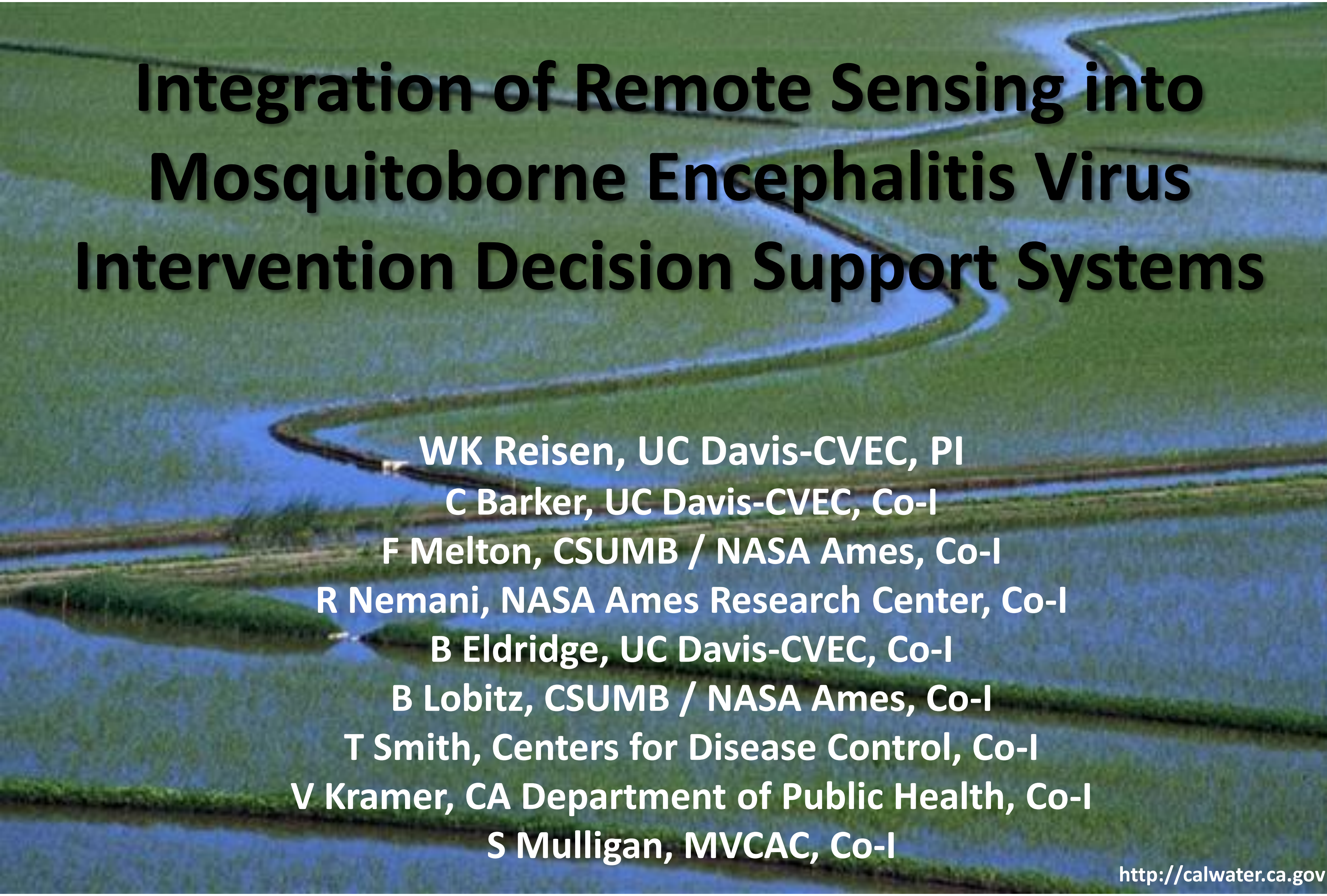
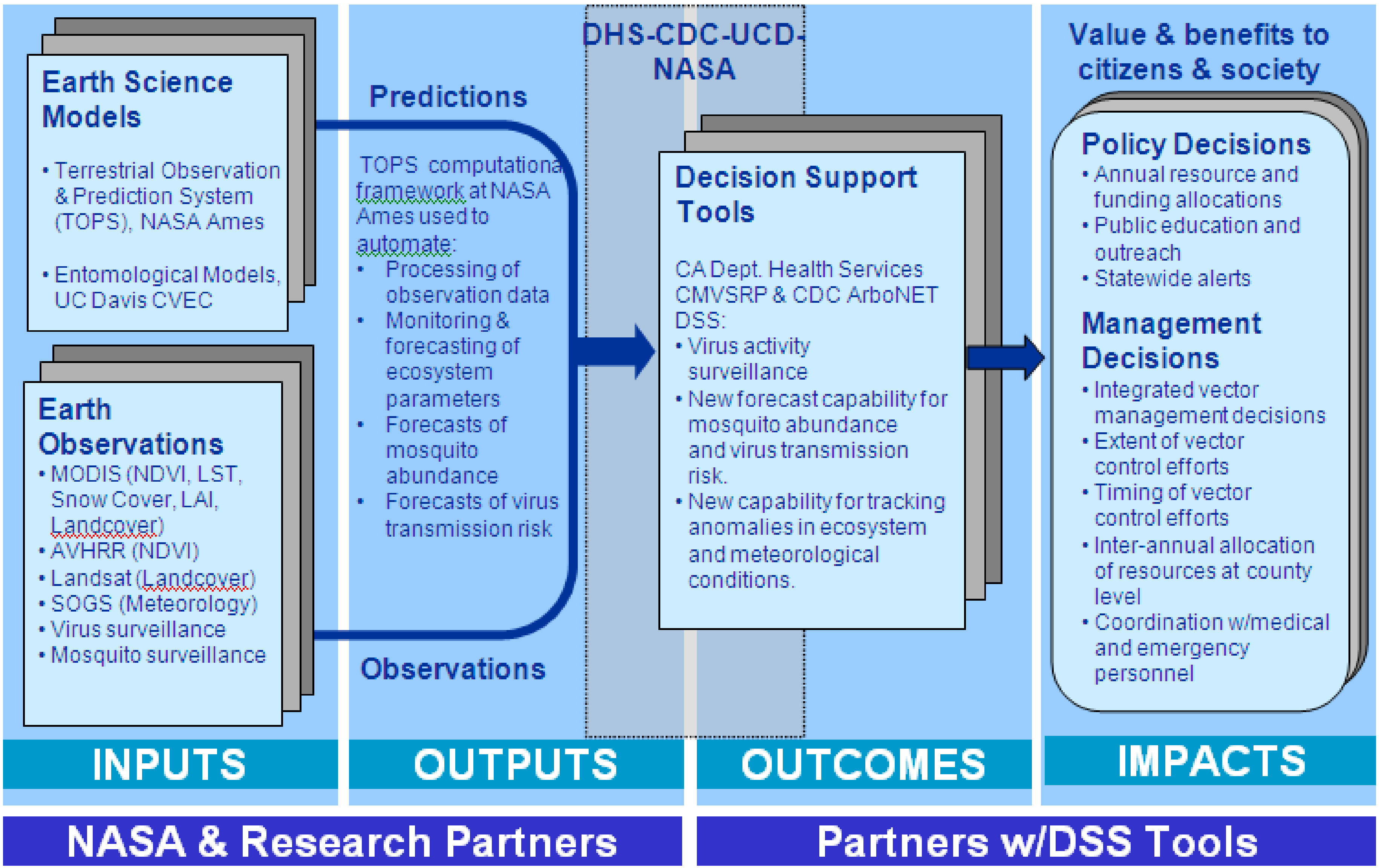


Integration of Remote Sensing into Mosquitoborne Encephalitis Virus Intervention Decision Support Systems

WK Reisen, UC Davis-CVEC, PI
C Barker, UC Davis-CVEC, Co-I
F Melton, CSUMB / NASA Ames, Co-I
R Nemani, NASA Ames Research Center, Co-I
B Eldridge, UC Davis-CVEC, Co-I
B Lobitz, CSUMB / NASA Ames, Co-I
T Smith, Centers for Disease Control, Co-I
V Kramer, CA Department of Public Health, Co-I
S Mulligan, MVCAC, Co-I

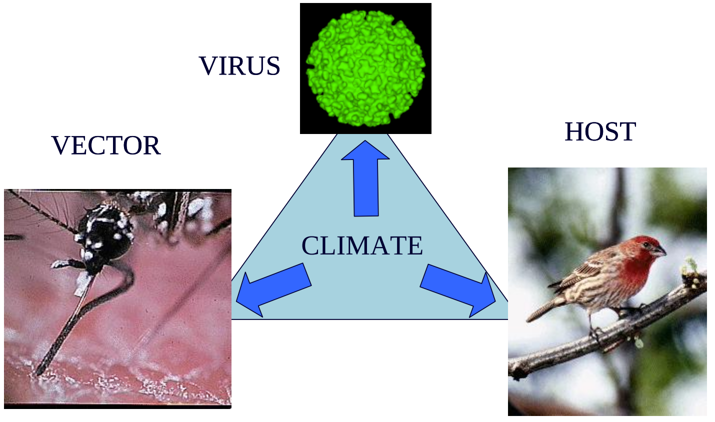
http://calwater.ca.gov

CMVSRP & ArboNET: Integrated System Solutions Architecture



Overview

- Encephalitis vectors, transmission cycles and intervention strategies
- California surveillance and response plan
- CalSurv Gateway
- Models for mosquito abundance and virus transmission
- Extension to other areas
- Progress to date and plans for final year



Culex tarsalis and the *Culex pipiens* complex

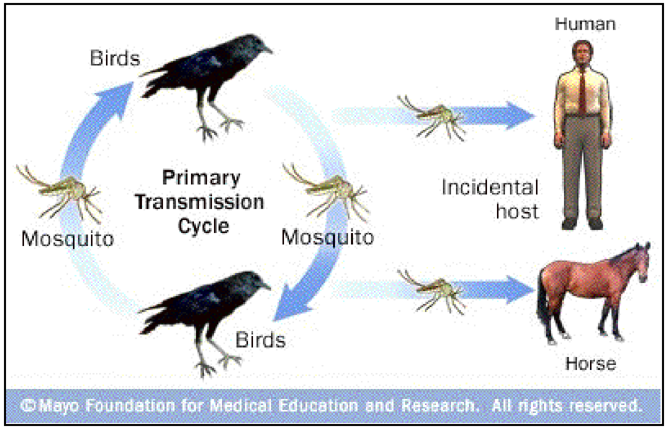
- Most important vectors of arboviruses in western North America
- Targets of vector control and arbovirus surveillance programs
- Forecasting models are needed to guide vector control and public health decisions

Culex tarsalis

- Typical larval habitats

Culex pipiens complex

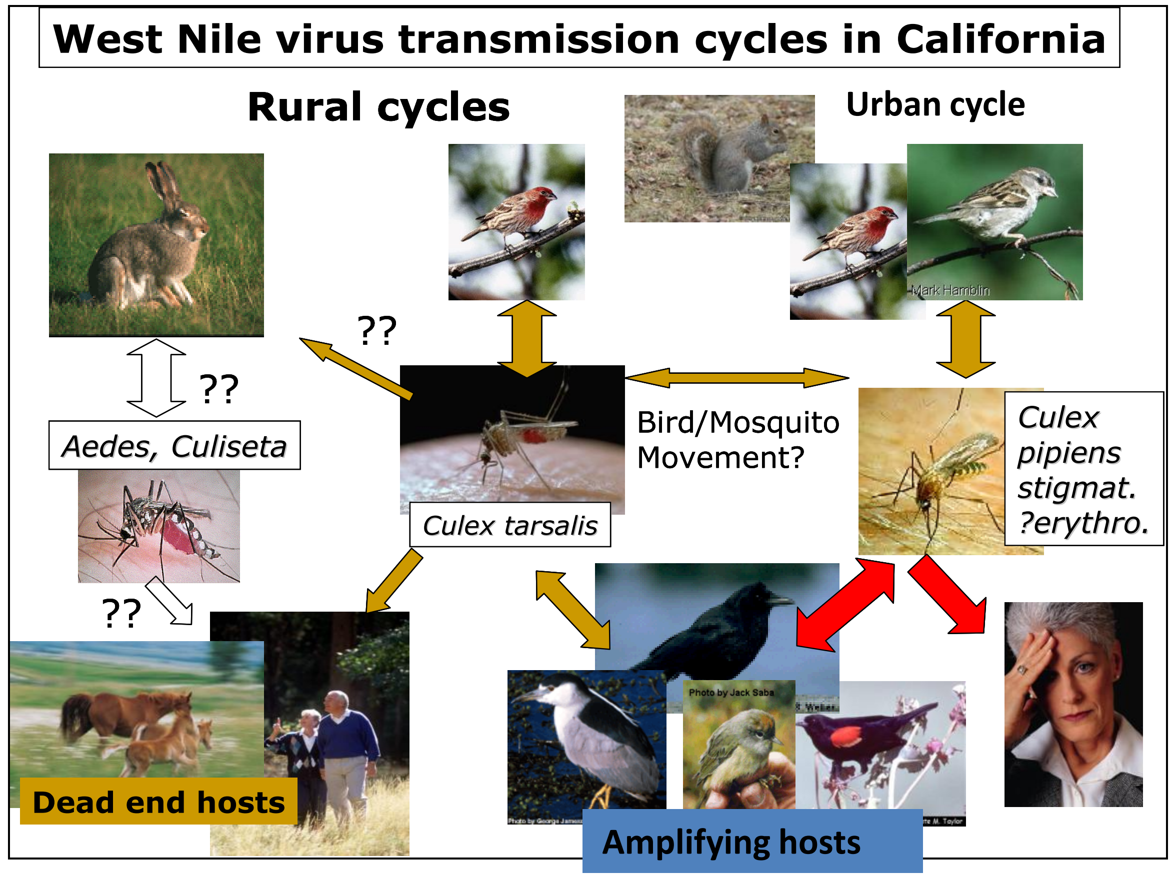
- Typical larval habitats



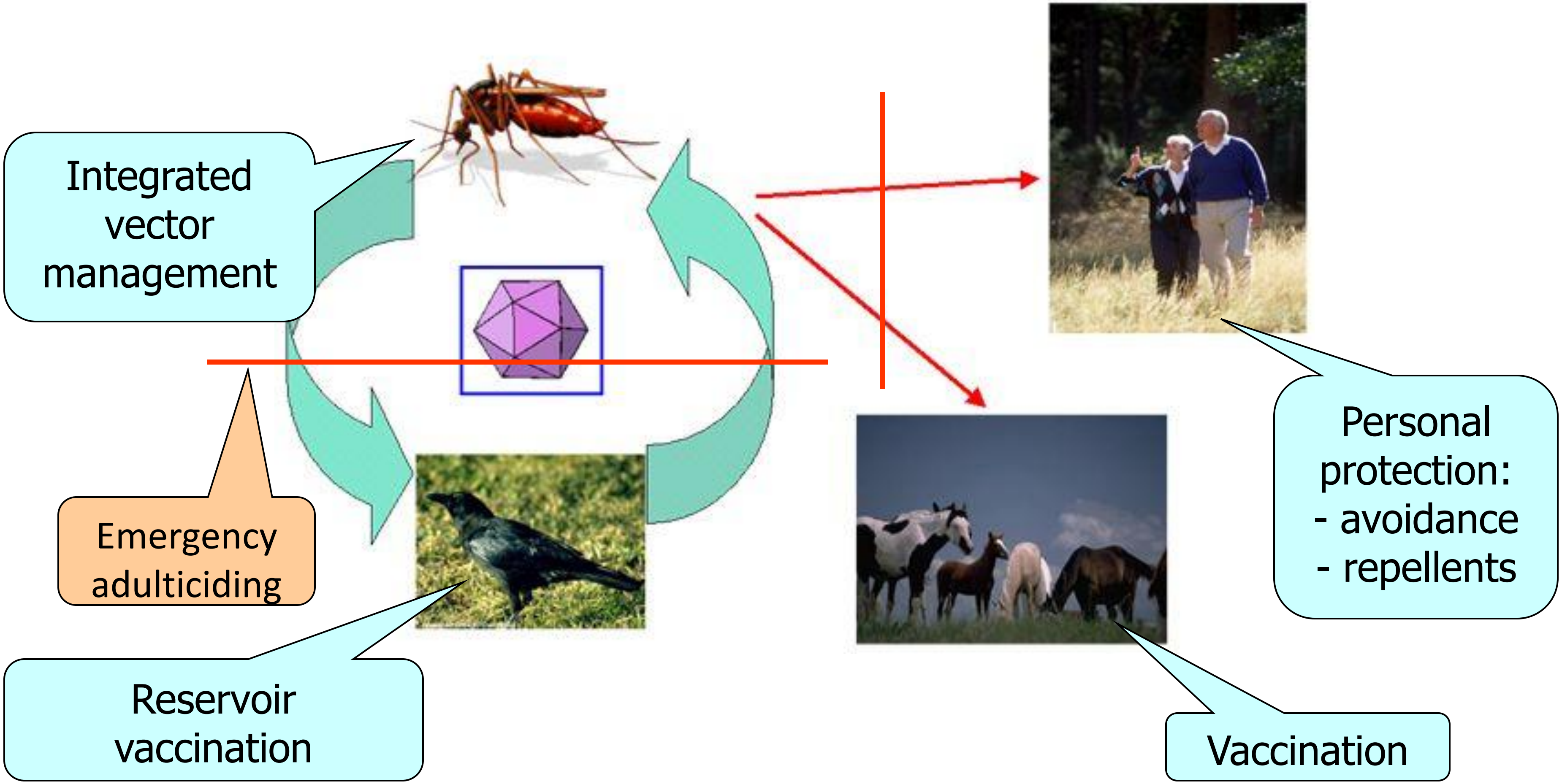
West Nile virus, a vectorborne zoonosis: Simplified amplification and tangential transmission cycles

