Predicting Temperature-Dependent Range Limits for the Red Imported Fire Ant (*Solenopsis invicta*) in Hawaii

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INTRODUCTION:

The red imported fire ant is a notoriously destructive, invasive, and aggressive stinging ant that has serious impacts on biodiversity, as well as on industry, the economy, and quality of life. Native to the Pantanal, a seasonally flooded wetland in Argentina and Brazil, the red imported fire ant is dispersed primarily through commerce and has invaded much of the southern U.S., several islands in the West Indies, and just recently, California and Queensland, Australia. Although not known to occur in Hawaii, recent establishment of this ant in California puts Hawaii at high risk of invasion by this pest due to the huge quantities of goods shipped here from California.

The red imported fire ant is one of the world's worst ant pests and poses a huge risk to Hawaii's native biota. In order to assist in targeting quarantine and monitoring efforts, and allow resource managers to determine which areas are at highest risk of RIFA invasion, future potential range of the red imported fire ant in Hawaii was predicted following a modeling method developed by Dr. M. Korzukhin and others.

METHODS:

Future potential range of the red imported fire ant in Hawaii was predicted following the methods of Korzukhin et al. (2001). The primary component of these methods is a model that simulates colony growth and calculates subsequent production of reproductive females (alates) based on soil temperature, the key ecological factor determining red imported fire ant colony growth and metabolism (Markin et al. 1973; Porter and Tschinkel 1987; Porter 1988; Tschinkel 1993). The model was run on temperature data from 129 weather stations in Hawaii (Figure 1). Results were compared to those at five calibration sites located at the extreme northern limits of the current red imported fire ant range on the U.S. mainland (Figure 2). Average alate production at these calibration sites was used to define zones of probable red imported fire ant colony proliferation. Alate production calculated for each Hawaii weather station site was mapped according to these colony proliferation definitions.

As per Korzukhin et al 2001, a precipitation threshold of 510mm/yr was used to indicate regions where arid conditions may prohibit colony growth in areas without supplemental water sources, such as irrigation, stock ponds, streams, lakes, etc. This precipitation threshold corresponds to a semiarid region in southern Texas where fire ants have been reported to survive in natural mesquite scrub lands.

RESULTS/DISCUSSION:

The results of this study show that the red imported fire ant has the potential to colonize much of Hawaii (Figure 3), with exceptions occurring at some high elevation and leeward sites. Results predict red imported fire ants will be climate limited at only 25 (19%) of the 129 locations studied. These 25 locations include eight high elevation sites (those above 1500m on Hawaii, some sites above 1900m on Maui, and one at approximately 1000m on Kauai) where colonization is predicted to be temperature-limited, 16 primarily leeward sites where colonization is predicted to be precipitation-limited, and one site (at the top of Mauna Kea) where colonization is predicted to be both temperature and precipitation-limited. It should be noted that many of the precipitation-limited leeward sites include areas with man-made sources of water that would provide more than adequate moisture for colony establishment and proliferation.

Variable results seen at higher elevations on east Maui are primarily due to varying daily minimum temperatures (Tmin) recorded at different weather stations. Red imported fire ant colony dynamics are affected primarily by temperature (Markin et al. 1973; Porter and Tschinkel, 1987; Porter, 1988; Tschinkel, 1993). Previous model runs using continental data show that daily Tmin fluctuations in the direction of low temperatures can have substantial effects on results. Just a few days of low Tmin values result in a considerable decrease is colony size, and, consequently, in colony alate production. The reasons for differing Tmin values at relatively close weather stations may be due to a variety of factors, including micro-climate in which weather stations are placed, and the time period over which the data were taken (for instance, data from recent years show trends towards warmer temperatures at night, when Tmin usually occurs (Tom Giambelluca, Pers.Comm.)).

It is important to note that the predicted range of the red imported fire ant presented is a conservative forecast, since it is based on the species current mainland range, and on average alate production. If red imported fire ants continue invading colder climates, the model may need to be recalibrated and the results recalculated. It is also important to note that the results presented are based solely on climate and do not take into account other factors that may influence red imported fire ant establishment, such as canopy cover and resource availability.

