Sharing is encouraged

EGU General Assembly 2023

NH9.9

Early Warning Systems for Infectious Disease Based on Climate and Environmental Variability

The first continental population dynamics model of the Asian tiger mosquito driven by climate and environment

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The Cyprus Institute
RESEARCH·TECHNOLOGY·INNOVATION

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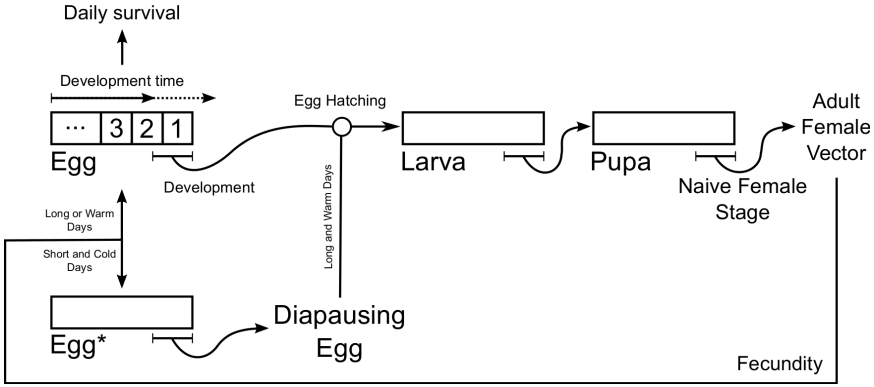
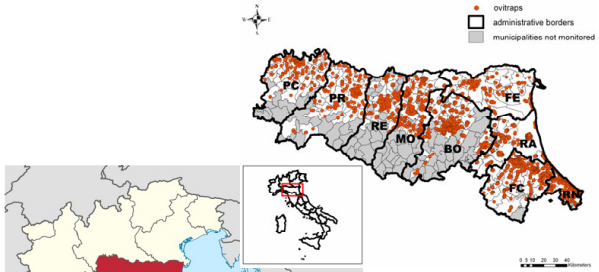
Climate-driven population dynamics of *Aedes albopictus*



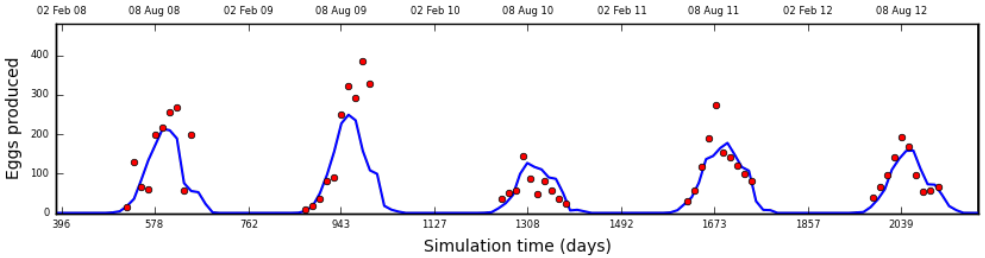


Albieri, A. et al. Environmental Science (2010)

Breeding site model
- Human population density
- Rainfall

Diapause thresholds
- Temperature
- Daylength

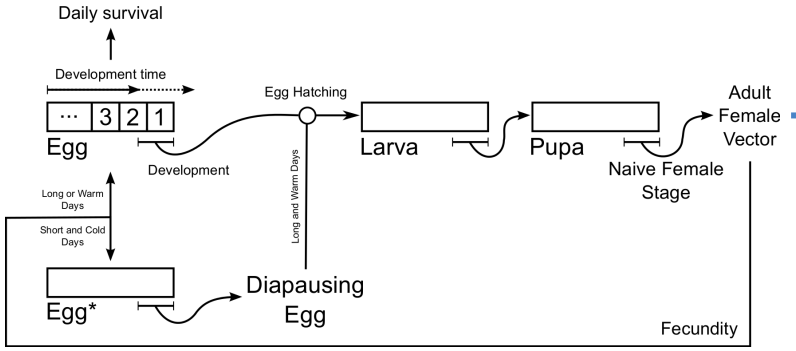
Density dependence
- Larva and pupa survival and development



Calibrated with Emilio-Romagna surveillance data for applicability to the field conditions

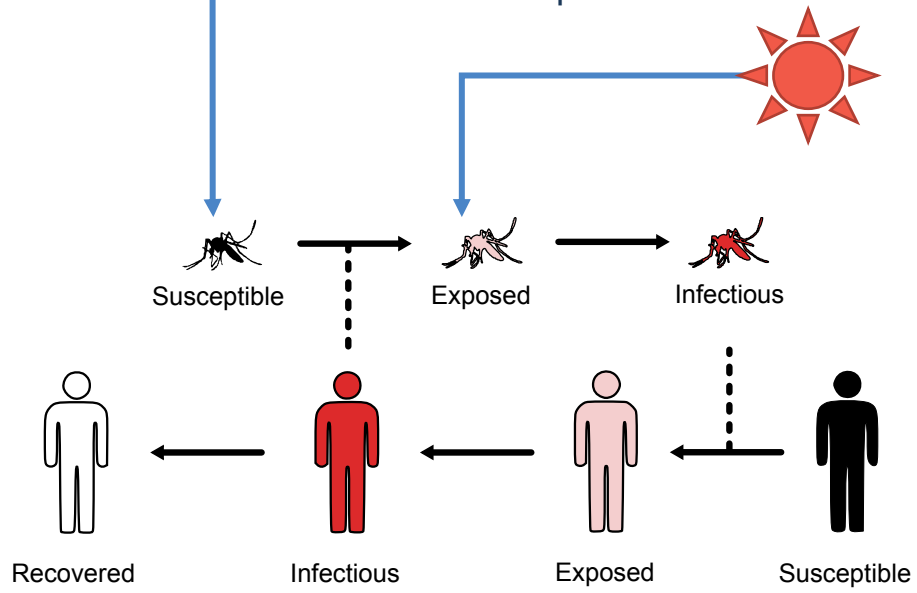
Erguler, K. et al. PLOS ONE (2016)