Actual rural and urban WNV transmission cycles in western NA:

- several *Culex* vectors
- variety of avian hosts
- no mammalian cycle

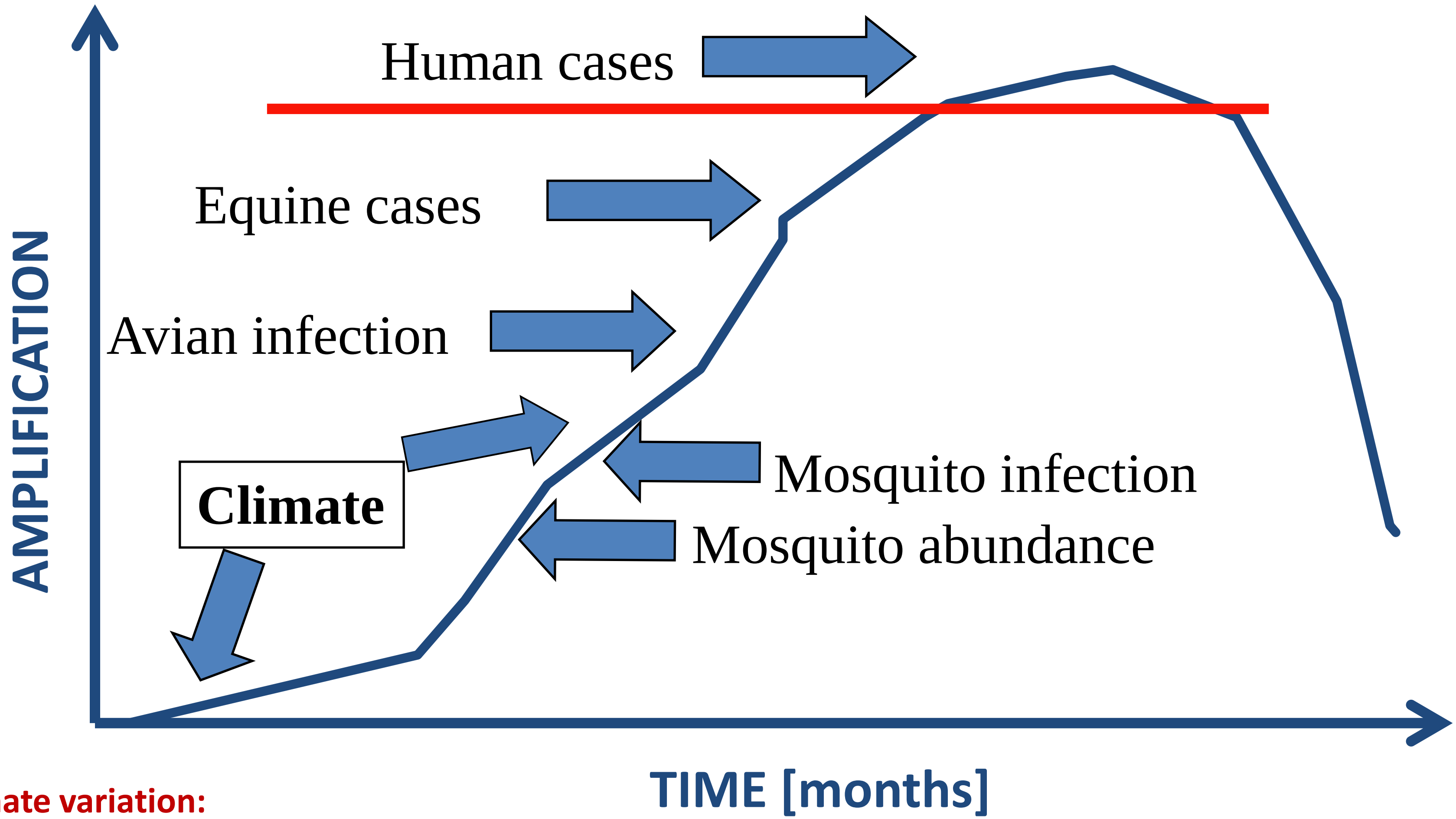


Mosquitoborne encephalitides: points of intervention



Modified from CDC website

Typical surveillance season



Climate variation:

1. **Only early season predictor**
2. **Determines, in part, the shape of the amplification curve**

WNV Risk Values

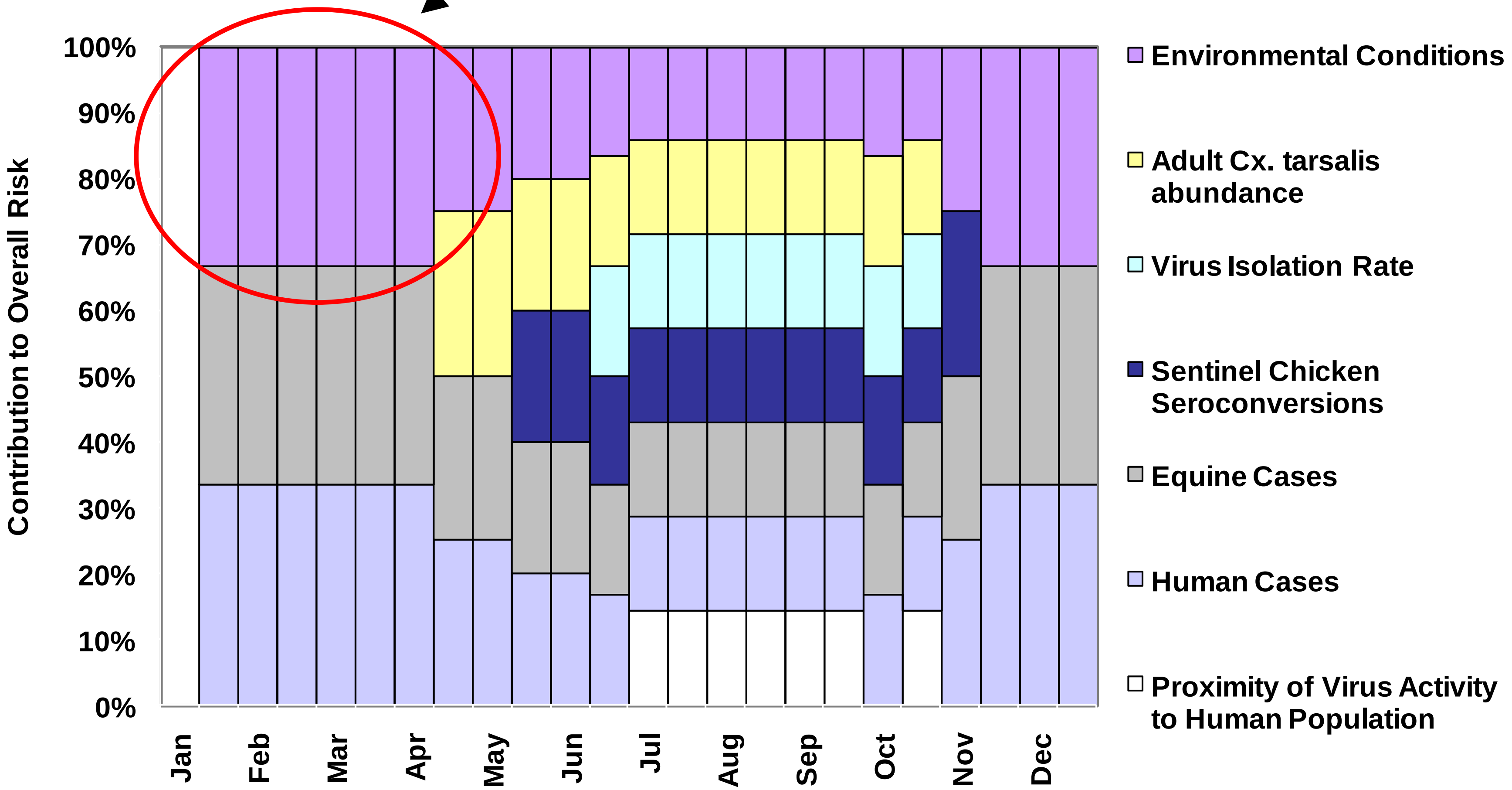
California Mosquito-borne Virus Surveillance and Response Plan

Risk Level	Avg. Daily Temperature	Adult mosquito abundance	Mosquito MIR/1,000	Chicken Seroconversions	Dead Bird Infections	Human Cases
1	<56ºF	< 50% 5-yr. Avg.	0	0 in region	0 in region	
2	57-65ºF	50-90% 5-yr. Avg.	0.1 – 1.0	≥ 1 in region, 0 in agency	≥ 1 in region, 0 in agency	
3	66-72ºF	91-150% 5-yr. Avg.	1.1 – 2.0	1 flock in agency	1 in agency	≥ 1 in region, 0 in agency
4	73-79ºF	151-300% 5-yr. Avg.	2.1 – 5.0	2 flocks in agency	2-5 in agency	1 in agency
5	>79ºF	> 300% 5-yr. Avg.	> 5.0	>2 flocks in agency	>5 in agency	>1 in agency

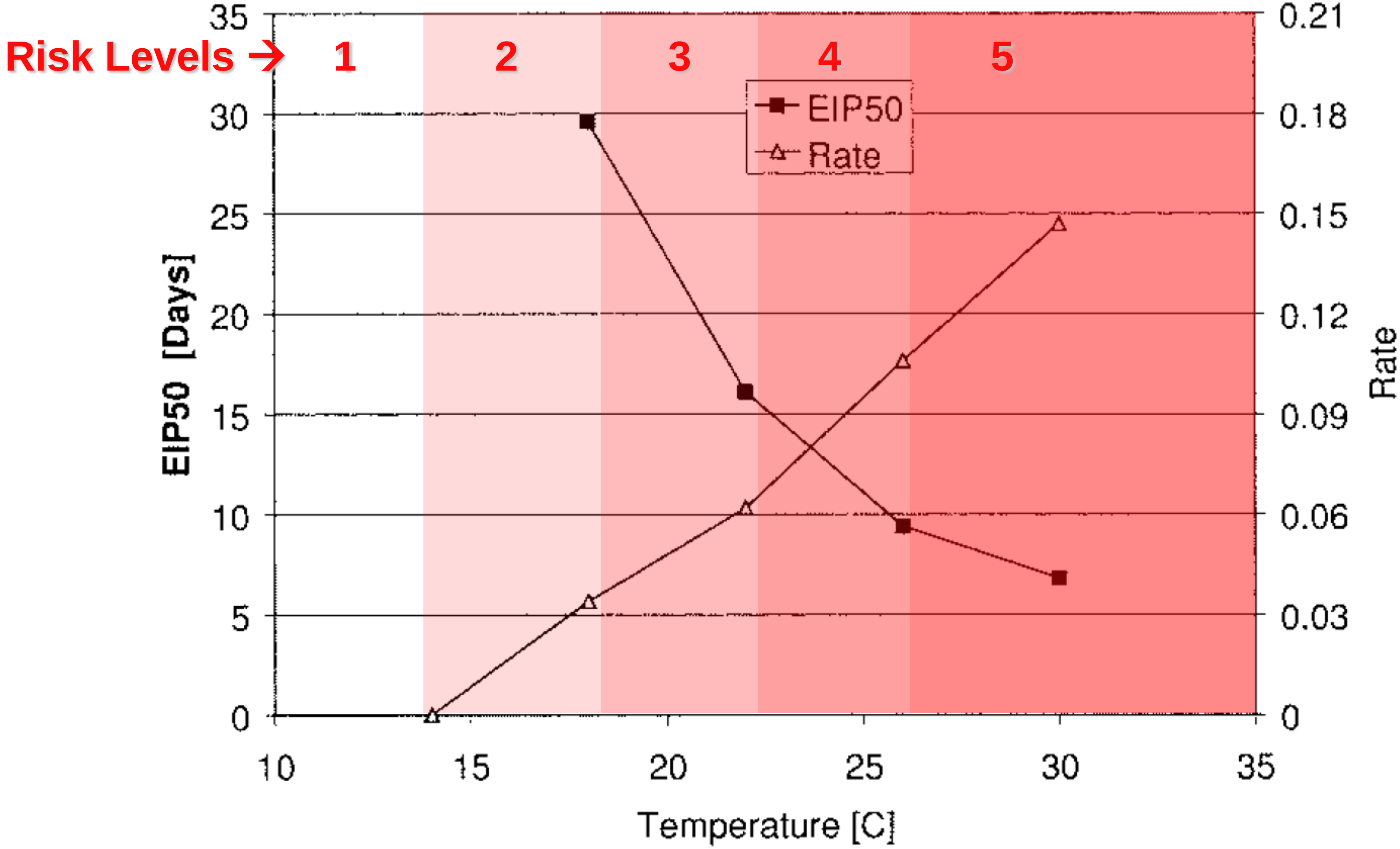
SCORE	RISK LEVEL
1.0—2.5	Normal season
2.6—4.0	Emergency planning
4.1—5.0	Epidemic

