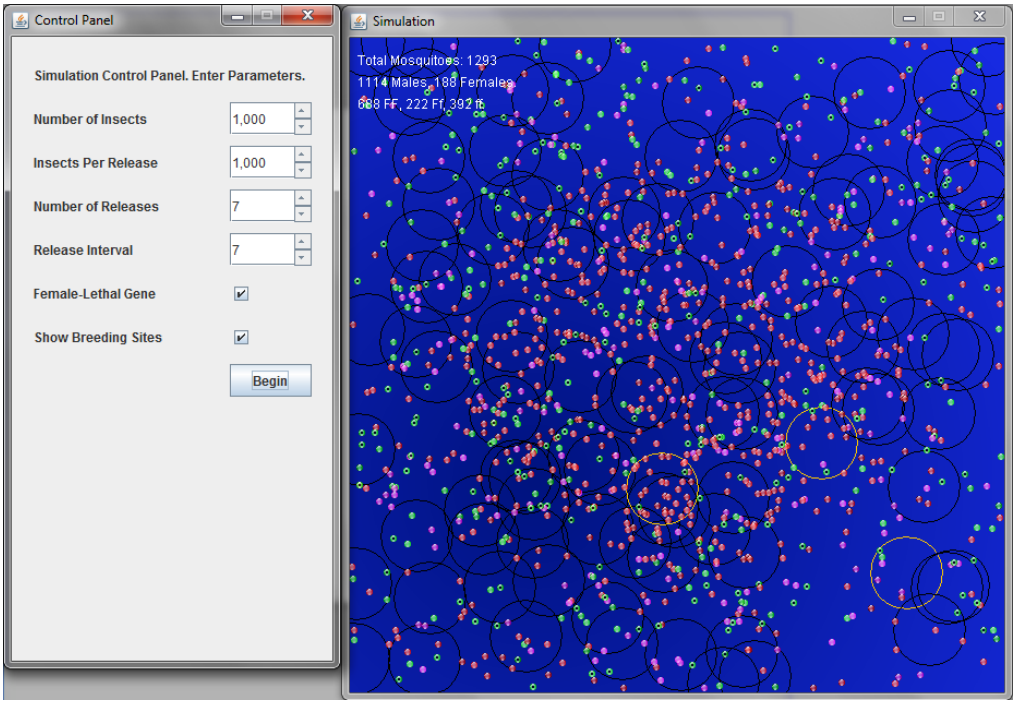
Mosquito Simulation - Description of major elements

Greg Chen

The goal of this simulation is to provide a graphical model of the introduction of a female specific dominant lethal gene to a population of *Aedes aegypti* mosquitoes. *Aedes aegypti* mosquitoes are an invasive species to the American continents and are the major carrier of Dengue fever, a viral tropical disease which currently has no vaccine or specific treatment.

The size of the simulation is scaled to a small Central American town. It creates a Data directory and saves data in an Excel file open closing the simulation window.