Aedes albopictus-borne arbovirus transmission model



Extrinsic incubation period (EIP)

- Temperature-driven
- Arbovirus-specific



Transmission model input

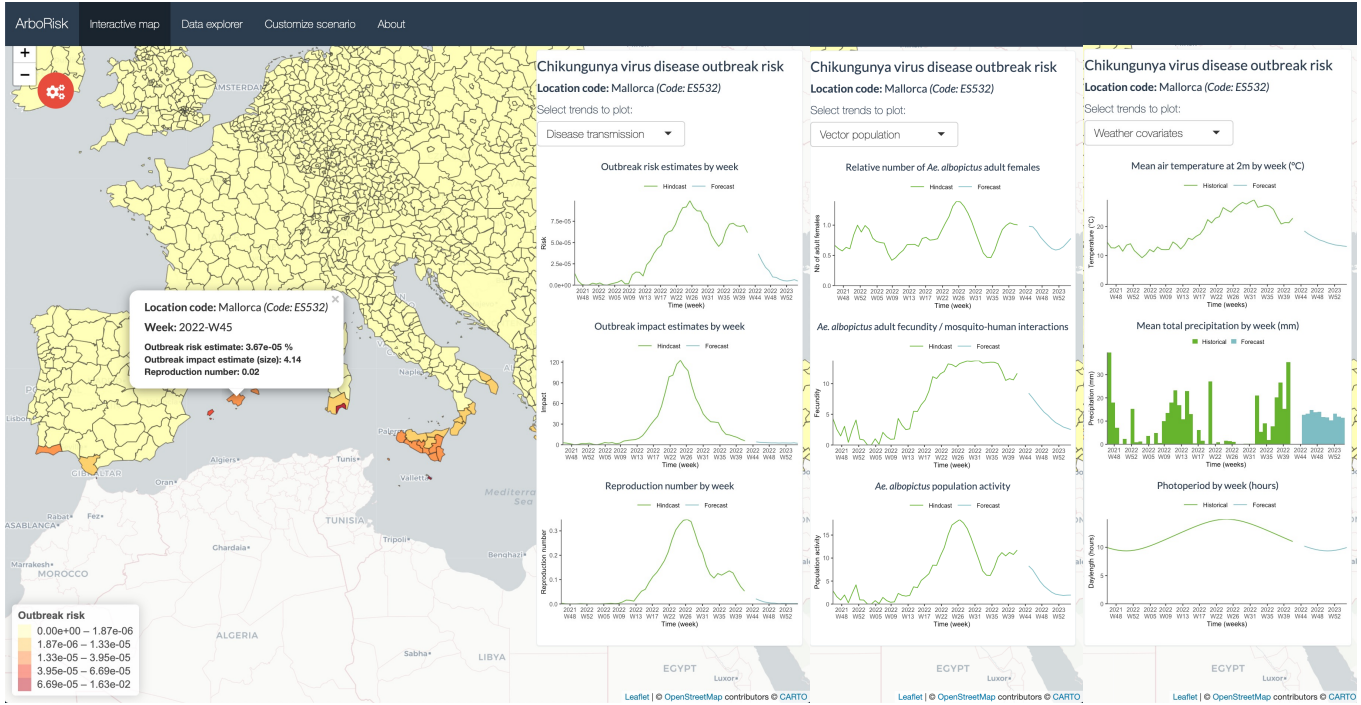
- (Relative) number of adult female mosquitoes
- Adult female mosquito lifetime
- Fecundity
- Mean air temperature

Number of vector-host interactions

- Maximum number of bites a human can stand
- Maximum number of bites a mosquito can deliver

The transmission model is based on Erguler, K. et al. PLOS ONE (2017)

The ArboRisk Tool



Interactive maps of *Aedes*-borne viral disease outbreak risk

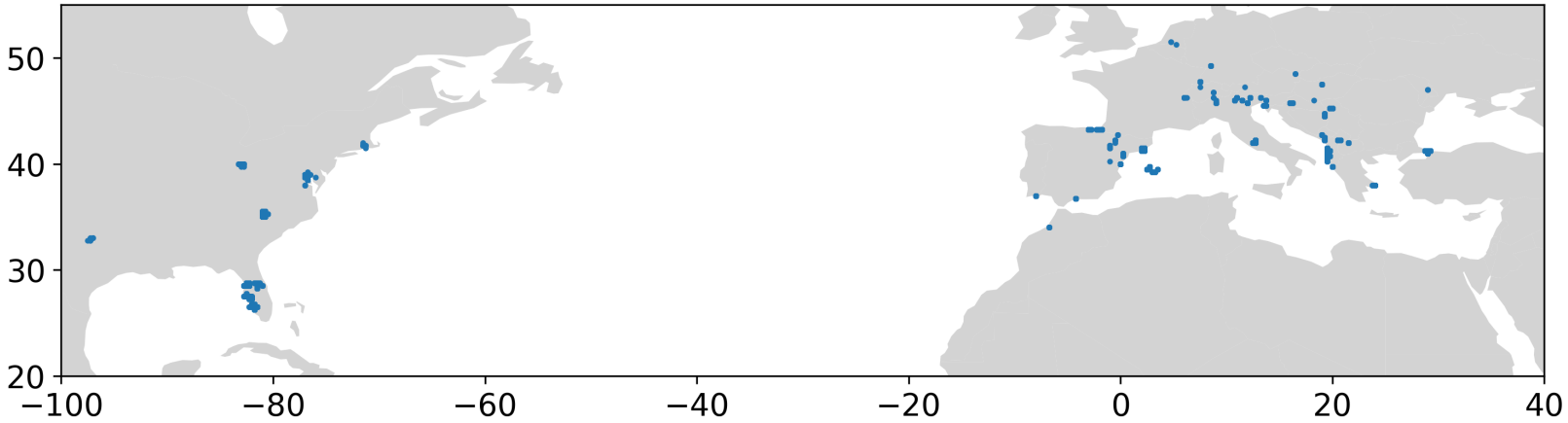
Autochthonous transmission risk of *Aedes*-borne viral disease

- dengue
- chikungunya, and
- Zika

in EU/EEA, based on the dynamic transmission model of The Cyprus Institute

The ArboRisk project (2021-2022) was commissioned by the European Centre for Disease Prevention and Control (ECDC).