Response Plan

Environmental conditions are the earliest indicators of virus transmission risk



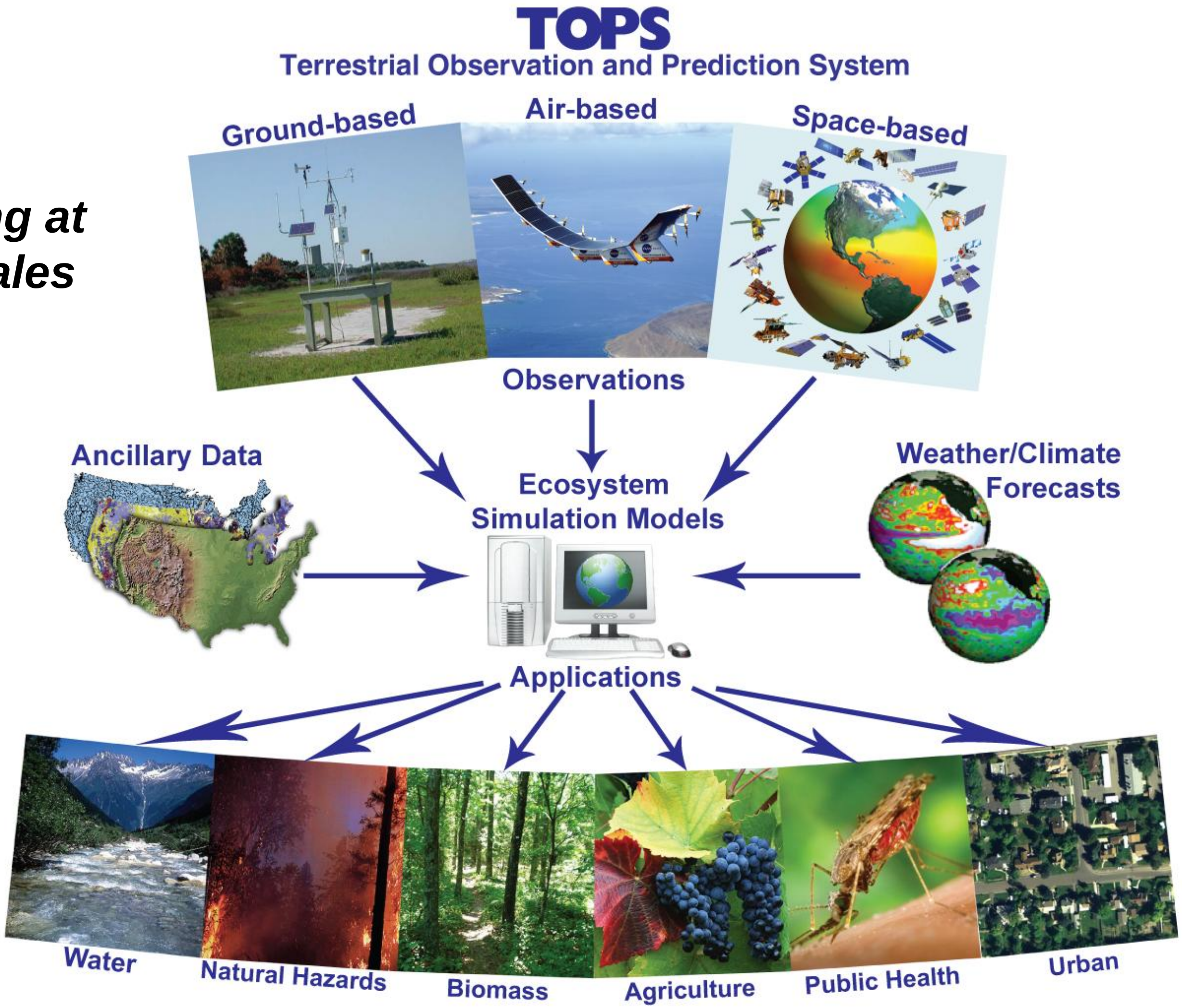
Temperature and WNV transmission risk



From Reisen et al. 2006. *J Med Entomol* 43: 309-317

TOPS: Common Modeling Framework

Monitoring, modeling, & forecasting at multiple scales

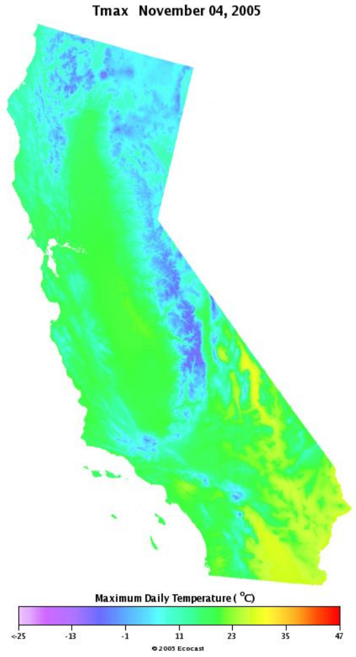


Nemani et al., 2003 and 2007

Regional Nowcasts: California

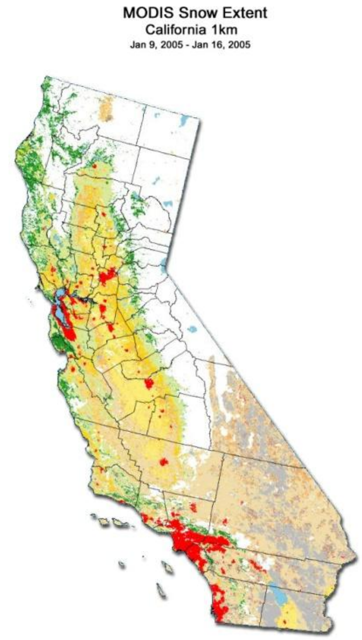
Tracking parameters related to mosquito abundance:

Meteorology (max Temp)



Hydrology (Soil moisture)

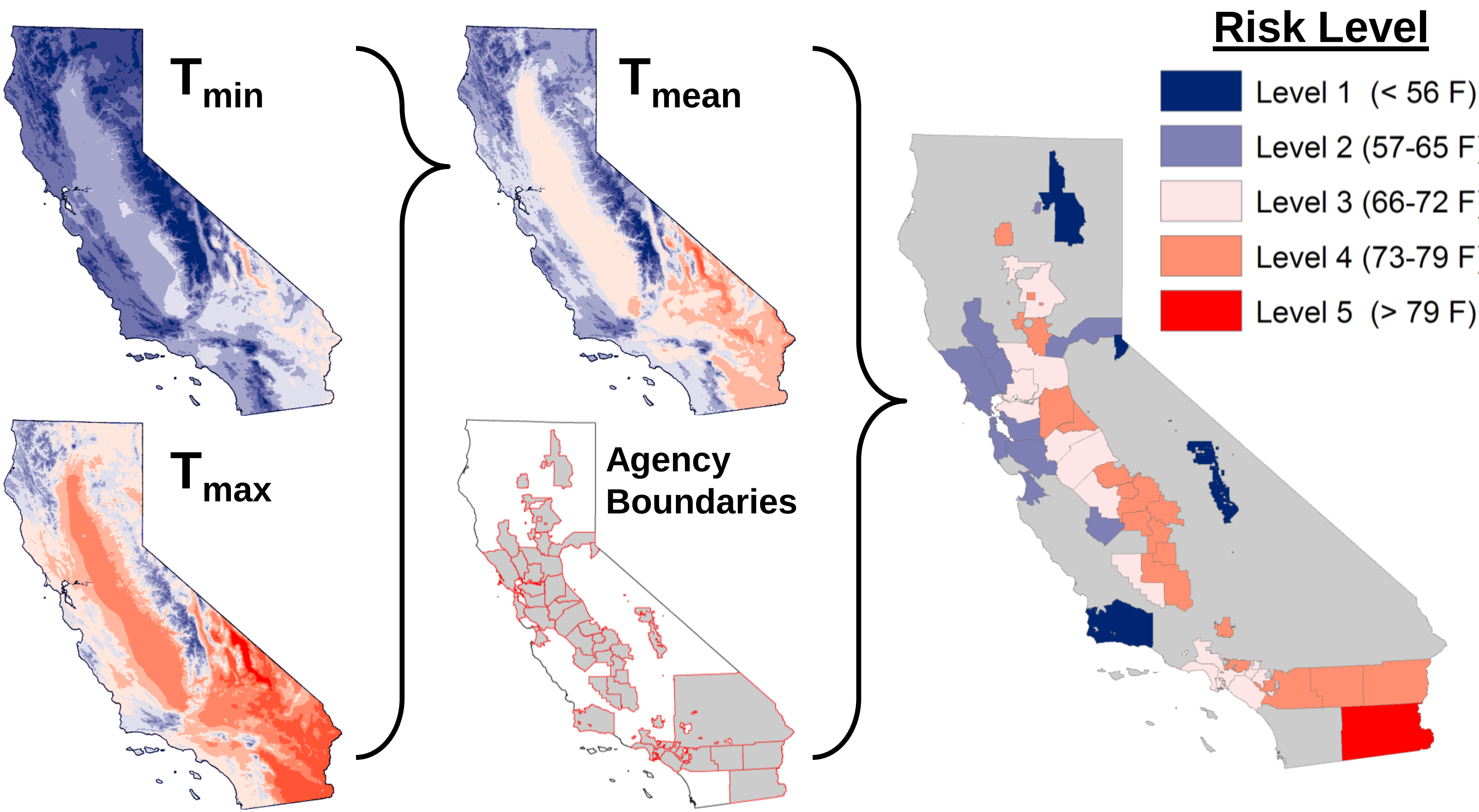
Hydrology (Snow Cover)



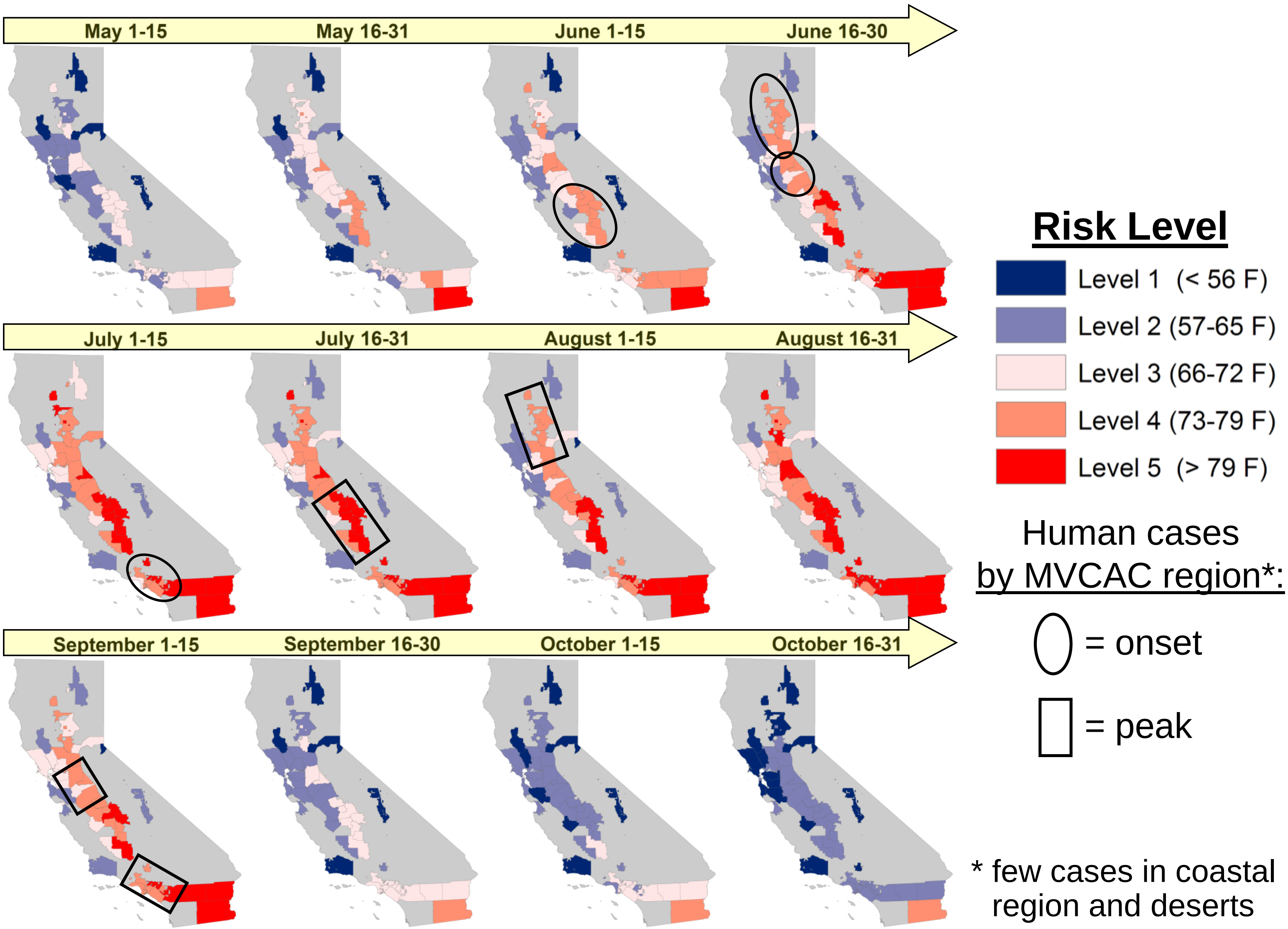
Vegetation (FPAR / NDVI)

Ecosystem (Gross Primary Prod.)