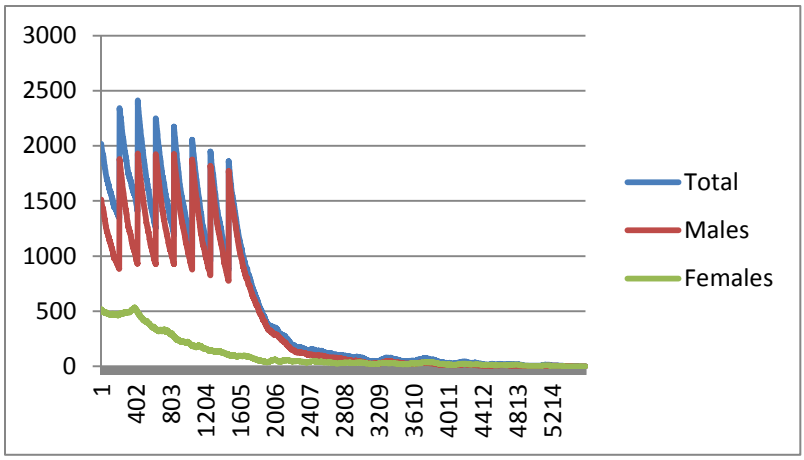
- Time is scaled as 1 simulation second = 1 day.
- Each mosquito is displayed as a small circle.
- Gender is indicated by the presence or absence of a black dot. Female mosquitoes have a black dot, and males have no dot.
- Genotype is indicated by colour. Red indicates homozygous dominant to the lethal gene; magenta indicated heterozygous to the gene, and green indicates homozygous recessive (wild-type) individuals
- When the Female-Lethal gene option is selected, females which are not homozygous recessive will die open emergence from a breeding site
- Mating occurs when a fertile female and male circle touch each other. Females have a limit to the number of times they can mate, and there is a refractory period after egg-laying in which mating cannot occur.
- Black circle outlines indicate breeding sites, which in real life are typically human water carrying containers such as old tires. Breeding sites flash yellow when a female deposits her eggs.
- Breeding sites keep track of larvae, which take around 10 days from egg hatching to emergence as mosquitoes
- Most of the density-dependent competition occurs in the larval stage. Each breeding site applies a density-dependent mortality probability to each larva.



Sample Data

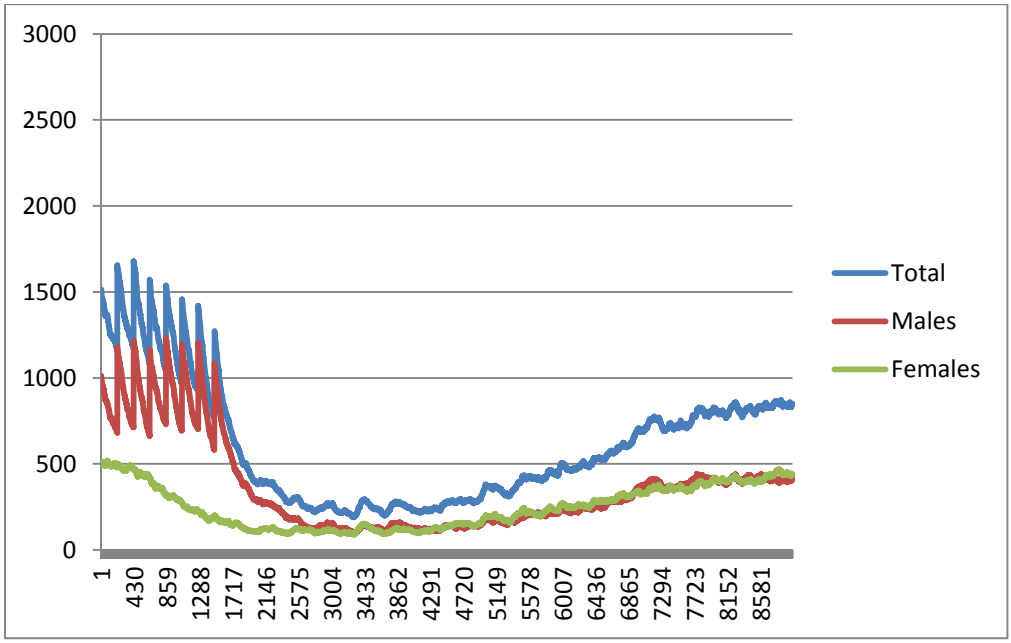
These graphs were generated using the outputted Excel data. The x axis is the number of time steps (30 per day).

Release of 8 weekly cohorts of 1000 mosquitoes



This release pattern eradicated the mosquito population.

Release of 8 weekly cohorts of 500 mosquitoes



This release pattern was not sufficient to eradicate the mosquito population. The population grew by an approximately logistic curve back to steady state values.