Harmonised continental surveillance datasets



Over 10,000 data points from continental surveillance datasets

We grouped them into 136 regular grid cells shown as blue dots

grid cell

0.25° resolution

~27 km

VectorBase
Bioinformatics Resources for Invertebrate Vectors of Human Pathogens

AIM
Aedes Invasive Mosquitoes

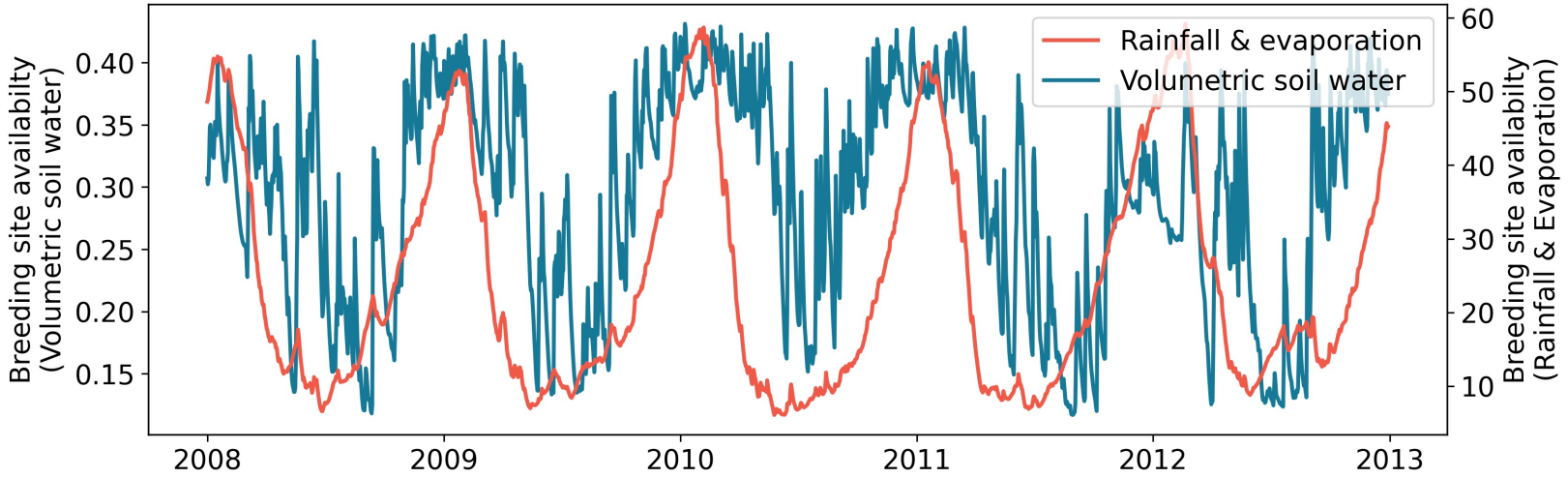
cost
EUROPEAN COOPERATION IN SCIENCE & TECHNOLOGY

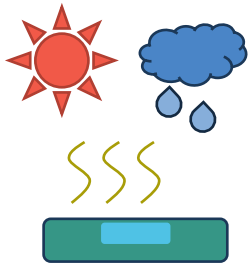
AIMSurv

vectorbase.org/popbio-map/web/

wellcome

Carrying capacity





Carrying capacity

- Increases with precipitation, land cover, and human activities
- Decreases with evaporation and breeding site removal