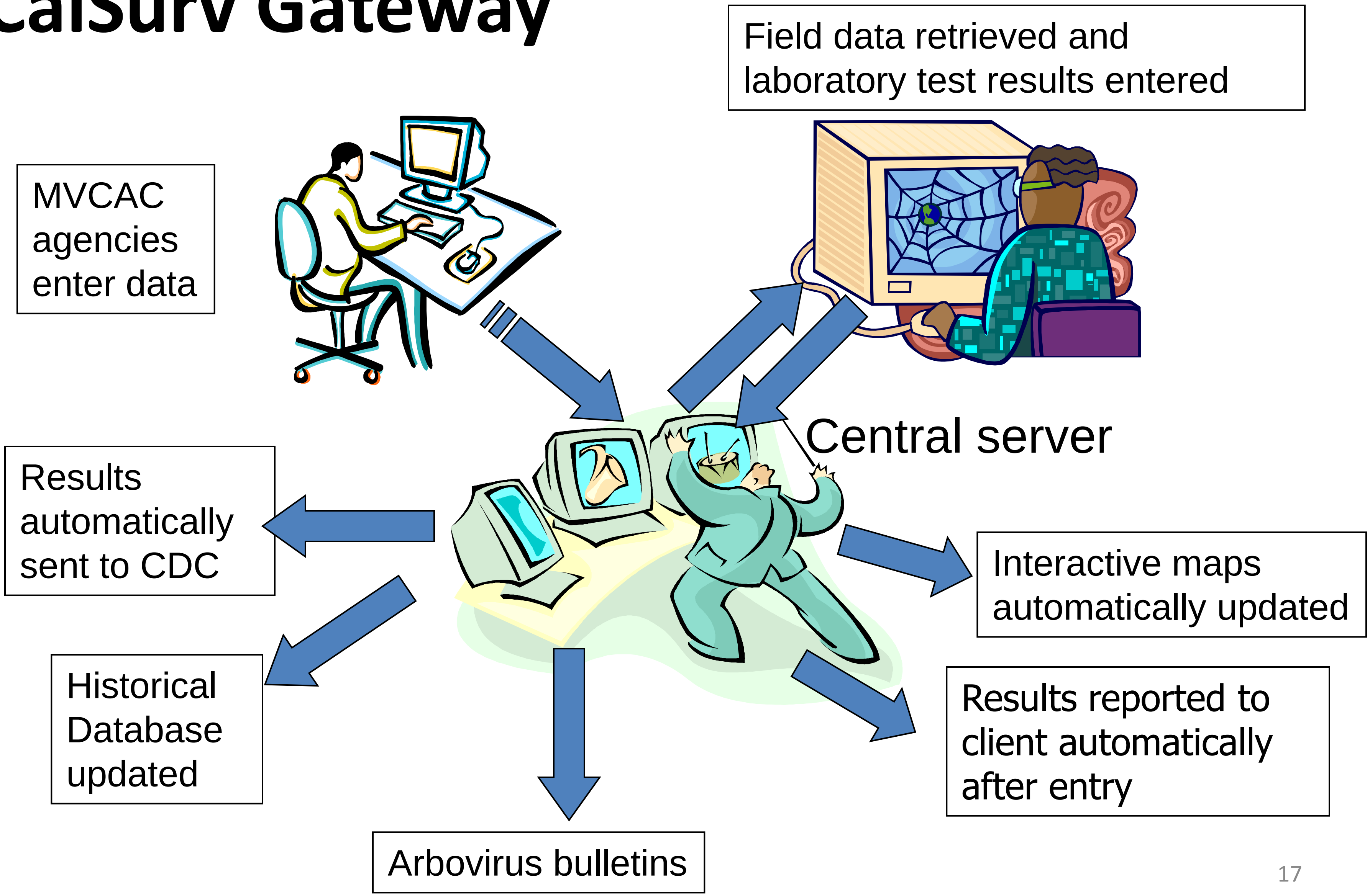
TOPS Temperatures



Temperature-related risk

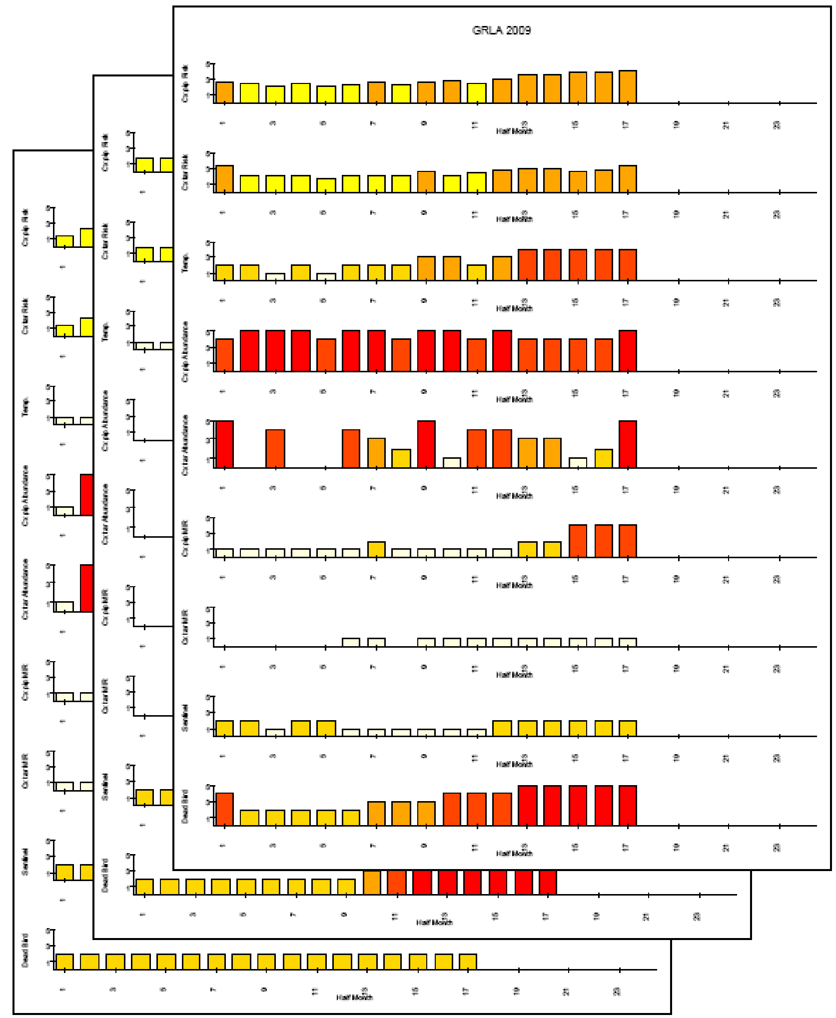


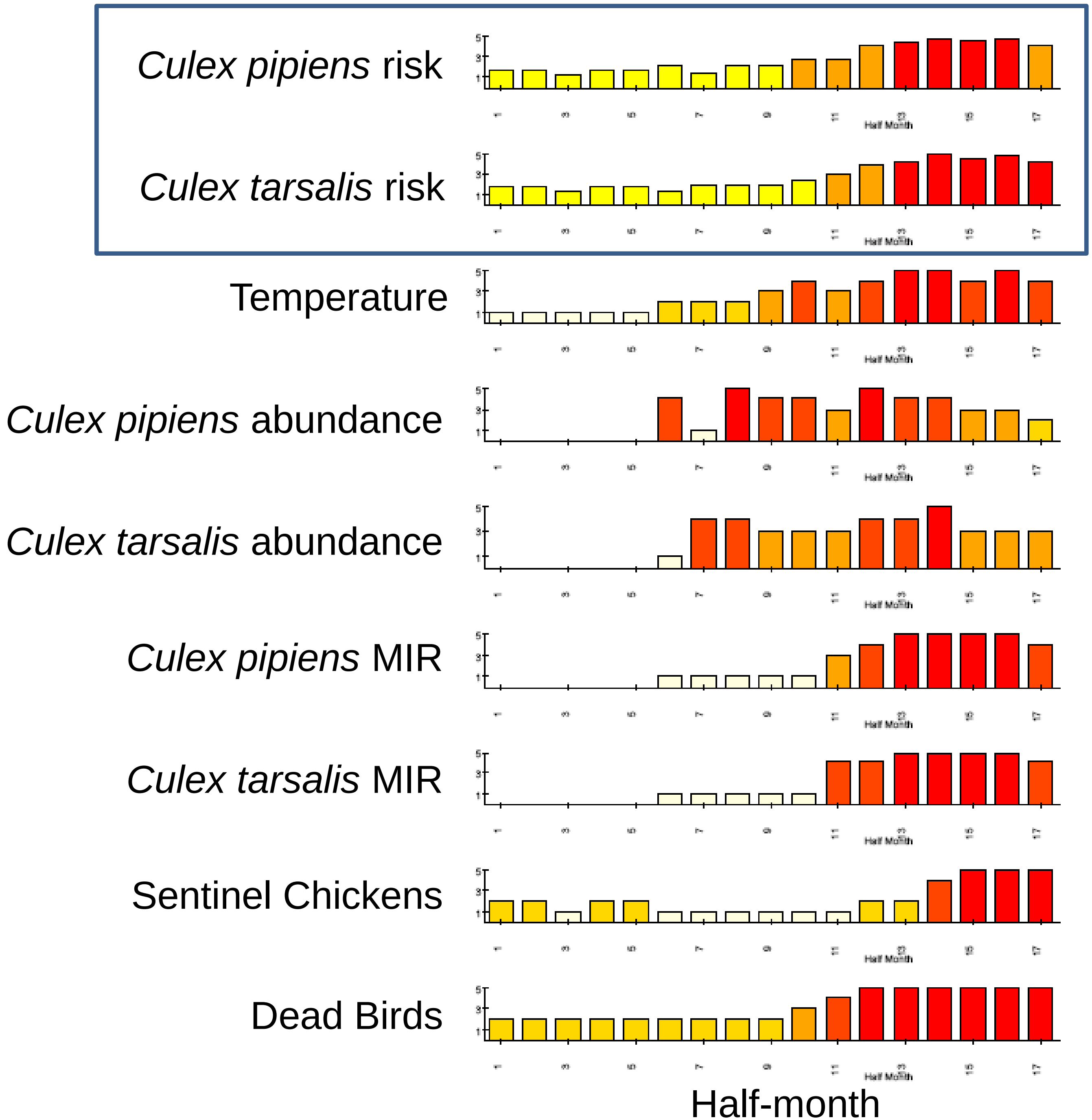
Rapid Arbovirus Data Acquisition: CalSurv Gateway



Risk Assessments

- PDFs are automatically generated and distributed via e-mail to vector control agencies every 2 weeks
- Risk calculated for each half-month using TOPS and surveillance data





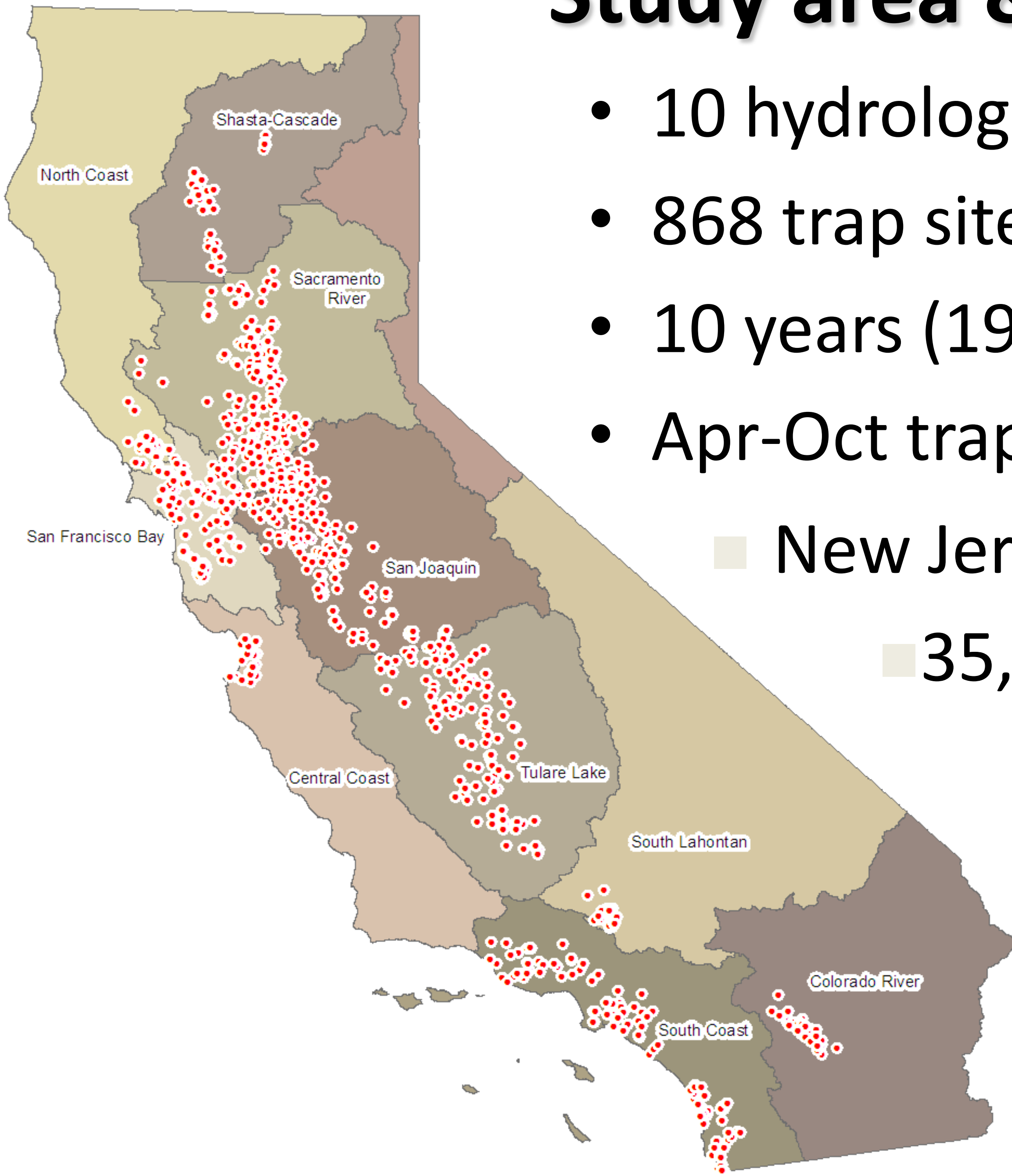
CMVSRP provides nowcasts of WNV transmission risk, but more lead time is needed

Toward a forecasting model…

- Vector abundance:
  - *Culex tarsalis* and the *Culex pipiens* complex
  - Phenology
  - Climate (interannual)
  - Land cover (spatial)
  - Spatial and temporal dependence
- Vector abundance → Arbovirus transmission:
  - *Culex tarsalis* and WEEV
  - Critical time windows?

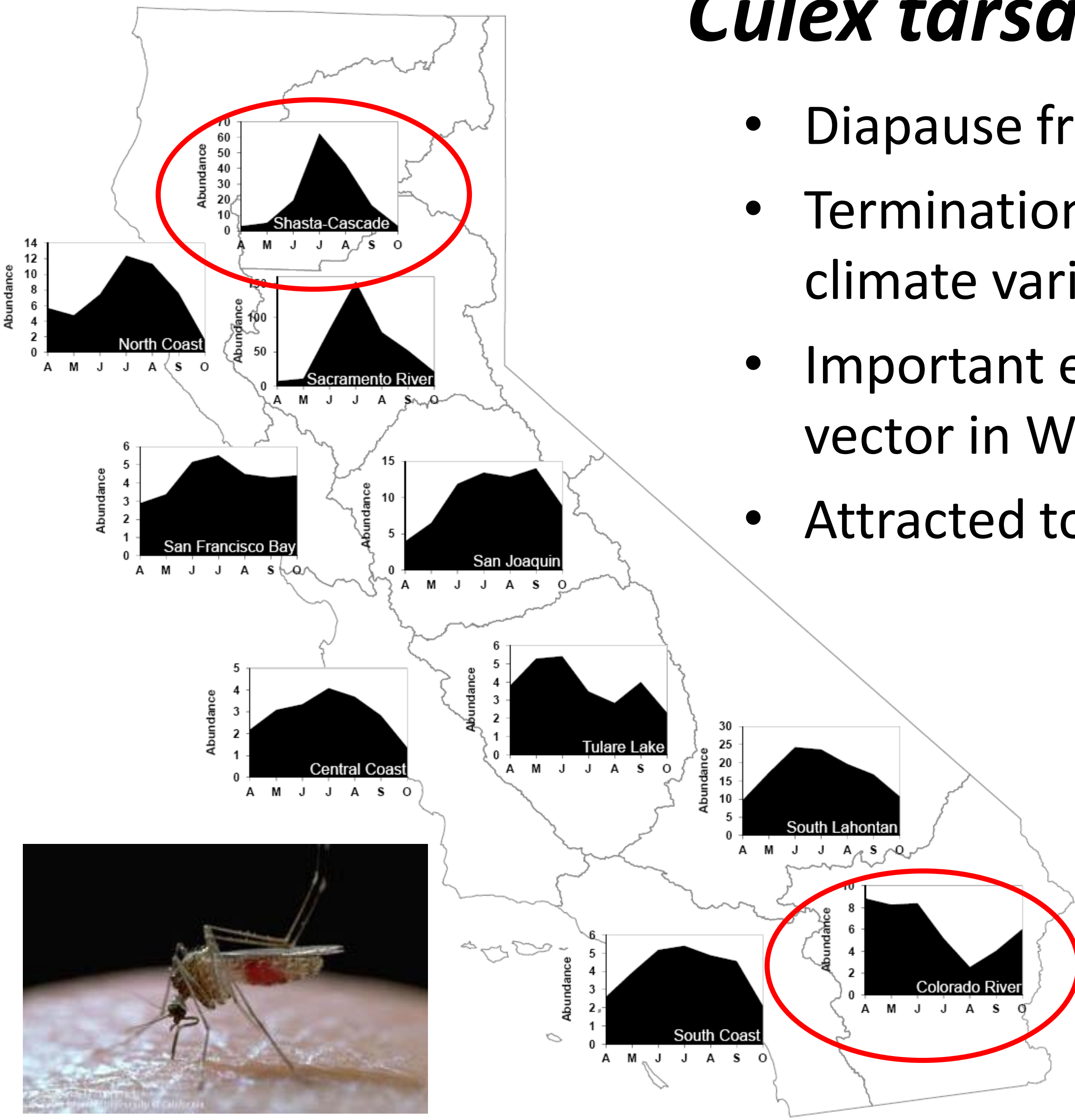
Study area & time period

- 10 hydrologic regions
- 868 trap sites
- 10 years (1991—2000)
- Apr-Oct trapping season
  - New Jersey light traps
    - 35,908 trap-months



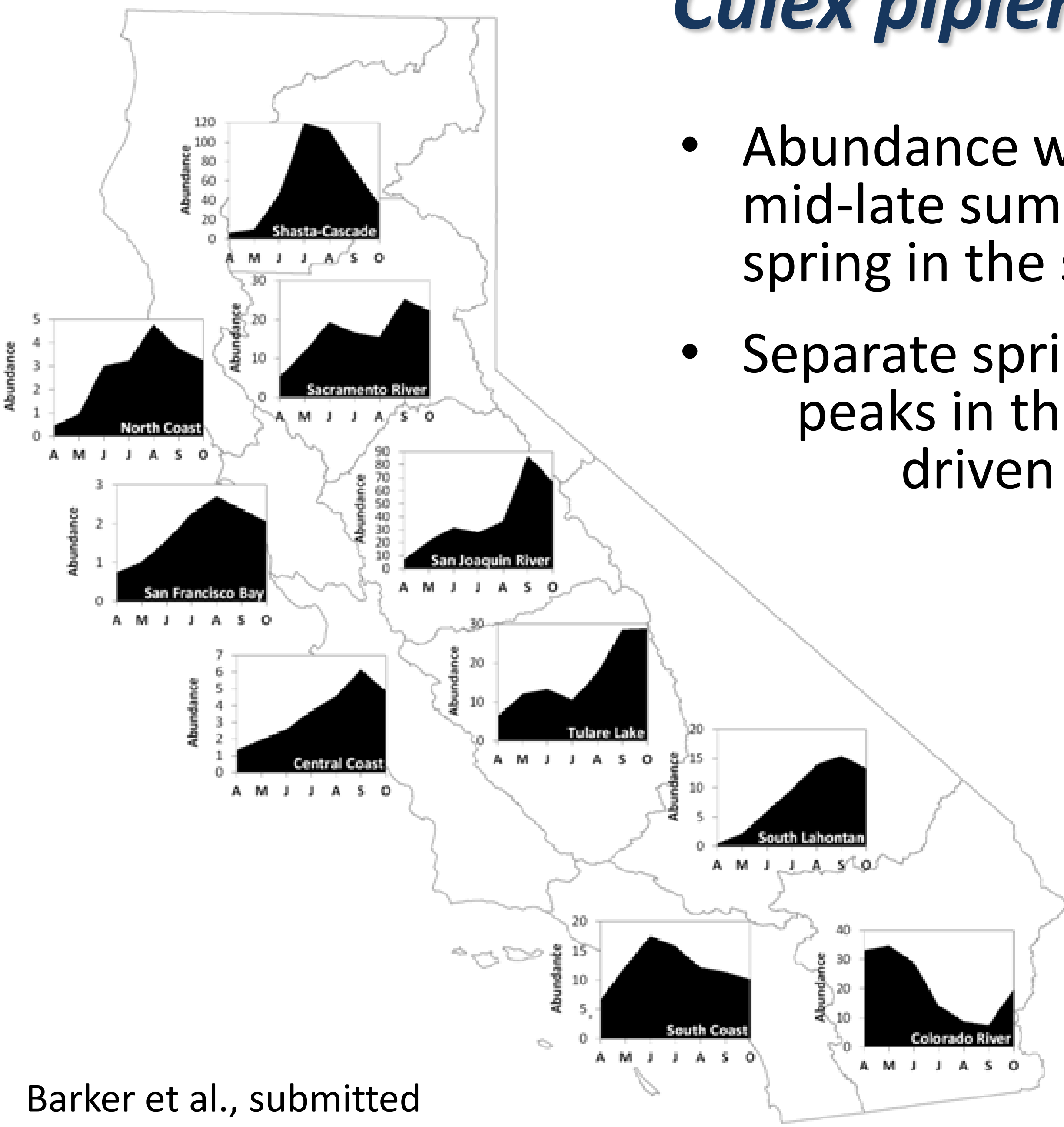
Culex tarsalis & Climate

- Diapause from Oct – Dec
- Termination and phenology climate variation dependent
- Important encephalitis virus vector in West
- Attracted to lights in rural areas