Simulation Parameters

- Probability of Daily Survival for adult *Aedes aegypti* mosquitoes: **85%** (Maciel-De-Freitas et al., 2007)
- Average number of eggs deposited per oviposition: **63** (Otero et al., 2006)
- Emergence of pupa to mature mosquitoes: **83%** (Otero et al., 2006)
- Number of hours after emergence until male mosquitoes are fertile: **15-24** (Hartberg, 1971)
- Number of hours after emergence until females are fertile: **48-72** (Hartberg, 1971)
- Average lifetime distance travelled from birth: **81-86 metres** (Maciel-De-Freitas et al., 2007)
- Lifetime maximum number of females for which each male can supply sufficient sperm to impregnate: **4-5** (Hausermann & Nijhout, 1975)
- Number of days until fertile after oviposition: **3** (based on Otero, 2006)
- Period of pregnancy between mating an oviposition: **2 days** (based on Otero, 2006)
- Carrying Capacity for Pupal Mosquitoes per breeding site: **25** (based on Focks et al., 1981)
- Daily Density-Depedent Mortality of a larval population of size *n* per container: **0.0108*n*** (based on Focks et al., 1981).
- Days from egg hatching to emergence from pupa: **9.7 ± 0.2**(Tun-Lin, Burkot, et al., 2000)

Sources

Benedict, M.; Robinson, A. "The first releases of transgenic mosquitoes: an argument for the sterile insect technique." *Trends in Parasitology.* 19.8. (2003).

Bonsall, M., Yakob, L. et al. "Transgenic control of vectors: the effects of interspecific competitions." *Israel Journal of Ecology and Evolution.* 26. 2010.

Dye, C. "Models for the Population Dynamics of the Yellow Fever Mosquito, Aedes aegypti." *Journal of Animal Ecology.* 53.1. (1984).

Esteva, L., Yang, H. "Mathematical model to assess the control of *Aedes aegypti* mosquitoes by the sterile insect technique." *Mathematical Biosciences.* 198. (2005).

Focks, D. et al. "Observations on container-breeding mosquitoes in New Orleans, Louisiana, with an estimate of population density of *Aedes aegypti.*" *American Journal of Tropical Medicine and Hygine.* 30.6. (1981).

Hartberg, W. "Observations on the Mating Behaviour of *Aedes aegypti* in Nature." *Bulletin of the World Health Organization.* 2775. (1971).

Hausermann, W.; Nijhour, H.F. "Permanent loss of male fecundity following sperm depletion in *Aedes aegypti." Journal of Medical Entomology.* 11.6 (1975).

Maciel-de-Freitas, R. et al. "Daily Survival Rates and Dispersal of *Aedes aegypti* females in Rio de Janeiro, Brazil." *American Journal of Tropical Medicine and Hygine.* 76.4. (2007).

Morens, D.; Fauci, A. "Dengue and Hemorrhagic Fever: A Potential Threat to Public Health in the United States." *Journal of the American Medical Assocaiation.* 299.2. (2008).

Otero, M. et al. "A stochastic population dynamics model for *Aedes aegypti:* Formulation and application to a city with temperate climate." *Bulletin of Mathematical Biology.* 68. (2006).

Roth, Louis M. "A Study of Mosquito Behavior. An Experimental Laboratory Study of the Sexual Behavior of Aedes Aegypti (Linnaeus)." *American Midland Naturalist.* 40.2. (1948).

Southwood, T. et al. "Studies on the life budget of *Aedes aegypti* in Wat Samphaya, Bangkok, Thailand." *Bulletin of the World Health Organization.* 46. (1972).

Thomas, D; Donnely, C. et al. "Insect Population Control using a Dominant, Repressible, Lethal Genetic System." *Science.* 287. (2000).

Tun-Lin, W.; Burkot, T.; Kay, B. "Effects of temperature and larval diet on development rates and survival of the dengue vector *Aedes aegypti* in north Queensland, Australia." *Medical and Veterinary Entomology.* 14. (2000).

Wise de Valdez, M. et al. "Genetic elimination of dengue vector mosquitoes." *Proceedings of the National Academy of Sciences.* (2011).

Yakob, L., Alphey, L. et al. "*Aedes aegypti* control: the concomitant role of competition, space, and transgenic technologies." *Journal of Applied Ecology.* 45. (2008).