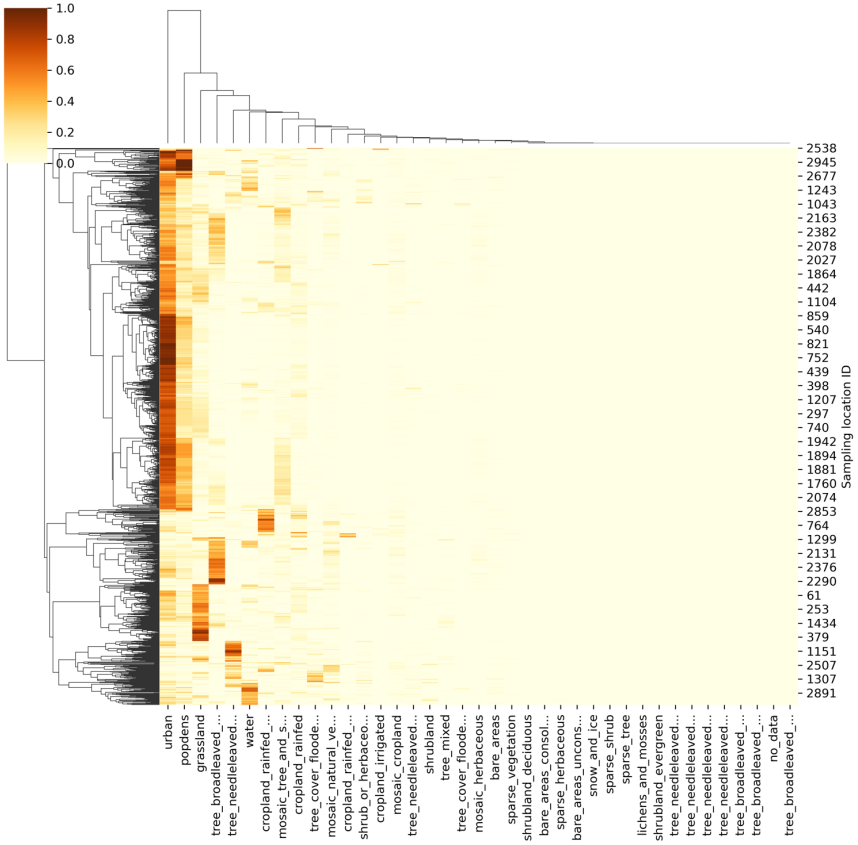
Hydrological model

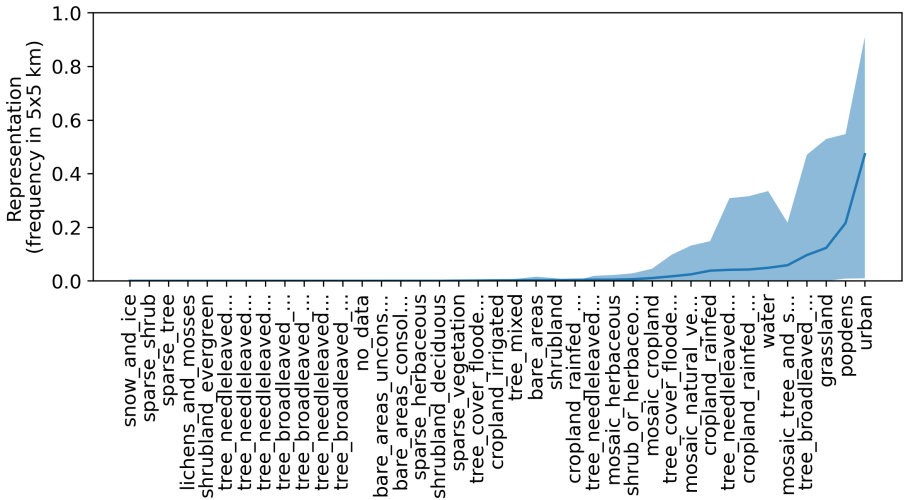
- Volume of water in soil (up to 7 cm depth) used as a proxy to breeding site availability (ECMWF Integrated Forecasting System)

Suitable for container breeders

Suitable for wetland mosquitoes

Environmental common ground





Land cover and (scaled) human population density found around the sampling locations

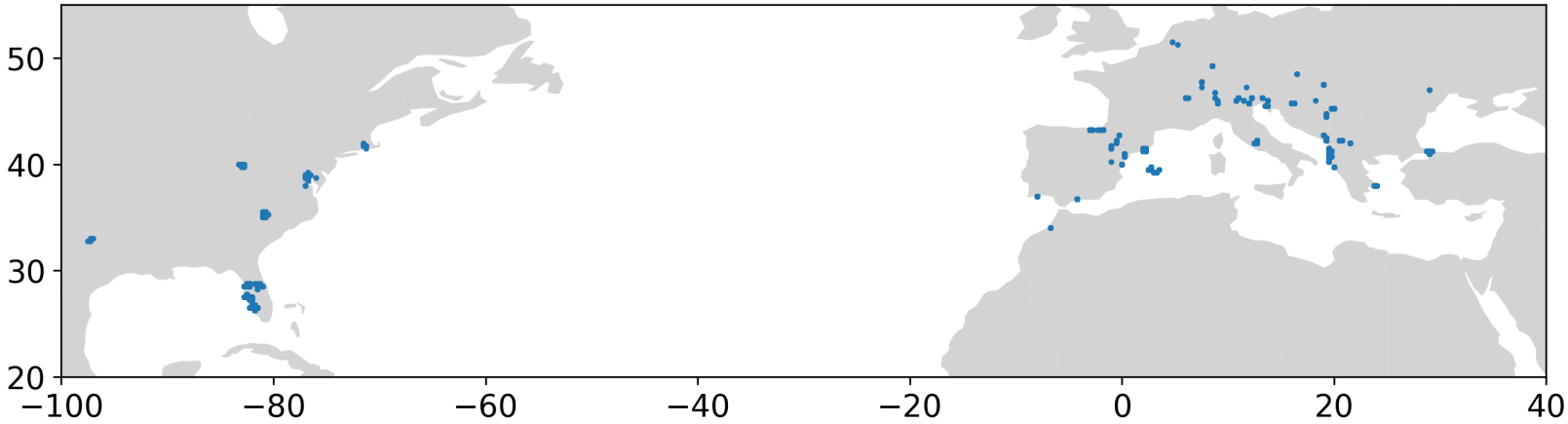
Characteristics of the land around vector-positive sampling locations:

- urban settings
- high population density
- grasslands

UN WPP-Adjusted Population Density, v4.11

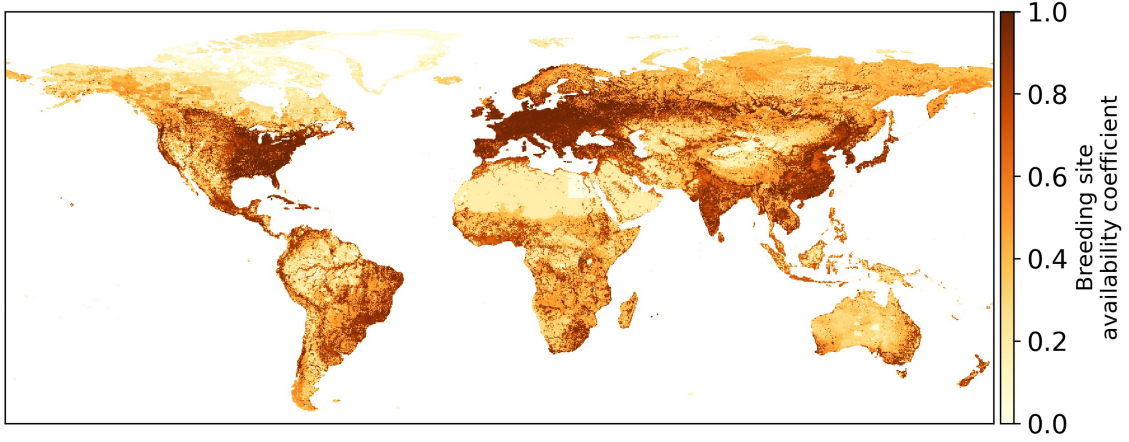
Copernicus Climate Change Service (C3S) Climate Data Store (CDS) Land cover classification (LCCS)