Barker et al., submitted

Culex pipiens complex



- Abundance was highest in mid-late summer in the north, spring in the south
- Separate spring and summer peaks in the Central Valley driven by urban → rural production
- Abundance increases were delayed in regions with the coldest winters

Barker et al., submitted

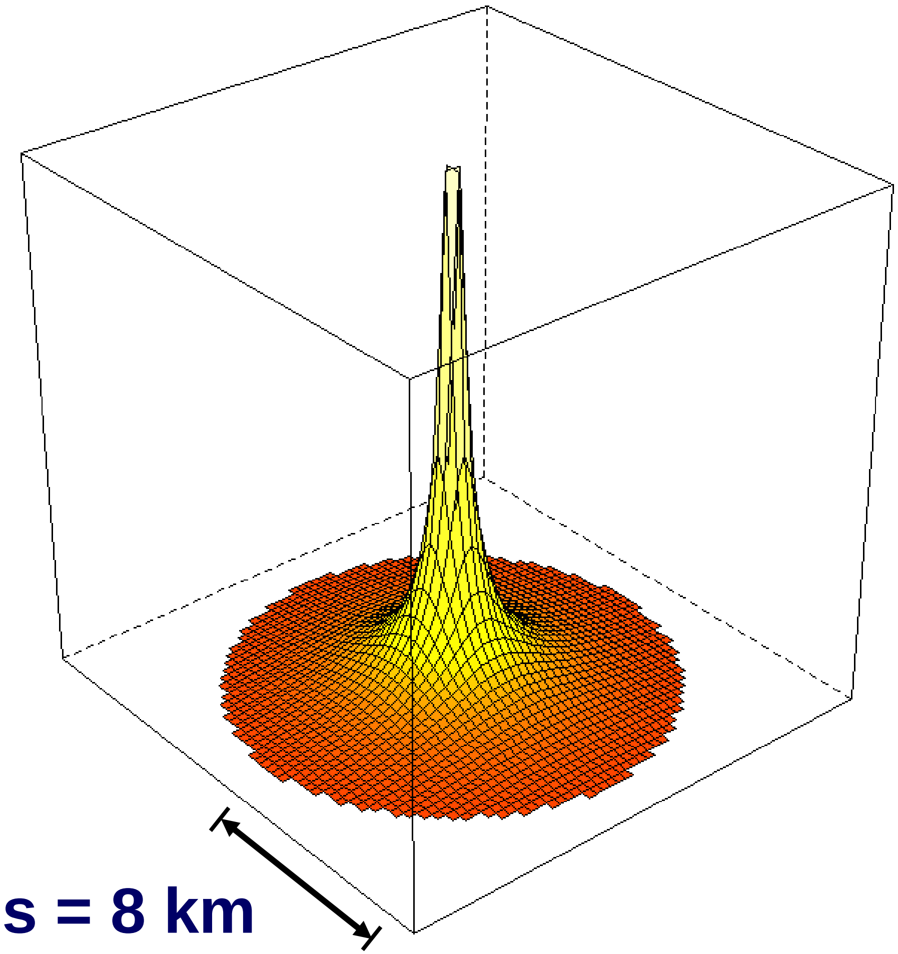
Model Structure

$$log(\lambda_{site(region),month}) = \underbrace{\beta_0 + X_1\beta_1 + \ldots + X_p\beta_p}_{fixed} + \underbrace{b_{site(region)} + W_{site(region),month}}_{random}$$

- Bayesian Poisson regression models fitted using MCMC in R and WinBUGS
- Models account for spatial and temporal autocorrelation among trap counts
- Adjustments in all models:
  - region-level annual abundance patterns (other predictors explain departures from the regional means)
  - human population density as a surrogate for light competition from non-trap sources

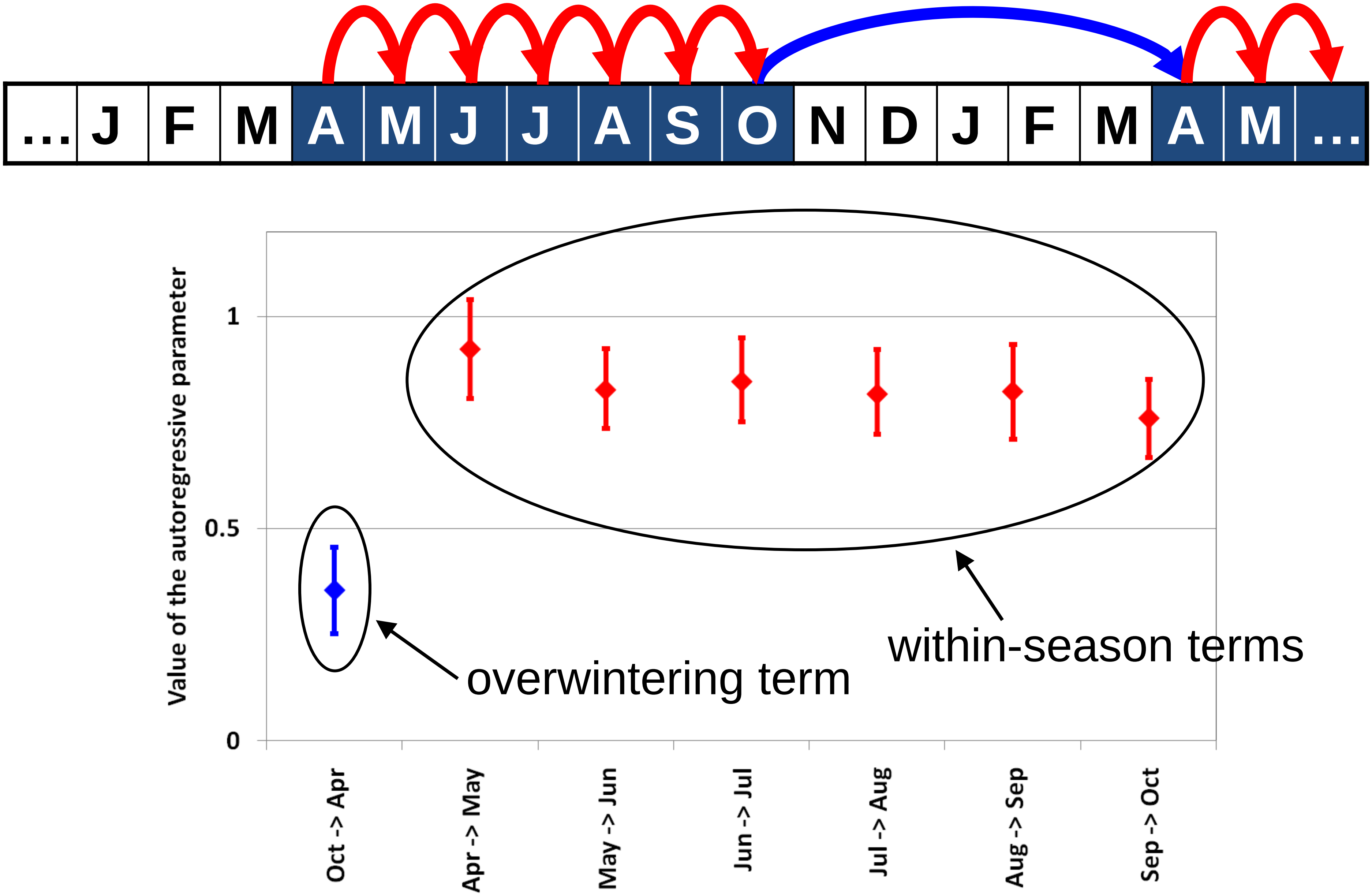
Spatial dependence

- Best-fit model had a gradual decay in dependence within a neighborhood
  - 1/distance weighting
  - 8-km neighborhood

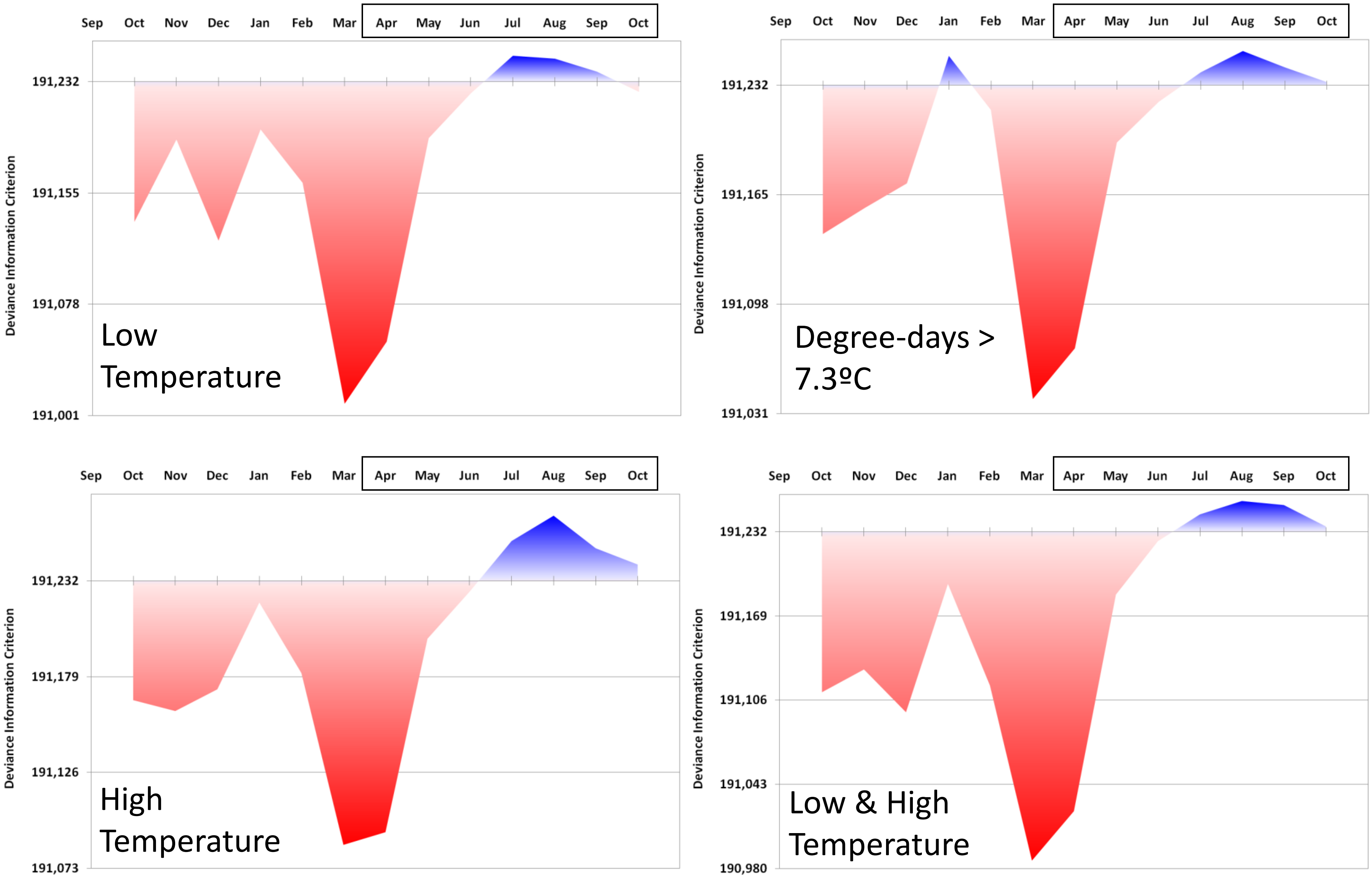


- Consistent with published flight ranges

Temporal dependence



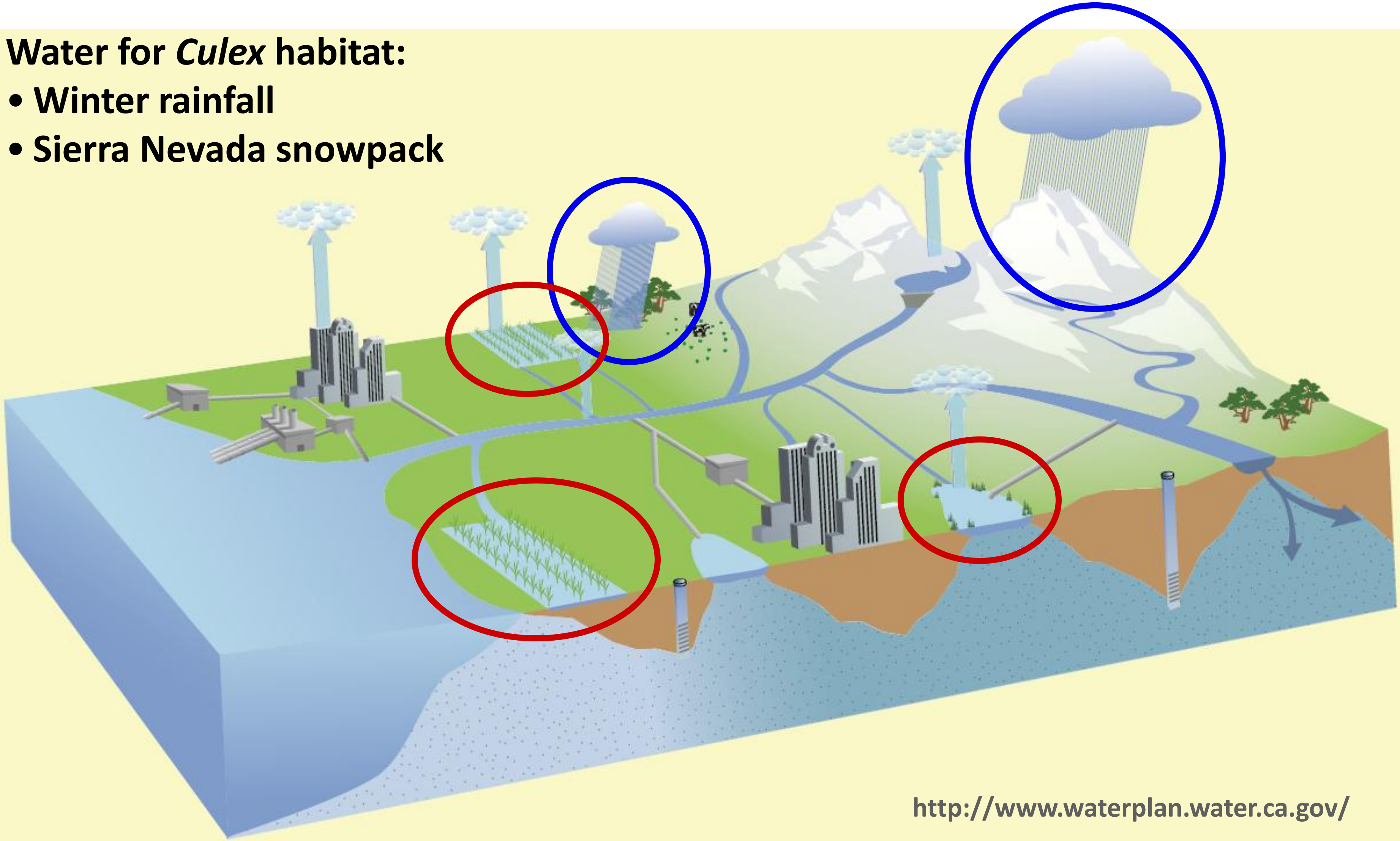
Late winter-early spring temperatures are important predictors



