

Evaluation of predicted medfly (*Ceratitis capitata*) quarantine length in the United States utilizing degree-day and agent-based models

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Abstract

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Keywords

Please list up to eight keywords to help readers interested in your article find it more easily.



Figure 1. Location of sites reported on.

Take-homes:

1. There is significant variation in predicted quarantine length at different times and locations.
 - (a) Captured by normals
 - (b) Climate
2. Variation in prediction within time / location (across years) is important.
 - (a) Captured by day-of-year (between-year) variation
 - (b) Informs reliability of prediction
 - (c) Influenced by rare events (eg. cold snaps)
 - (d) Prediction based on normal temps vs normal of predictions based on measured temps
3. DD vs ABS comparison
 - (a) ABS is better behaved
 - i. Seasonal swings less dramatic; Much less discontinuity at beginning of autumn
 - ii. Smaller overall range
 - iii. Captures common-sense effects missed by DD: eg. extreme cold kills
 - (b) Large disagreement between DD and ABS may indicate DD prediction is unreliable/broken
 - (c) Variance in predictions should inform management and planning. ABS variance is easier to interpret (KFAT being a dramatic example).

Introduction

The format of the main body of the article is flexible: it should be concise and in the format most appropriate to displaying the content of the article.

Methods

Sites and Temperature Data

Hourly air temperature data for 11 sites was downloaded from NOAA's Integrated Surface Database (ISD) dataset[1, 2]. The airport sites shown in Table 1 were chosen for their biological relevance and availability of high quality hourly data over a long time frame. Data was fetched and parsed using the "Fetching and parsing ISH.ipynb" program. Records for the same station callsign were merged, since identification, format, and precise location of stations has changed over the years.

The data was then cleaned using the "Cleaning temperatures.ipynb" program by removing outliers, identifying large gaps (gt 3 hours), resampling to every hour on the hour using linear interpolation, and filling the large gaps using day-over-day linear interpolation (interpolating using values for the same hour of day from previous and following days). The processing programs and resulting temperature datasets are provided in the Supplemental Materials.

Degree-Day Calculation

Degree-days were computed by the single-sine method[3] using a base development temperature of 12.39°C (53.3°F) and 345.56 degree-days Celsius (DDc; 622 DDf) per generation following the standard required by California Department of Food and Agriculture regulation 3406(b)[4, 5]. Since we have hourly temperature data, we also calculated degree-days by simple summation for comparison[6]. For each date, the number of days required to pass 3 generations of degree-day based life cycles was computed. These calculations are implemented in "Temperature functions.ipynb" in the Supplemental Materials.

Agent-based Simulations: MED-FOES

MED-FOES[7, 8] is an agent-based simulation explicitly modeling the eradication of a population of Medflies under inundative sterile male releases (aka: sterile insect technique or SIT). A MED-FOES simulation models a single non-spatial population starting from a given age distribution and number of individuals through the time the population experiences extirpation when the last potentially fertile female dies or mates with a sterile male. The simulation is parameterized on the initial population, additional mortality induced by control efforts, the effectiveness of SIT, and a large number of biological parameters for which ranges are known from the literature, including temperature-dependent development and mortality. The simulation is fed the same hourly timeseries of temperature values which was used for degree-day calculations and updated in hourly time steps.

Due to the fact that only ranges are known for many of the parameters, 2500 individual MED-FOES simulations were run for each given start date at each site sampling different regions of parameter-space using a Latin Hypercube Sampling[9] procedure. This set of simulations is referred to as a 'run'.

Varying the start date for different simulations was achieved by simply starting at different points in the input temperature file; for this study a run starting every 7 days over the range of dates available for each site. Each set of runs for a single site over a range of starting dates is referred to as a 'runset'. All runsets were conducted with the same input parameters aside from temperature. Initial population numbers were chosen as a standard outbreak based upon several real outbreaks modeled previously[8]. MED-FOES version 0.6.2 was run under OGS/Grid Engine 2011.11 on a CentOS 6.6 HPC cluster. The MED-FOES code, configuration files, and helper scripts are provided

Table 1. Sites.