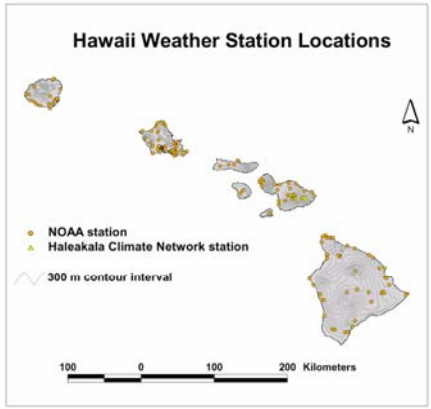

Figure 1. Locations of weather stations from which data were used.

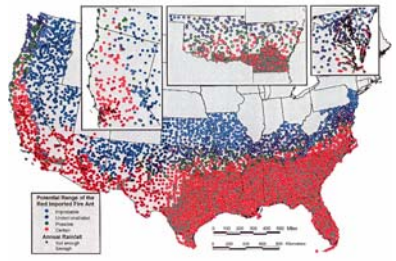

Figure 2. Calibration sites (circled areas) used in the model. Certain = female alate production (A) > 3,900; Possible = 2100 < A ≤ 3900; Undemonstrated = 0 < A ≤ 2100 Improbable = 0.

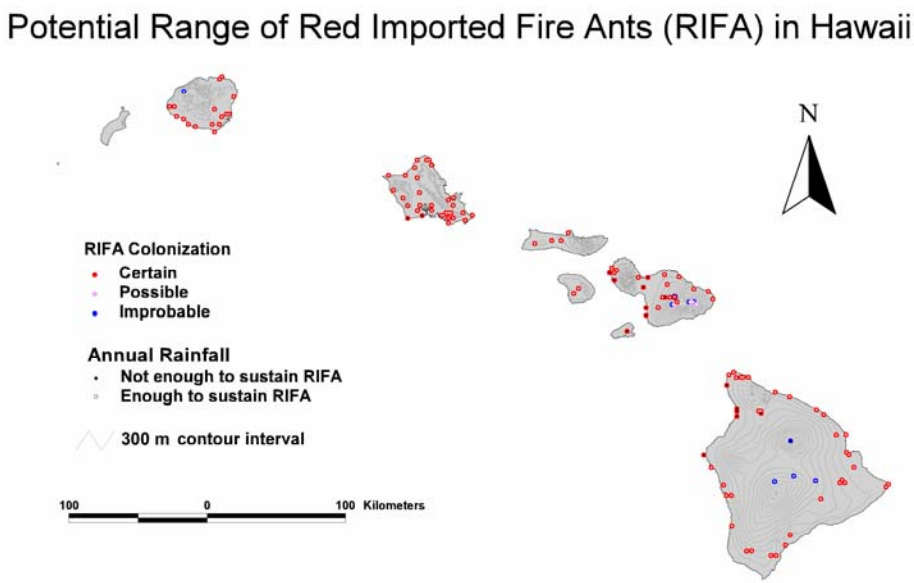

Figure 3. Potential range of the red imported fire ant in Hawaii. Colored circles depict sites with "certain" (red), "possible" (purple), and "improbable" (blue) reproductive success, defined as follows: Certain = female alate production (A) > 3,900; Possible = 2100 < A ≤ 3900; Improbable* = 0 ≤ A ≤ 2100 ***(*This category includes both the "undemonstrated", and "improbable" categories of Korzukhin et al. 2001, and corresponds to sites with weather conditions where red imported fire ants have no record of success and sites where colonies did not survive to produce female alates).*** White dots inside colored circles correspond to sites with sufficient precipitation (estimated at 510mm/yr) to sustain red imported fire ants in the landscape. Black dots indicate arid sites which likely have insufficient rain to sustain the species. However, it is important to note that red imported fire ants will survive in arid areas that are irrigated or have natural sources of water.

CITATIONS

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