California Water Supply

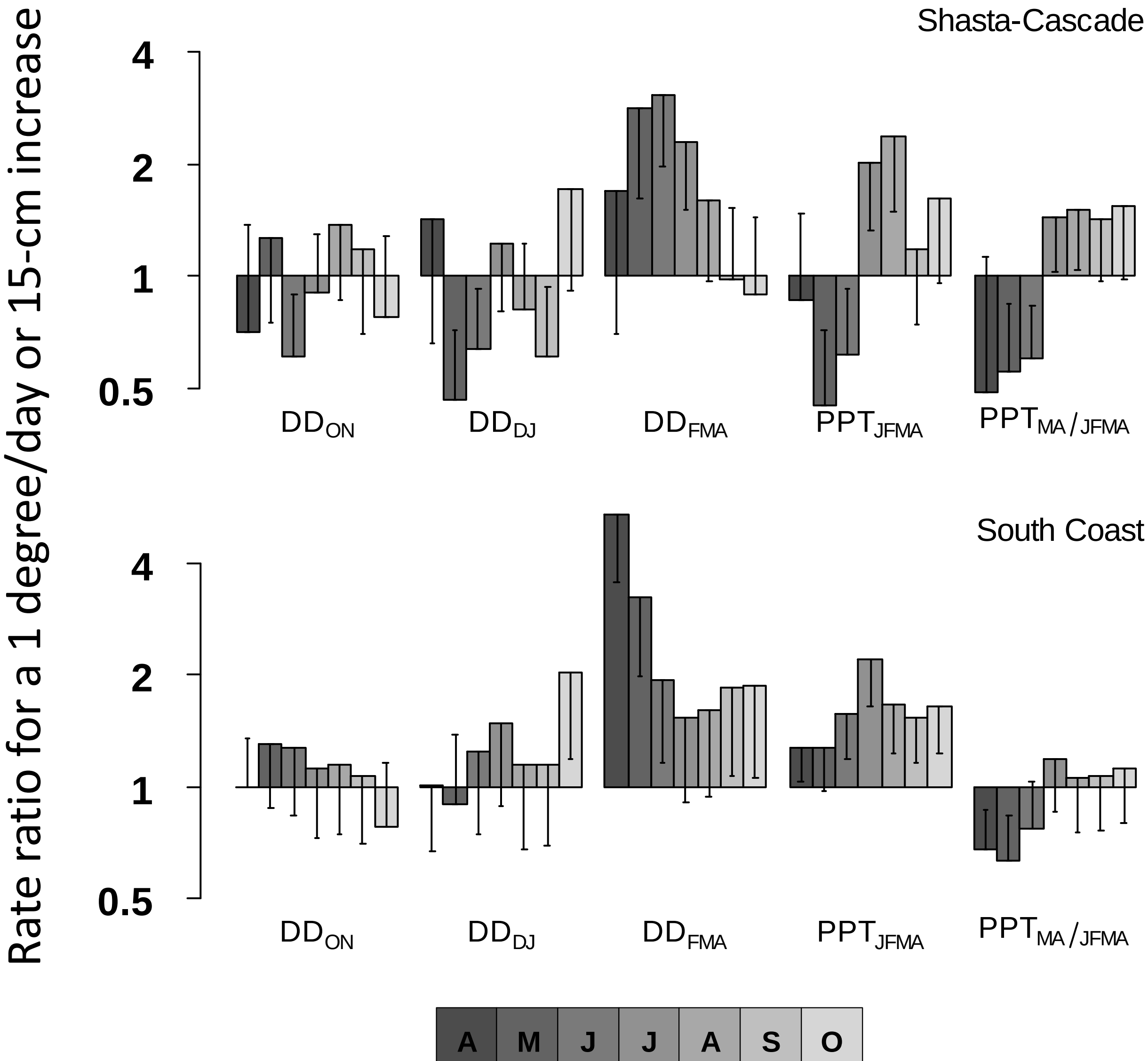
Water for *Culex* habitat:

- **Winter rainfall**
- **Sierra Nevada snowpack**



http://www.waterplan.water.ca.gov/

Cx. pipiens complex



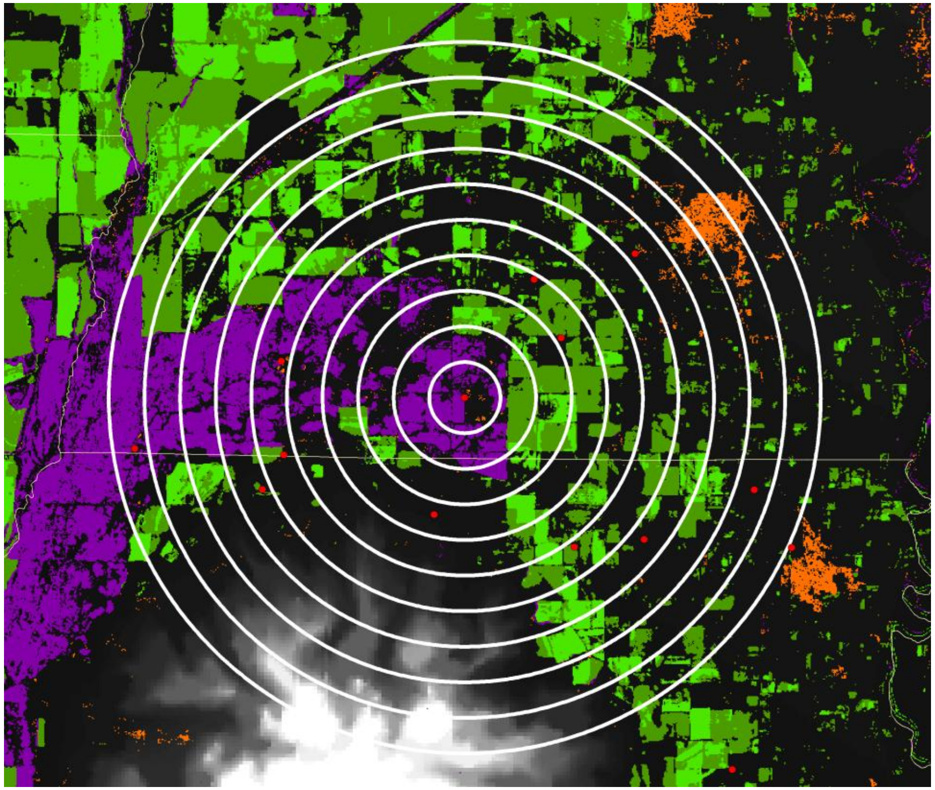
- Higher spring temperatures led to higher abundance
- Evidence for flushing effect of spring rains
  - wet winter → dry spring was ideal

Land cover

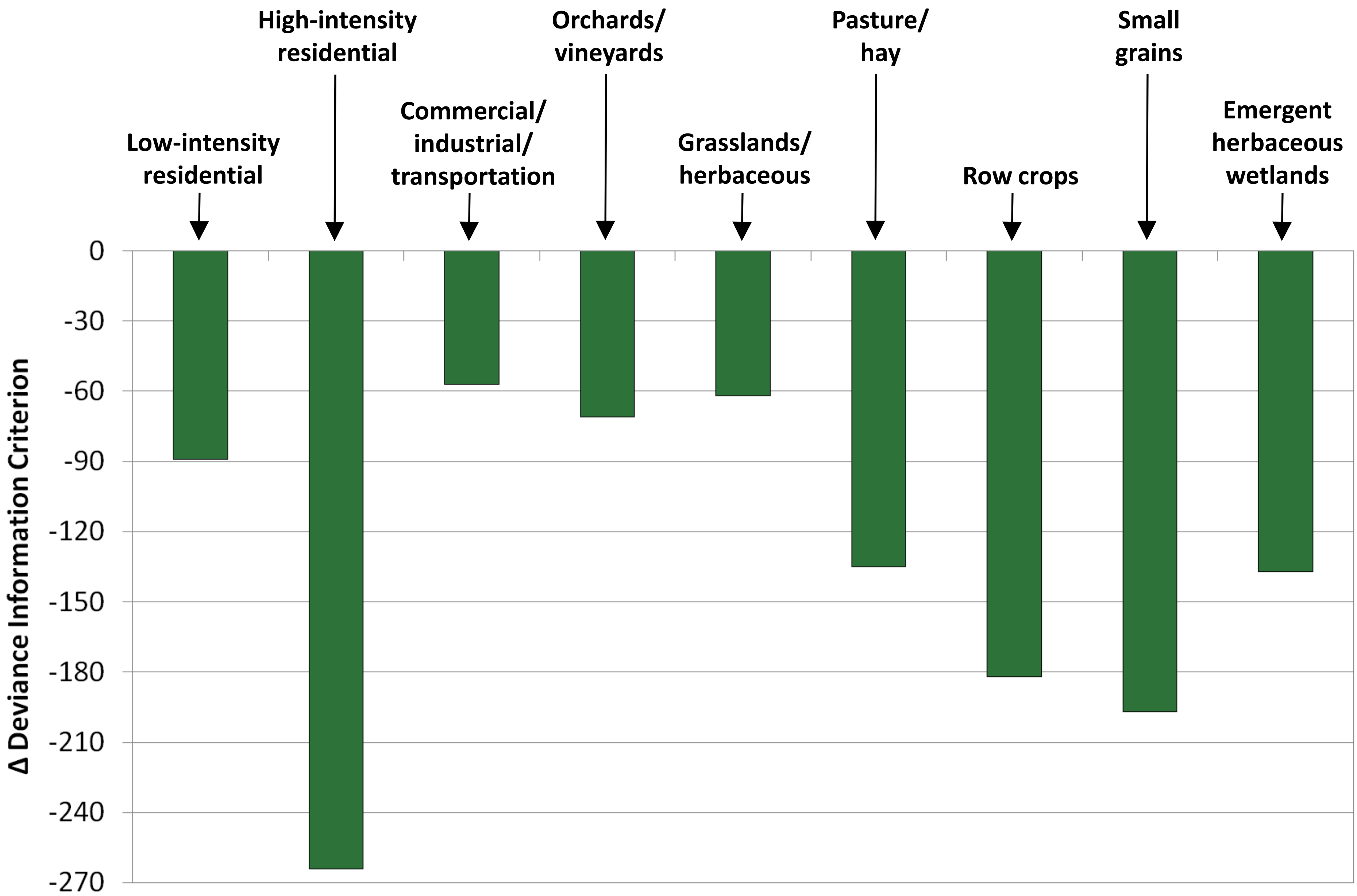
- National Land Cover Dataset

- Calculated area covered by each land cover class within buffer zones

  1, 2, …, 10 km

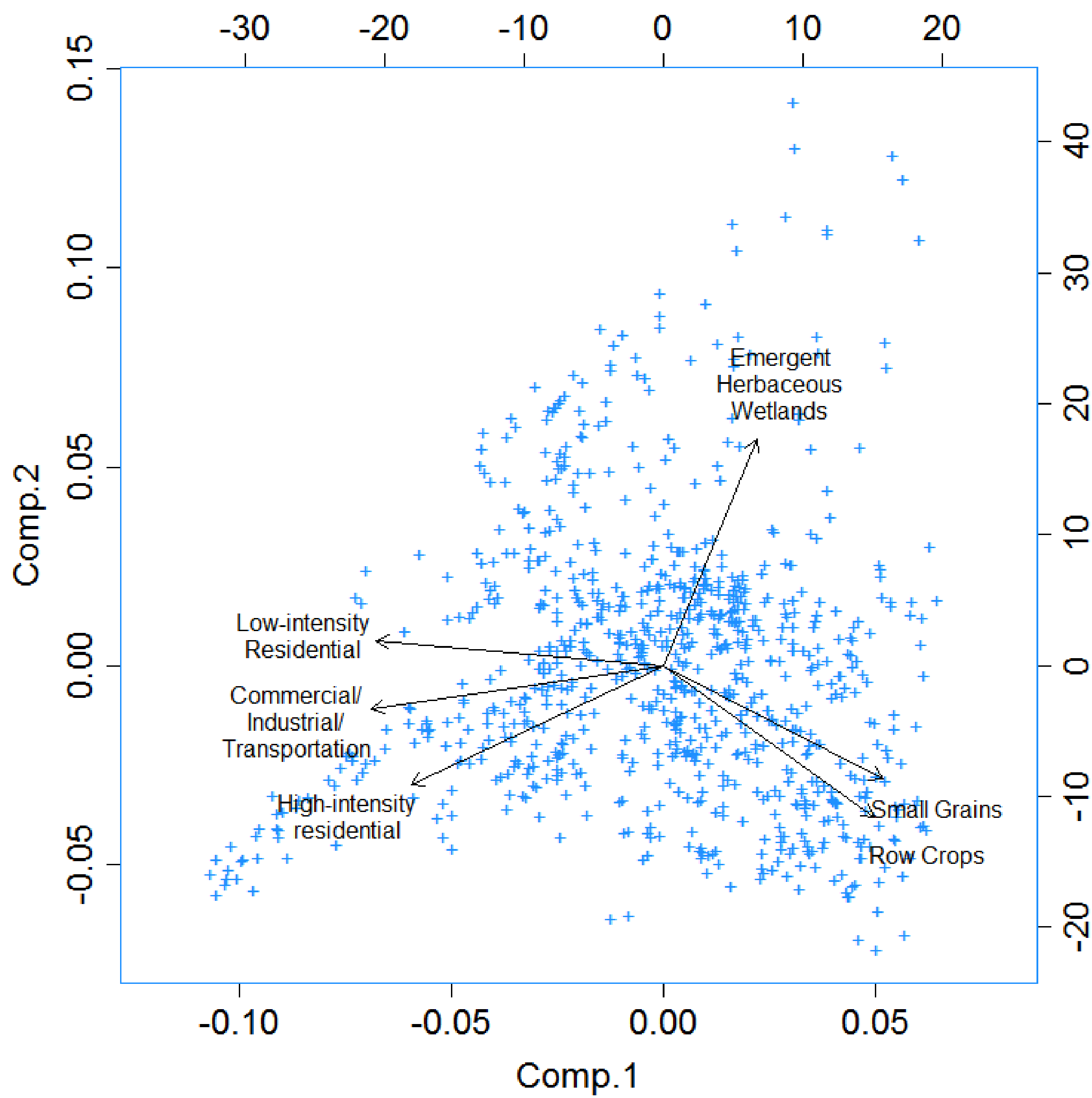


Model comparisons, land use

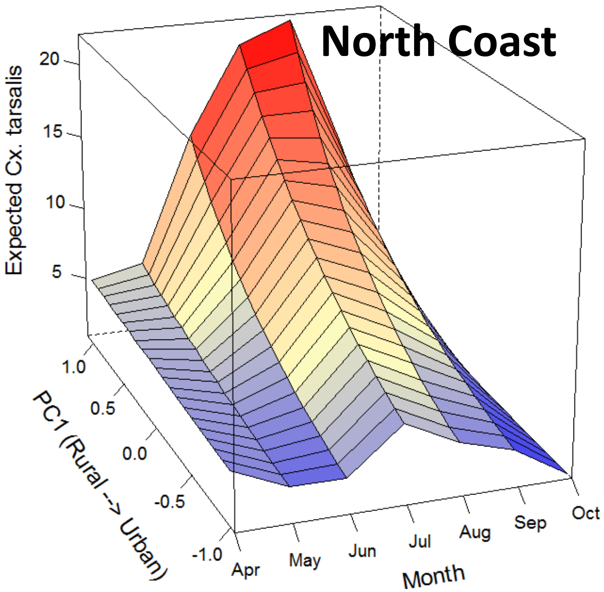


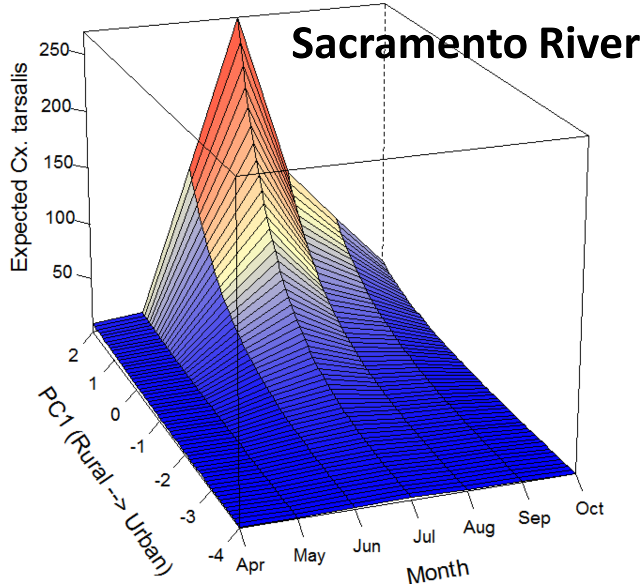
Principal Components Analysis

- Based on 6 land cover classes from the National Land Cover Dataset
- PC_1 separates rural from urban areas
- PC_2 separates wetlands from agricultural areas

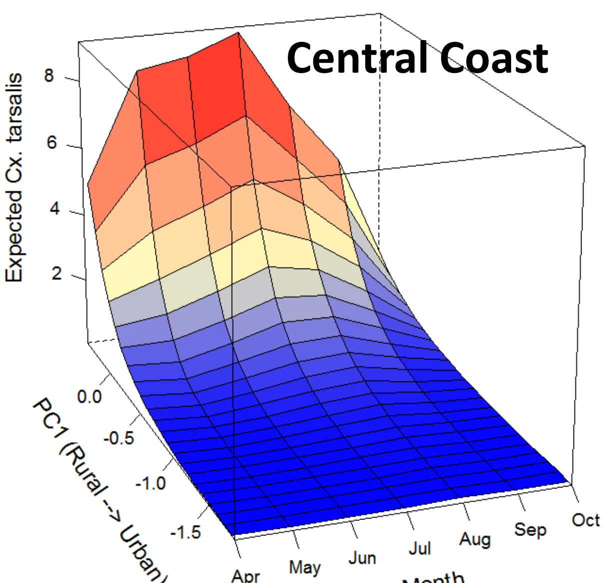


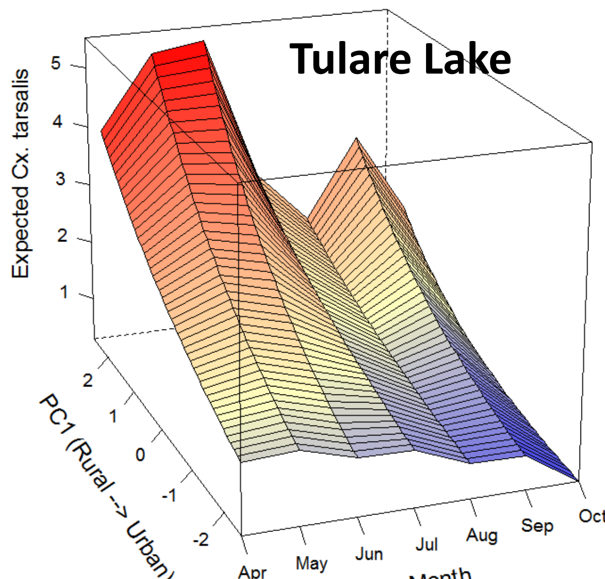
Predicted *Cx. tarsalis* based on PC_1

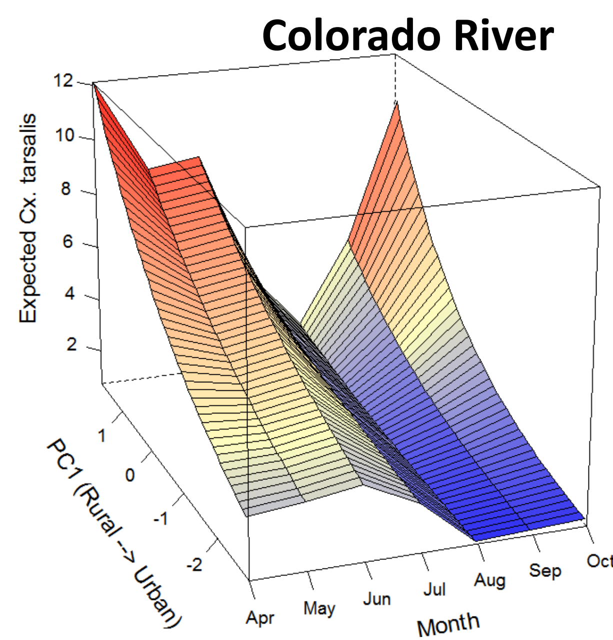




- Highest abundance in rural areas
- Unimodal in some areas, bimodal in others







Q: When is mosquito abundance associated with virus transmission?

