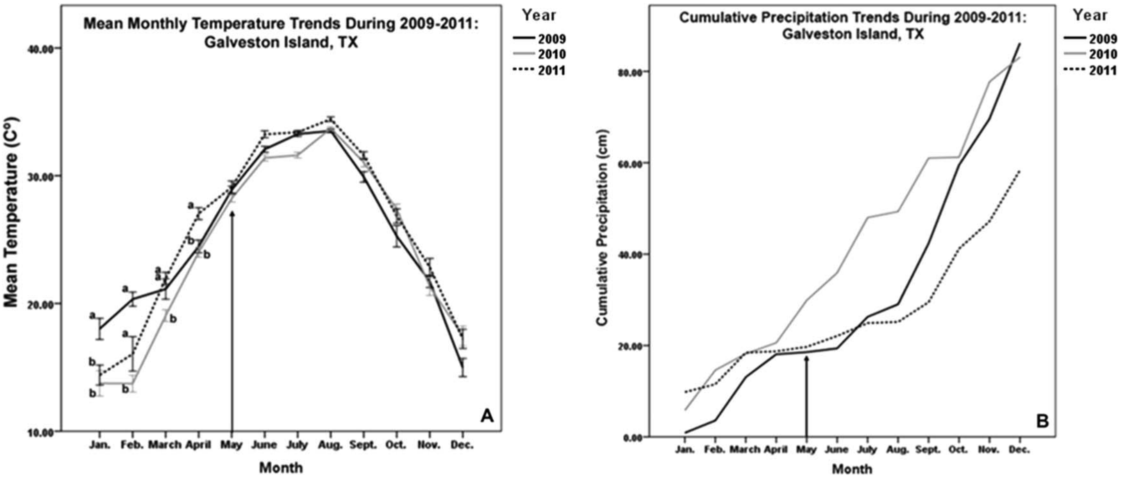

Fig. 6. (A) Mean ± SE monthly temperatures on Galveston Island, TX, during 2009, 2010, and 2011. Vertical arrow indicates month of initiation of *C. formosanus* dispersal flights during each sampling season. (B) Accumulated precipitation on Galveston Island, TX, during 2009, 2010, and 2011. Vertical arrow indicates month of initiation of *C. formosanus* dispersal flights during each sampling season.

gression composed of all climatic estimation variables produced a combination effect that resulted in significant predictive values for *C. formosanus* dispersal flight initiation ($F = 7.82$; df = 4; $P < 0.01$). The most predictive three-variable model used mean temperature, mean wind speed, and mean precipitation ($F = 10.44$; df = 3; $P < 0.01$). The most predictive two-variable model used mean temperature and mean precipitation to determine flight initiation ($F = 15.51$; df = 2; $P < 0.01$). Finally, the most accurate single-variable in predicting flight initiation was mean temperature ($F = 29.18$; df = 1; $P < 0.01$). Single-variable models of mean humidity ($F = 0.29$; df = 1; $P = 0.59$), mean precipitation ($F = 2.04$; df = 1; $P = 0.15$), and mean wind speed ($F = 2.16$; df = 1; $P = 0.14$) were unreliable predictors of *C. formosanus* dispersal flight initiation.