Breeding site availability and land cover

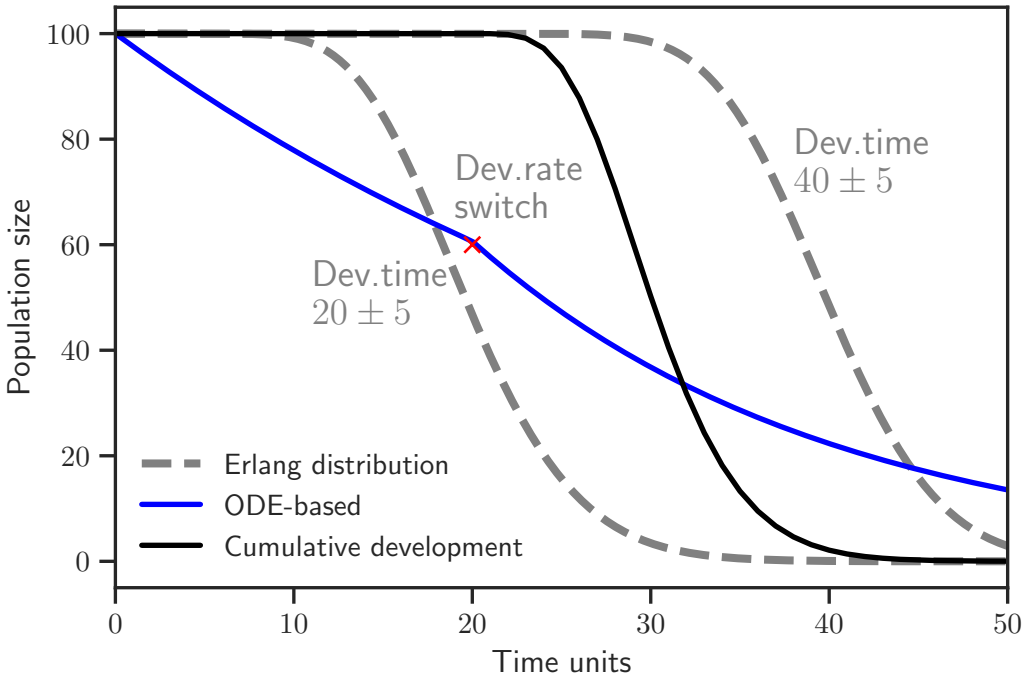


Assumption

Land characteristics similar to those around vector-positive sampling locations provide more breeding opportunities



Population dynamics under variable conditions



A model for insect life cycle under variable conditions

We developed a dynamically structured population model

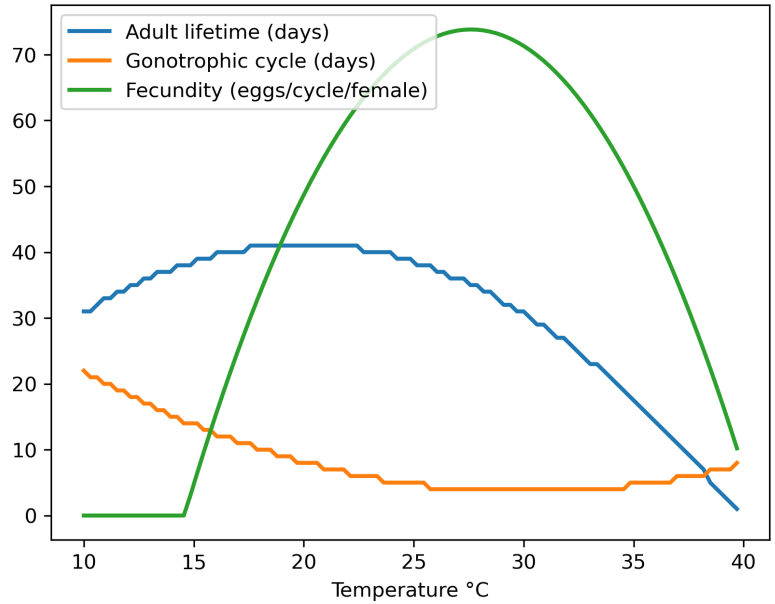
Development proceeds at different rates as conditions change, and the progress is recorded

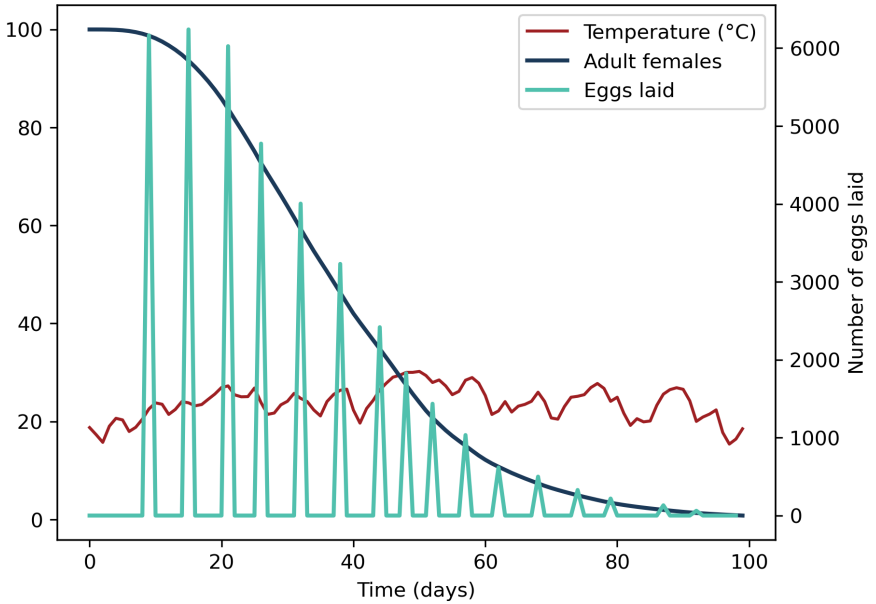
Several processes can be combined to act upon a life stage

github.com/kerguler/Population
github.com/kerguler/Population.jl (thanks to Sean L. Wu)