- Reeves (1971) proposed abundance thresholds for light trap counts that were related to the intensity of virus transmission

- Earlier study found a positive relationship between seasonal *Cx. tarsalis* abundance indices and incidence of WEEV in humans and sentinel chickens; reduction at highest abundance? (Olson 1977, Olson et al. 1979)

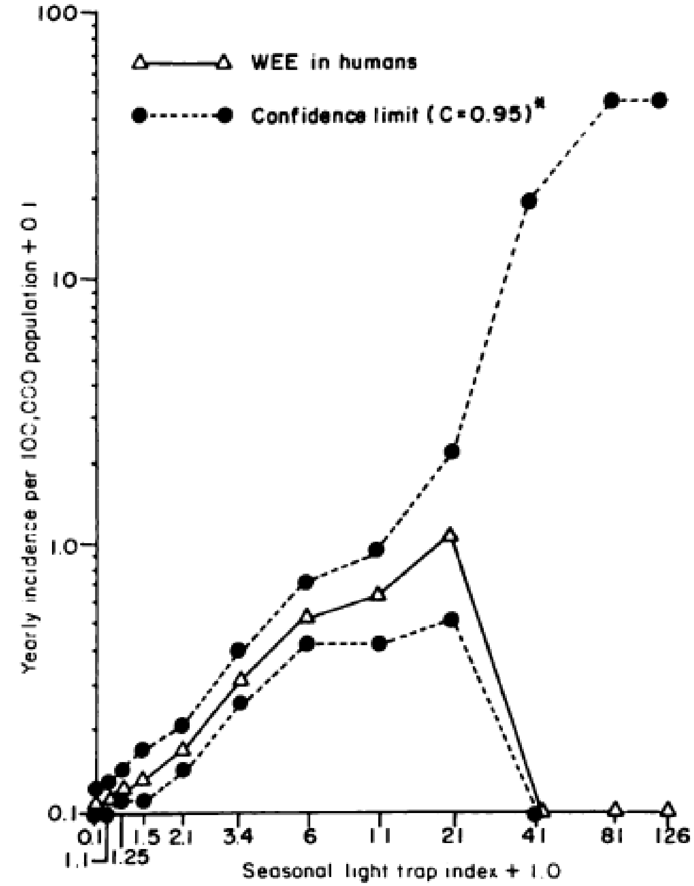
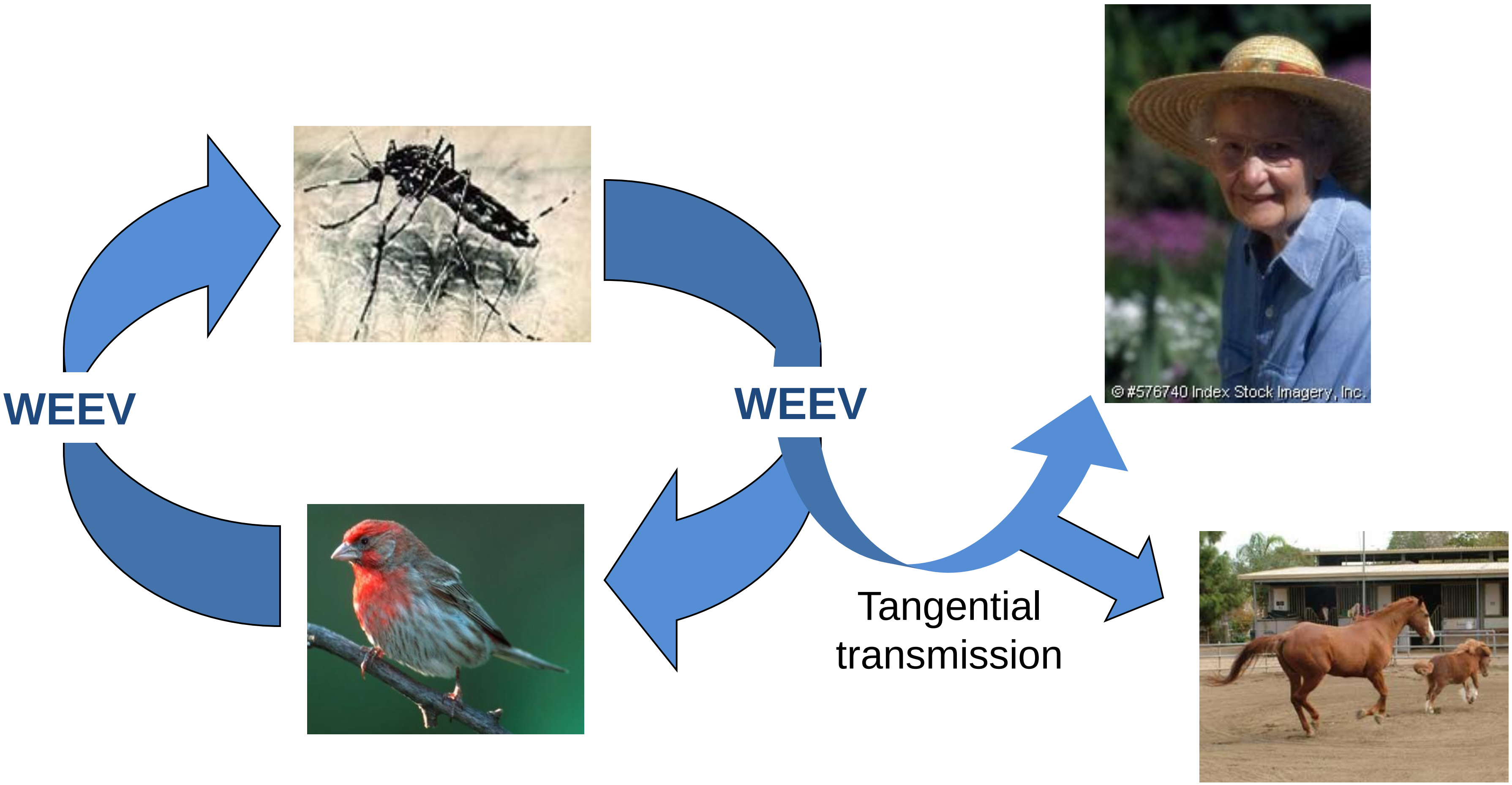


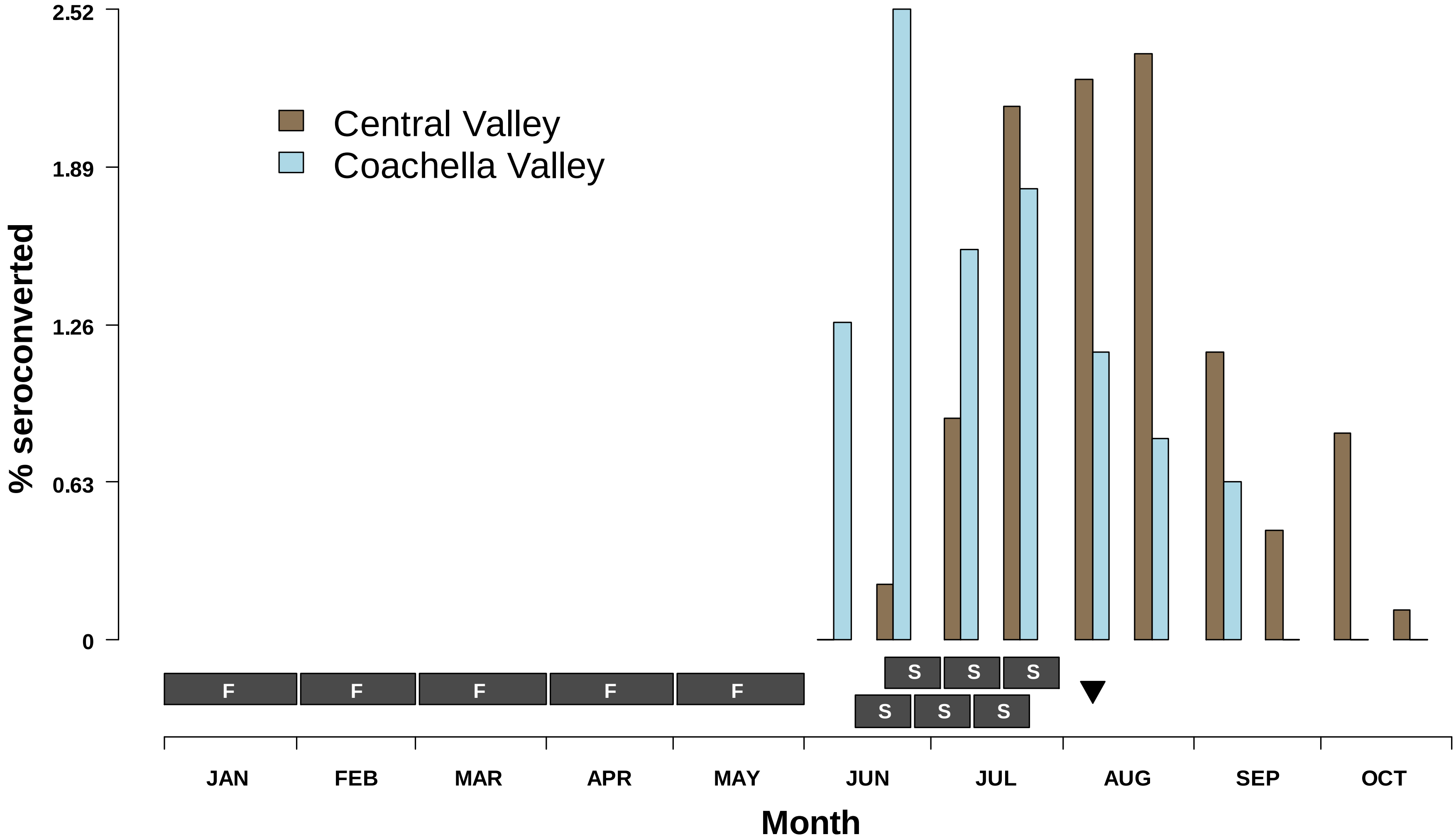
FIGURE 2. Seasonal urban occurrence of female *Culex tarsalis* and yearly incidence of western equine encephalomyelitis in humans, California, 1953–1973.

Olson et al. 1979 AJTMH

Western equine encephalomyelitis virus (WEEV)

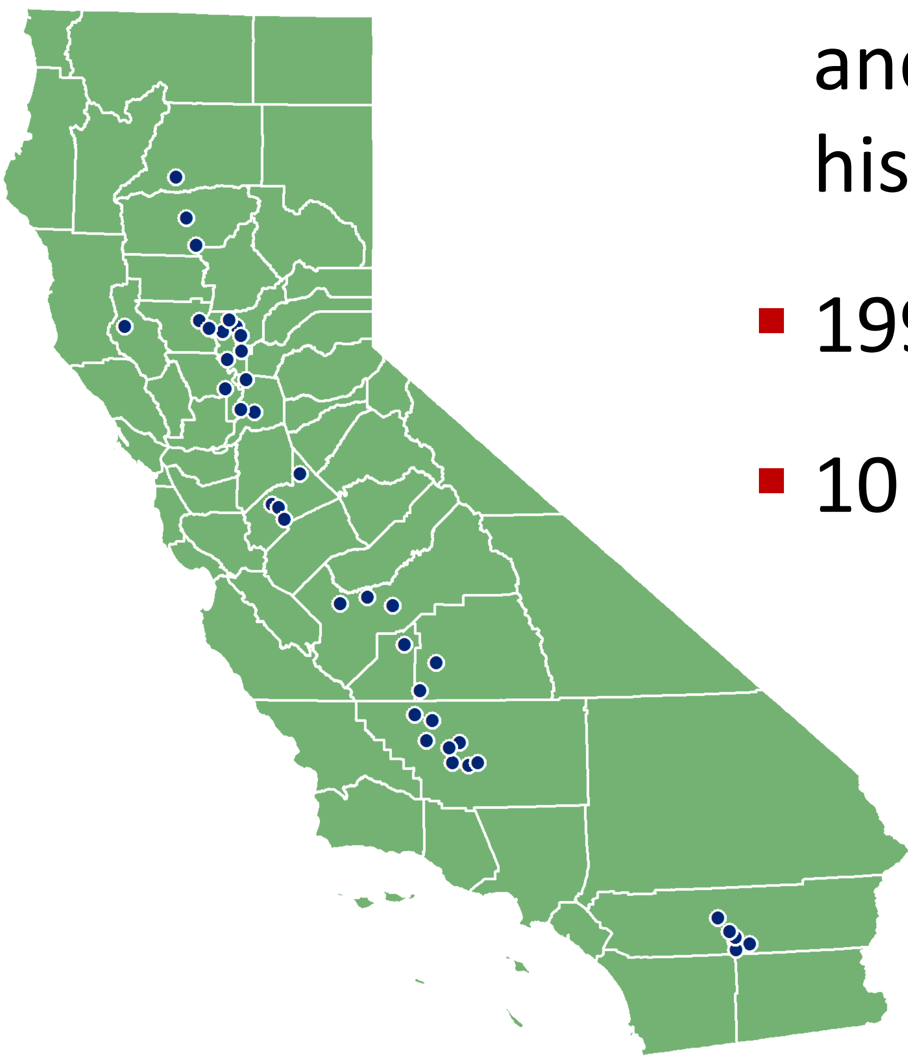


Sentinel Chickens



- Considered abundance at fixed and lagged intervals prior to the bleeding date for sentinel chickens