Discussion

Many environmental factors appear to contribute to the seasonal timing of subterranean termite dispersal flights. Recent rainfall before flights (Sun et al. 2007), heat unit accumulation since dispersal during the previous year (Nix 2005), relative humidity levels (Higa and Tamashiro 1983), and wind velocity (Leong et al. 1983) have all been implicated as environmental factors that influence *C. formosanus* dispersal timing and intensity. Additionally, biotic factors, such as availability of food resources, are known to impact dispersal activity in termites (Korb and Katrantzis 2004). The annual initiation of *C. formosanus* reproductive flights on Galveston Island, TX, appears to be predictable around the 19th full week of the year, with flight intensity peaks occurring between the 19th and 21st full week. The temperature trends on Galveston Island depicted in Fig. 6A demonstrate that mean high temperatures from July through December were very similar across years. However, mean high temperatures from January through May tended to be more variable from year to year, and it is speculated that such differences resulted in the *C. formosanus* flight intensity peak date differentials observed during this study. That is, the mean maximum temperatures during January through May were significantly higher in either or both 2009 and 2011, relative to those of 2010. Not surprisingly, the 2010 *C. formosanus* dispersal peak occurred two weeks later (Week number 21) than in 2009 and 2011 (Week number 19). Additionally, the peak percentage of traps that collected alates in 2010 occurred on Week number 21, which was 1 wk later than that of 2009 and 2 wk later than that of 2011. This anecdotally suggests that the accumulation of temperature units in the months just before the initiation of *C. formosanus* flights may be of greater importance to dispersal timing than that of the entire postflight period, as suggested by Nix (2005). This potential phenomenon remains to be resolved, but it is our intention to critically evaluate this in future studies. It is also important to note that while many combinations of the four climatic variables included in our multivariable model regression analyses of climate and dispersal flight initiation (mean temperature, precipitation, humidity, and wind speed) were significant predictors of *C. formosanus* flight initiation, when climatic variables were analyzed independently, only temperature was found to be a significant predictor. Interestingly, mean monthly precipitation was not significantly different across sampling years, and accumulated precipitation totals were greater during the dispersal flight period in 2010 than that of 2009 and 2011. Despite this, the flight intensity peak was delayed in 2010, relative to that of 2009 and 2011, suggesting that at this location accumulated temperature is a more significant driver of dispersal flight phenology than mean monthly or accumulated precipitation. Notably, acute rain events that lasted from 1 to 2 d occurred during, or within 24 h of the initiation of *C. formosanus* dispersal during each year of observations. This was not unexpected, and further suggests that the accumulation of heat units above a physiological threshold followed by acute rainfall events provides a more accurate predictive tool with respect to the initiation of *C. formosanus* dispersal flights than the accumulation of rainfall at a particular site. Additionally, these results are similar to those of Gold and Furman (2002) who noted the relationship between subterranean termite flight initiation across interior Texas, and the accumulation of temperature units followed by acute precipitation events. However, it should noted that their work addressed flight initiation of *Reticulitermes flavipes* (Kollar), which is known to disperse diurnally.

The traps used in this research represent a consolidation of components from devices that have been successfully used by other researchers to sample *C. formosanus* alates. For example, attaching glue boards to ensnare alates that were attracted to light provided by either "private utility lights or public street lights" or in some cases by LED lamps similar to those used in our monitoring has been used extensively to monitor *C. formosanus* dispersal behavior and distribution (Thompson 1985, Lax and Osbrink 2003, Sun et al. 2007, Lax and Wiltz 2009). The decision of which light source chosen (fixed or movable lights) for such trapping must be made thoughtfully, and only after carefully considering the benefits and costs associated with each source of *C. formosanus* attractant. For the monitoring reported in this study, we simply could not rely on the poststorm island infrastructure to reliably deliver electricity to all utility and residential lights across the island. Thus, it was necessary to build and trial a relatively inexpensive trap. Although the costs associated with construction of our traps were reasonable (US$23.57 per trap), the expense was obviously one that would not have been encountered if we had used fixed lights along the island. The traps performed well, and delivered reliable and repeatable results, despite their relatively low level of illumination as compared with brighter illumination of competing light sources across the island. In fact, with respect to the peak percentage of traps collecting termites and the length of dispersal flight season, the results of this study related to mean percentage of traps that collected *C. formosanus* alates were very similar to the transect sampling results of Lax and Wiltz (2009), which used a combination of glue boards affixed to LED lights or utility lights. Additionally, Lax and Wiltz's (2009) work demonstrated that annual *C. formosanus* dispersal is predictable at their study location (Poplarville, MS) during the same general time period (Week number 18) as the initiation of dispersal flights at our location (Week number 19). This is notable, as these sampling locations are separated by ≈550 km, a full degree of latitude, five degrees of longitude, and they are uniquely different in terms of most measurable aspects of their ecosystems. However, close comparison of the results of these two projects shows that the peak dispersal flight intensity documented on Galveston Island lasted for a much shorter period of time than those observed in and around Poplarville, MS, by Lax and Wiltz (2009). Furthermore, the number of termites collected by Lax and Wiltz (2009) was at least an order of magnitude greater than that of our study. This suggests either dramatic differences in *C. formosanus* densities at these two locations, differential trap efficiency, or both. It should be noted that many of the trapping locations in the Lax and Wiltz (2009) study used utility lights and street lights, which emit much more light than the LED lamps used in our study, and are presumed to attract a greater relative number of *C. formosanus* alates. Additionally, our lights were in competition with all manner of artificial light on and around the properties that were used in this study. This represents another possible explanation for the differences between the total number of alates collected in our study and that of Lax and Wiltz (2009).