Erguler, K. et al. Sci Rep (2022)

Population dynamics under variable conditions





Adults can have an Erlang-distributed lifetime and an Erlang-distributed gonotrophic cycle, both of which are climate sensitive

github.com/kerguler/Population
github.com/kerguler/Population.jl (thanks to Sean L. Wu)

PopJSON

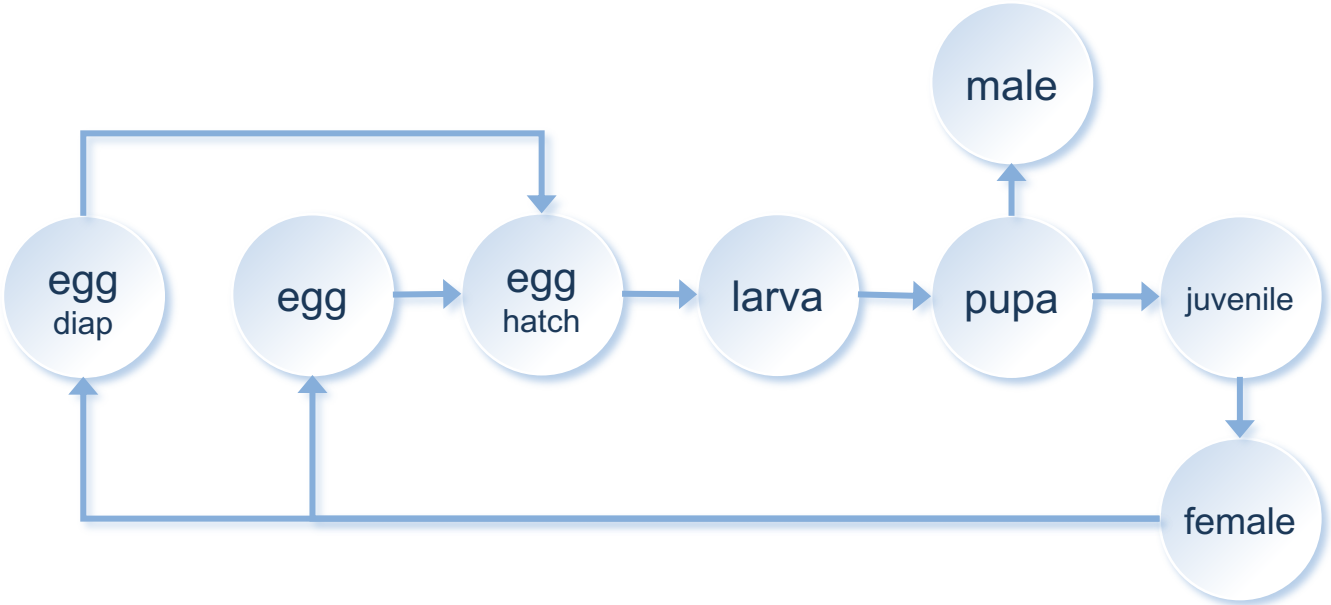
We defined a JSON-based representation for climate sensitive population dynamics models

We wrote a parser in Node.js to turn PopJSON into C code

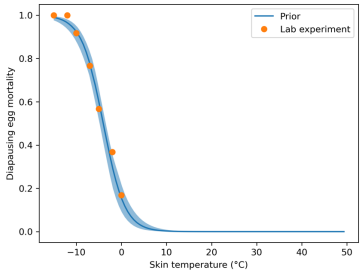
Accelerates model development, and helps to prevent errors