Callsign	Station Name	State	Latitude	Longitude	Elevation	Start year
KSFO	SAN FRANCISCO INTERNATIONAL A	CA	+37.620	-122.365	2.4	1950
KFAT	FRESNO YOSEMITE INTERNATIONAL	CA	+36.780	-119.719	101.5	1950
KBUR	BURBANK-GLENDALE-PASA ARPT	CA	+34.201	-118.358	236.2	1973
KLAX	LOS ANGELES INTERNATIONAL AIR	CA	+33.938	-118.389	29.6	1950
KRIV	MARCH AIR RESERVE BASE	CA	+33.900	-117.250	468.2	1950
KSAN	SAN DIEGO INTERNATIONAL AIRPO	CA	+32.734	-117.183	4.6	1950
KJAX	JACKSONVILLE INTERNATIONAL A	FL	+30.495	-81.694	7.9	1950
KIAH	G BUSH INTERCONTINENTAL AP/HO	TX	+29.980	-95.360	29.0	1970
KMCO	ORLANDO INTERNATIONAL AIRPORT	FL	+28.434	-81.325	27.4	1973
KTPA	TAMPA INTERNATIONAL AIRPORT	FL	+27.962	-82.540	5.8	1950
KMIA	MIAMI INTERNATIONAL AIRPORT	FL	+25.791	-80.316	8.8	1950

in the Supplemental Materials. Overall, we created 11 runsets (one for each site), each containing runs starting every 7 days over the input temperature data range for that site, where each run contained 2500 individual simulations sampling different regions of biologically plausible parameter space.

The MED-FOES data is summarized here by the number of days from the start date required 95% of the simulations in a run to go be eradicated.

Results

This section is not essential for Web Tool papers.

Discussion

The discussion should include the implications of the article results in view of prior work in this field.

Conclusions

Please state what you think are the main conclusions that can be realistically drawn from the findings in the paper, taking care not to make claims that cannot be supported.

Author contributions

In order to give appropriate credit to each author of an article, the individual contributions of each author to the manuscript should be detailed in this section. We recommend using author initials and then stating briefly how they contributed.

Competing interests

All financial, personal, or professional competing interests for any of the authors that could be construed to unduly influence the content of the article must be disclosed and will be displayed alongside the article.

Grant information

Please state who funded the work discussed in this article, whether it is your employer, a grant funder etc. Please do not list funding that you have that is not relevant to this specific piece of research. For each funder, please state the funder's name, the grant number where applicable, and the individual to whom the grant was assigned. If your work was not funded by any grants, please include the line: 'The author(s) declared that no grants were involved in supporting this work.'

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References

- [1] Adam Smith, Neal Lott, and Russ Vose. The Integrated Surface Database: Recent Developments and Partnerships. *Bulletin of the American Meteorological Society*, 92(6):704–708, June 2011. doi: 10.1175/2011BAMS3015.1.
- [2] Integrated Surface Database (ISD) | National Centers for Environmental Information (NCEI) formerly known as National Climatic Data Center (NCDC). URL <https://www.ncdc.noaa.gov/isd>. Last visited 2017-07-05.
- [3] G. L. Baskerville and P. Emin. Rapid estimation of heat accumulation from maximum and minimum temperatures. *Ecology*, 50(3):514–517, 1969. doi: 10.2307/1933912.
- [4] Mediterranean fruit fly: Regulation and quarantine boundaries. URL <https://www.cdffa.ca.gov/plant/medfly/regulation.html>. Last visited 2017-07-17.
- [5] California code of regulations, title 3, section 3406. URL <https://www.cdffa.ca.gov/plant/medfly/docs/regs/3406-TXT-medfly.pdf>. Last visited 2017-07-17.

- [6] William J. Roltsch, Frank G. Zalom, Ann J. Strawn, Joyce F. Strand, and Michael J. Pitcairn. Evaluation of several degree-day estimation methods in california climates. *International Journal of Biometeorology*, 42(4):169–176, Mar 1999. doi: 10.1007/s004840050101.
- [7] Nicholas C. Manoukis, Brian Hall, and Scott M. Geib. A computer model of insect traps in a landscape. *Scientific Reports*, 4:7015, November 2014. doi: 10.1038/srep07015. WOS:000344760700005.
- [8] Nicholas C. Manoukis and Kevin Hoffman. An agent-based simulation of extirpation of *Ceratitis capitata* applied to invasions in California. *Journal of Pest Science*, 87(1):39–51, March 2014. ISSN 1612-4758, 1612-4766. doi: 10.1007/s10340-013-0513-y. URL <https://link.springer.com/article/10.1007/s10340-013-0513-y>.
- [9] S. M. Blower and H. Dowlatabadi. Sensitivity and uncertainty analysis of complex models of disease transmission: An hiv model, as an example. *International Statistical Review / Revue Internationale de Statistique*, 62(2): 229–243, 1994. ISSN 03067734, 17515823. URL <http://www.jstor.org/stable/1403510>.