This study provides an example of the benefits that can be realized from coordination between researchers and a willing residential population. However, it also illustrates nuanced difficulties and methodological hurdles that are often confronted when such studies are undertaken. For example, while the dramatic differences between the percentage of traps that collected *C. formosanus* alates across the three sampling years (71.11, 38.23, and 20.00% in 2009, 2010, and 2011, respectively) was almost certainly due in some measure to differential climatic variables, the possibility also exists that the placement of traps affected individual trap success, and thus the percentage of traps hit by alates. Ambient light levels at each property almost certainly fluctuated over the course of the sampling seasons, perhaps nightly. To observe this would have required constant nightly monitoring of each sampling location. We simply did not have the resources to continually monitor this at a location that is ≈240 km from our headquarters, and no attempt was made to measure the ambient light levels at each trap location over the course of the study. Additionally, we essentially doubled the number of trap locations during 2010 and 2011, relative to that of 2009 (Fig. 2). Reliance on residents to volunteer properties for the study resulted in a disproportionate number of trap sites within areas of high human population density, and as properties were added to the study, the discrepancy between the number of traps in high human density areas in the northeastern portion of the island versus those in less populated areas along the southwestern portion of the island only grew larger.

This project resulted in the ability to predict the seasonal dispersal flight phenology and periodicity of *C. formosanus* on Galveston Island, TX, which are similar to other locations at this general latitude. This information will allow pest management professionals and homeowners at this location to better predict the timing of *C. formosanus* dispersal flights, the most conspicuous behavior of this important invasive pest insect, thus allowing for more efficient surveillance and control efforts. Additionally, it is presumed that our interactions with island residents as a result of our visibility on the island during sampling seasons, and dissemination of project goals and milestones through various media outlets, has resulted in a more acute awareness of the degree of infestation and potential for loss or destruction of property on Galveston Island. Although the number of *C. formosanus* alates collected over the course of this study was far less than that of the Lax and Wiltz (2009) study, we consider this work to be a successful *C. formosanus* surveillance program as demonstrated by the ability of our trap design to reliably signal *C. formosanus* presence and dispersal flight initiation. Further, this work demonstrated the success of a portable trap design that was not restricted to use in urban settings. It is hoped that this new understanding will better inform municipal leadership and residents of the challenges posed by these insects, thus allowing all involved to better surveil, predict, and manage *C. formosanus* infestations.

Acknowledgments

Brett Neff, Ryan Neff, Chris Swain, Danny McDonald, and Shawn Fazzino all assisted with collection of glue boards from traps during this study and have our sincere appreciation. We thank Laura Nelson for her helpful reviews and comments on earlier drafts of this document. Funding for this work was provided in part by the U.S. Department of Agriculture–Agricultural Research Service Operation Fullstop: National Formosan Subterranean Termite Program (Project number 6435-32000-011-19S).

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Received 6 August 2013; accepted 19 May 2014.