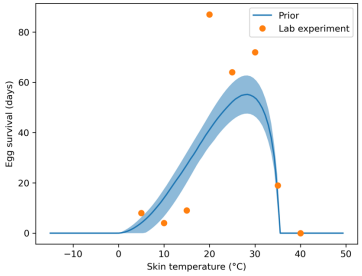
github.com/kerguler/PopJSON

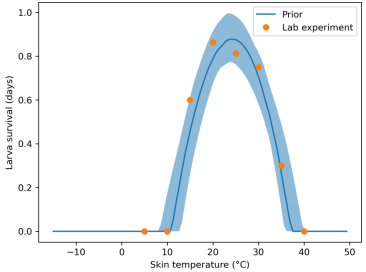
Climate dependence of the life cycle

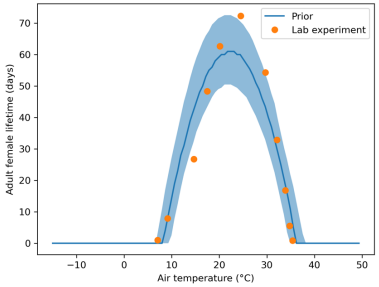


Climate dependence of the life cycle









egg diap

egg

egg hatch

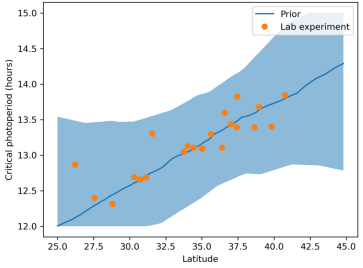
larva

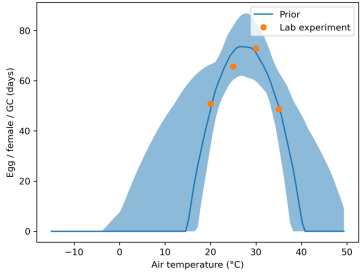
pupa

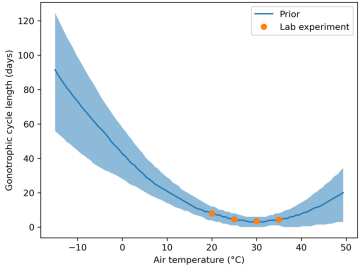
male

juvenile

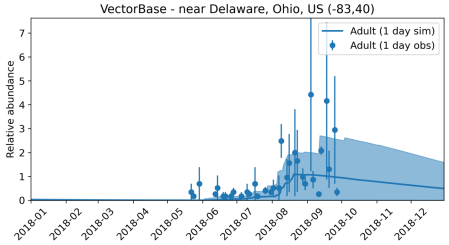
female

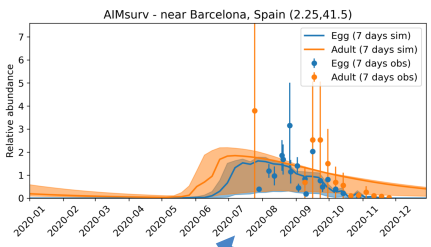


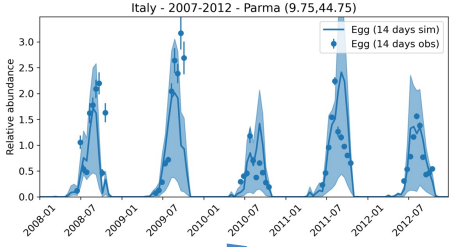


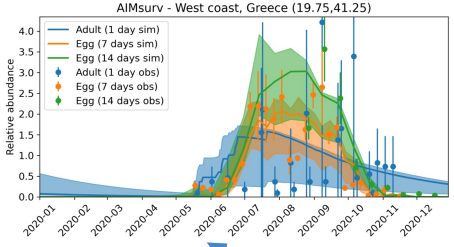


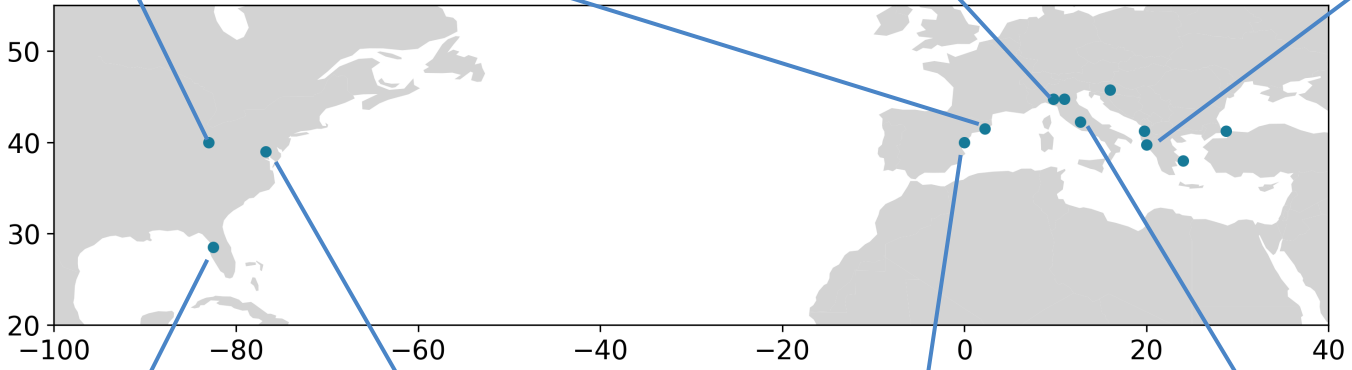
Calibration on longitudinal surveillance

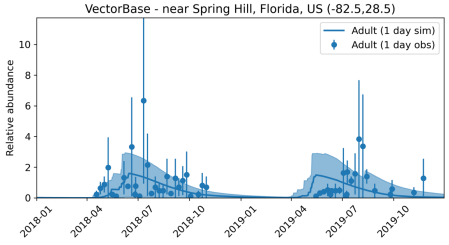


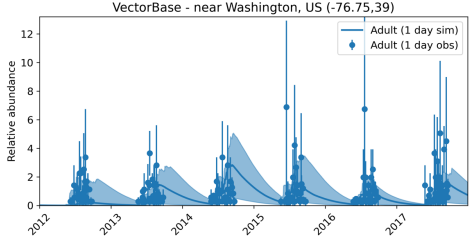


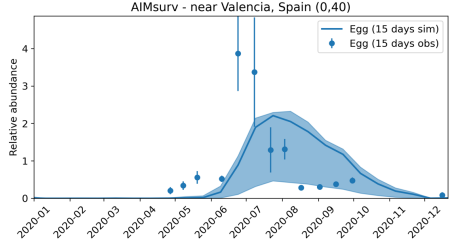


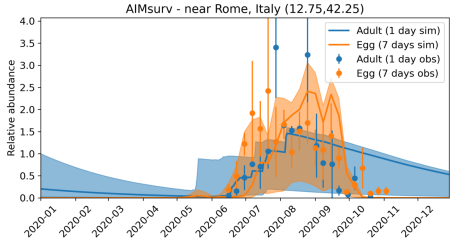




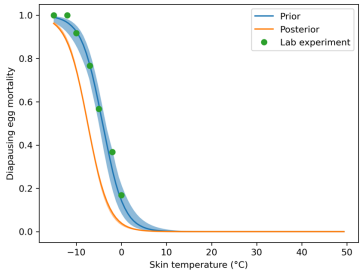


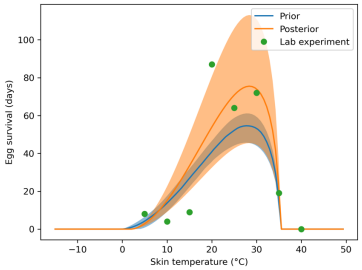


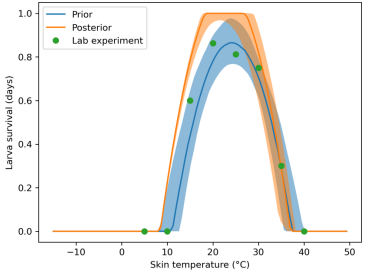


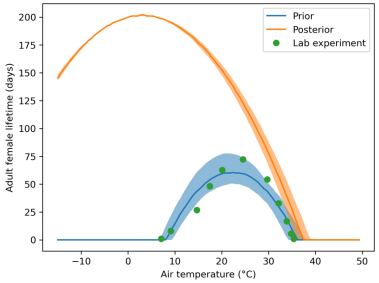


Climate dependence of the life cycle









egg diap

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male

juvenile

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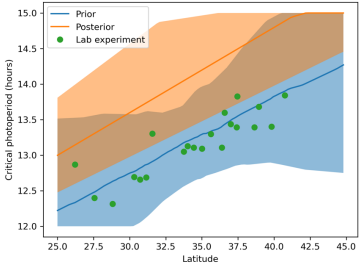
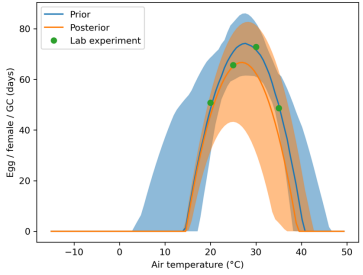
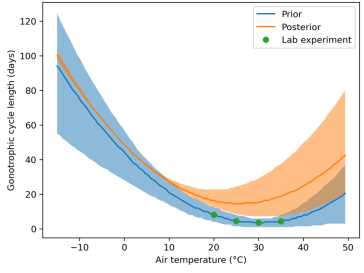
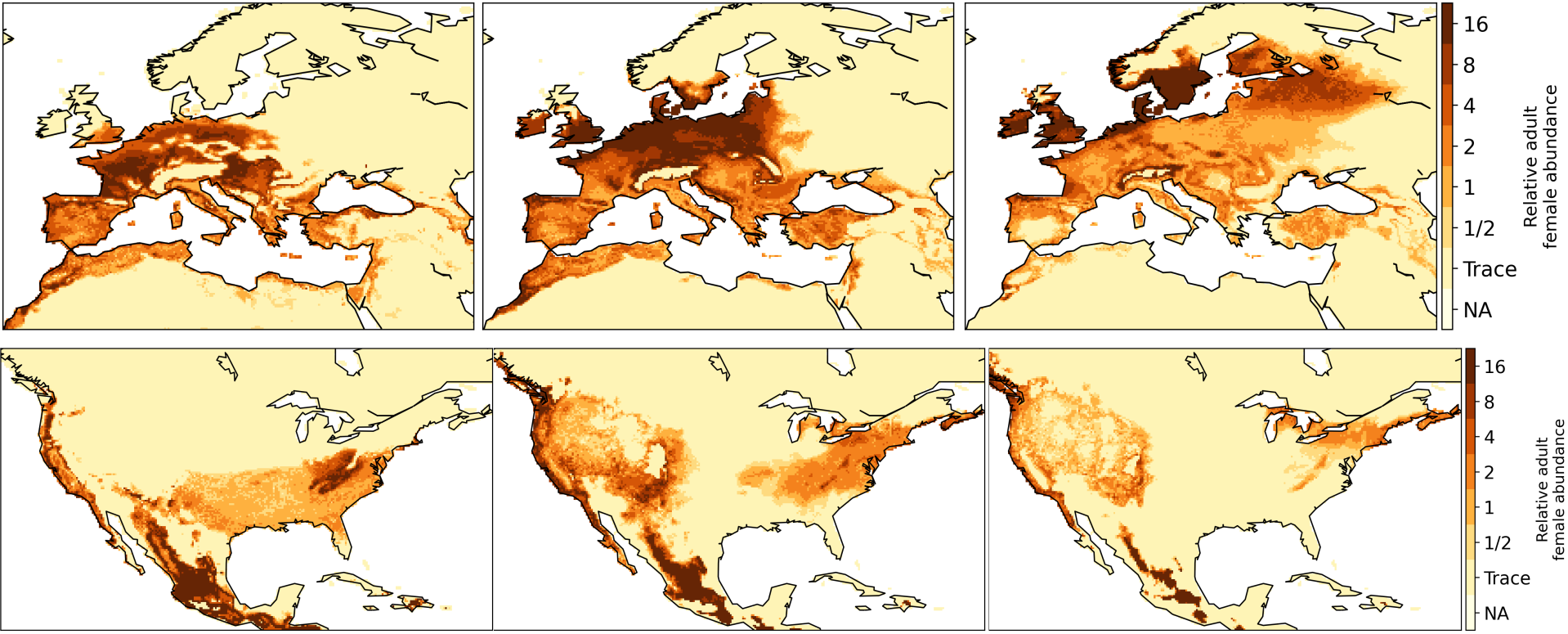






Vector abundance – current and future projections

ERA5 (2010-2020) CMIP6 ssp245 (2090-2100) CMIP6 ssp585 (2090-2100)



CMIP6: ACCESS-CM2 of the NEX-GDDP-CMIP6 dataset

Under development

VEClim

Climate-driven vector-borne disease risk assessment

Model and data repository

- Dynamic open-access repository of vector-pathogen models, climate projections, environmental variables, and surveillance data

Short/medium/long-term predictions

- Risk maps, seasonal activity, temporal projections of vector activity and disease transmission

Decision support tool

- Web-based interactive GIS platform to display risk, run customized scenarios, and inform prevention and control

Wellcome Trust Digital Technology Development Awards
Climate-Sensitive Infectious Disease Modelling

THANK YOU

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The Cyprus Institute
- Kamil Erguler
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- Yiannis Proestos
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- Jos Lelieveld
  (Max Planck Institute for Chemistry)

ERGO
- William Wint

AviaGIS
- Cedric Marsboom

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