Sentinel Chicken Data

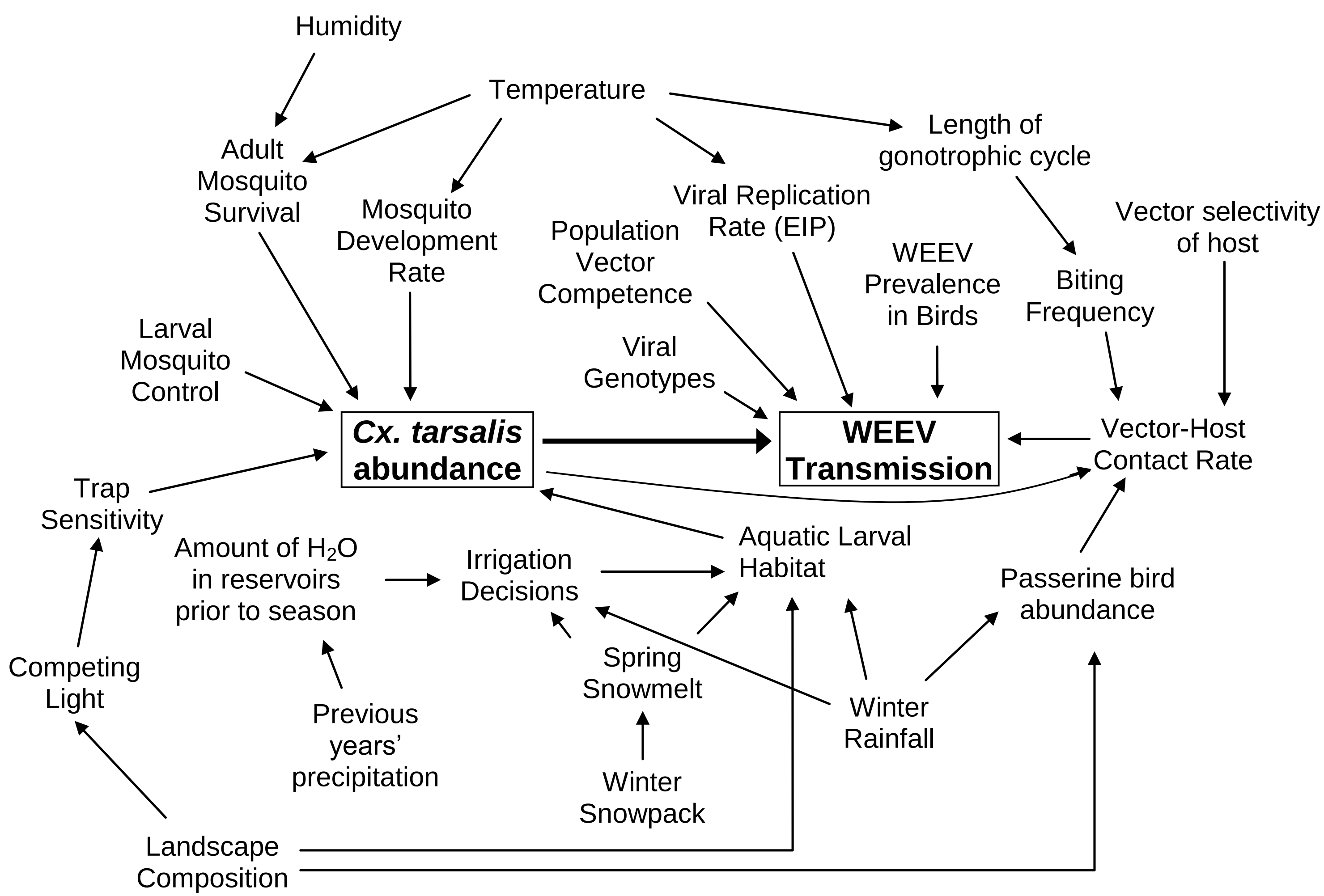


- 41 flock sites in the Central and Coachella Valleys with a history of WEEV transmission
- 1992-2000
- 10 chickens per flock
  - Bled biweekly from Apr [Jun] – Oct and tested for IgG to WEEV

Sentinel Chicken Flocks

- Specific indicators of arbovirus transmission
- Paired with a nearby NJ-style light trap
- Delay of 8+ days from transmission → seroconversion (Reisen 1994 JAMCA)

Vector abundance vs. WEEV transmission



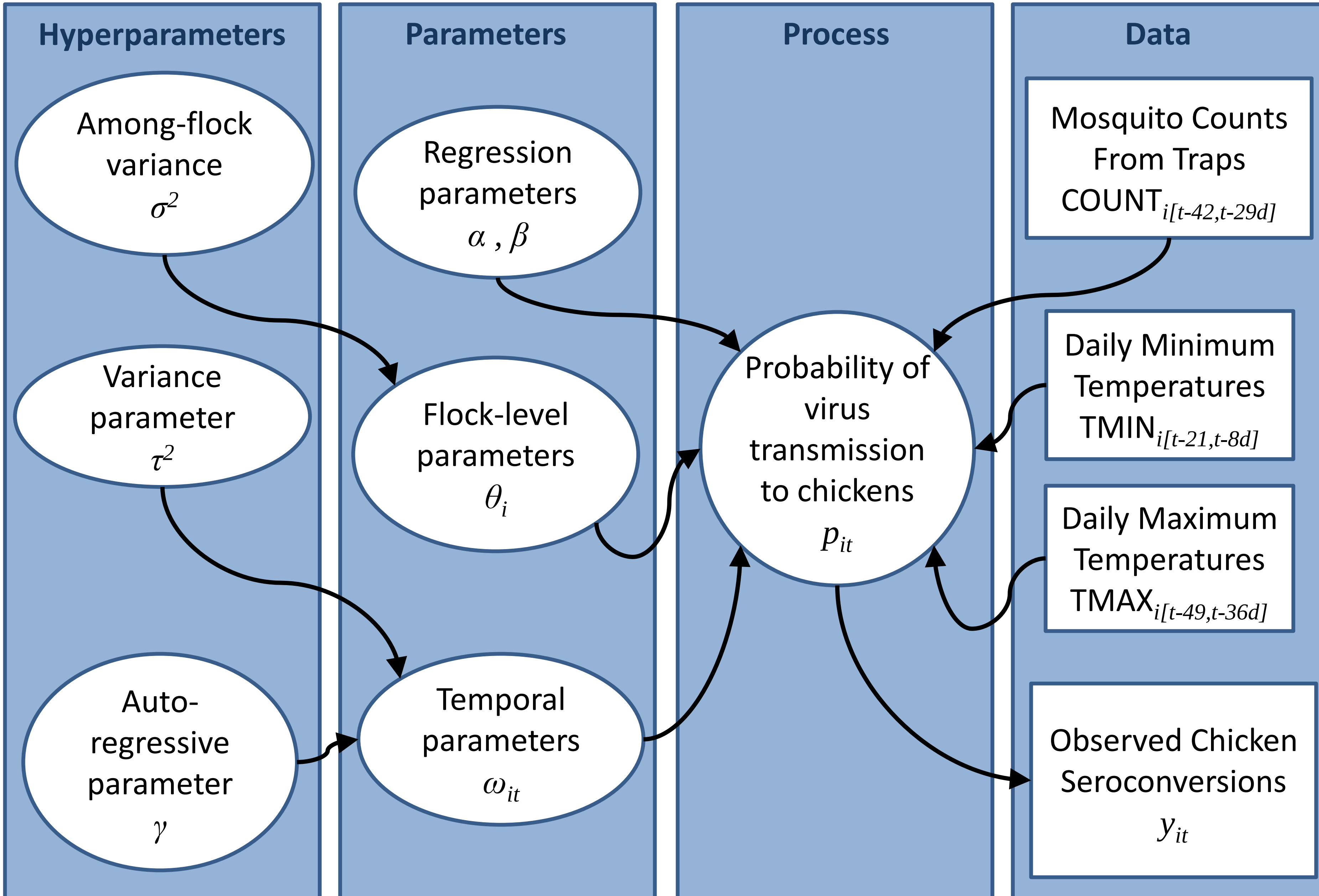
- Need adjustment for temperature and landscape composition

Model Structure

$$\operatorname{logit}(p_{it}) = \beta_{0i} + \beta_1 X_{1i} + \ldots + \beta_q X_{qi} + \theta_i + \omega_{it}$$

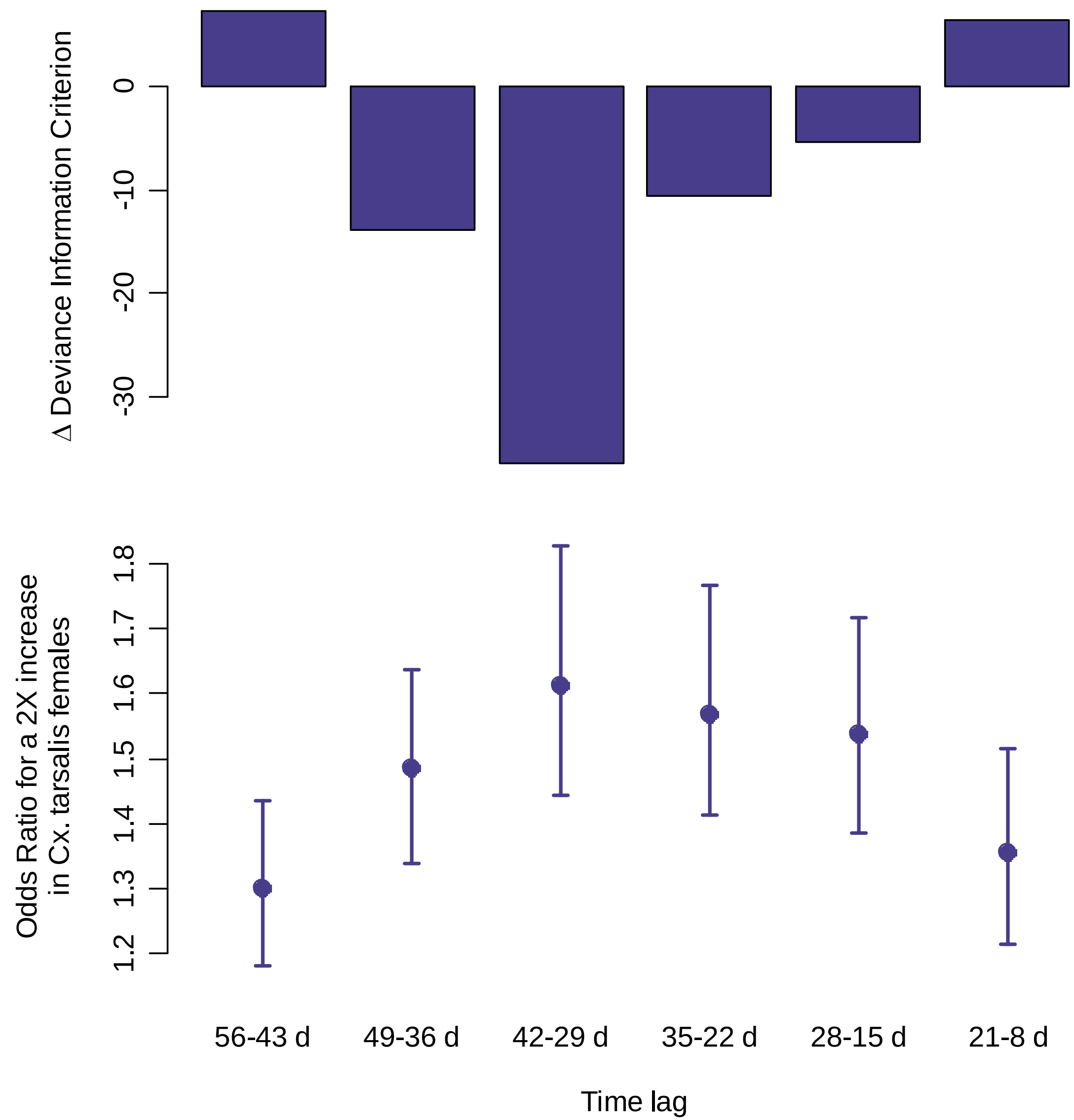
- Bayesian logistic regression models
- θ_i represent terms for variation in transmission probabilities among flocks
- ω_{it} represent temporal connections from each half-month to the next within a season

Model Structure

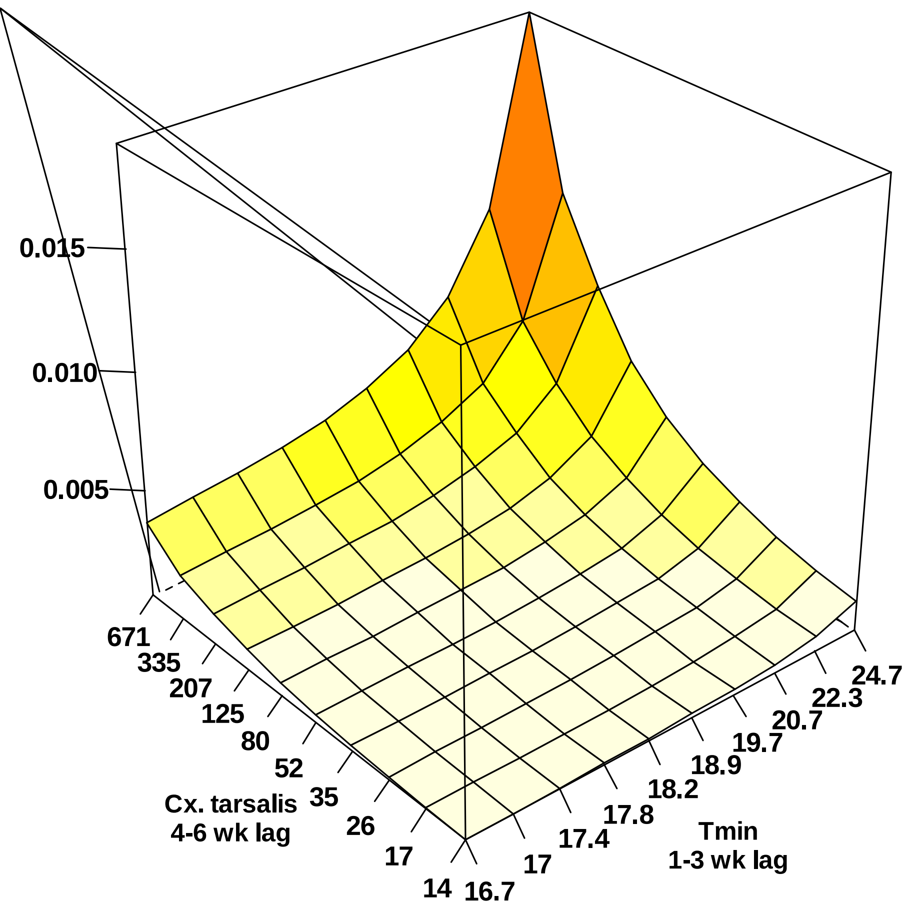


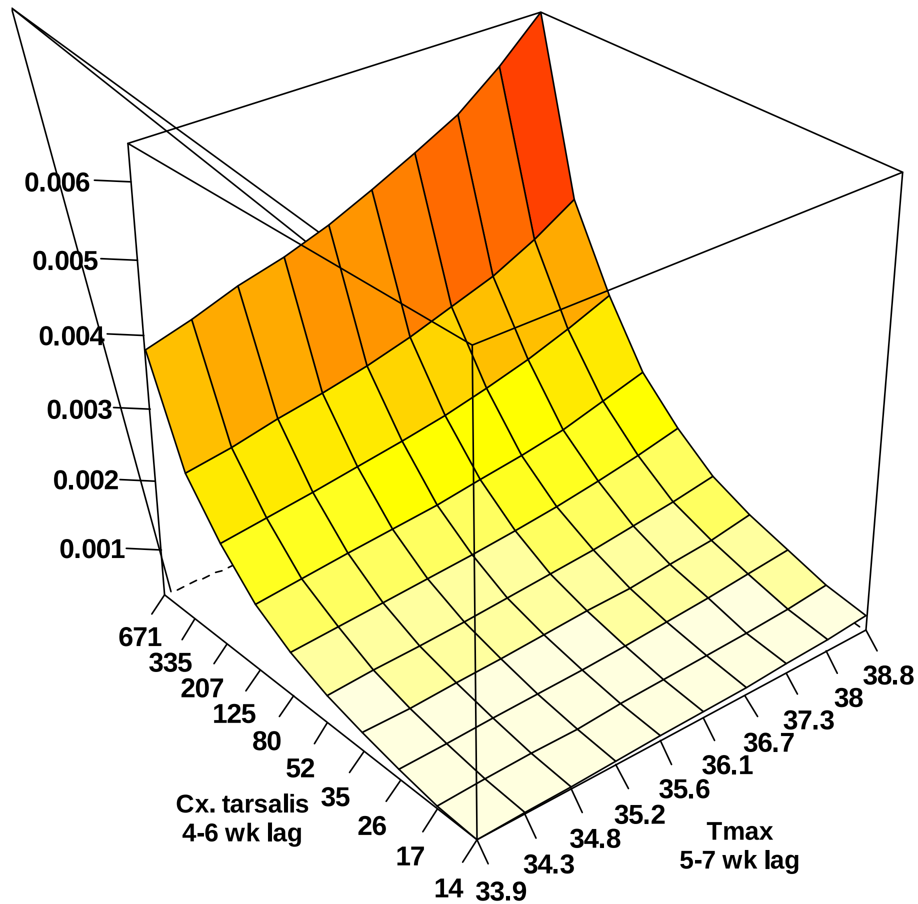
Sentinel Chicken Flocks

- *Cx. tarsalis* abundance 4-6 wks prior to bleeding date resulted in the best model fit and strongest association with seroconversion probabilities



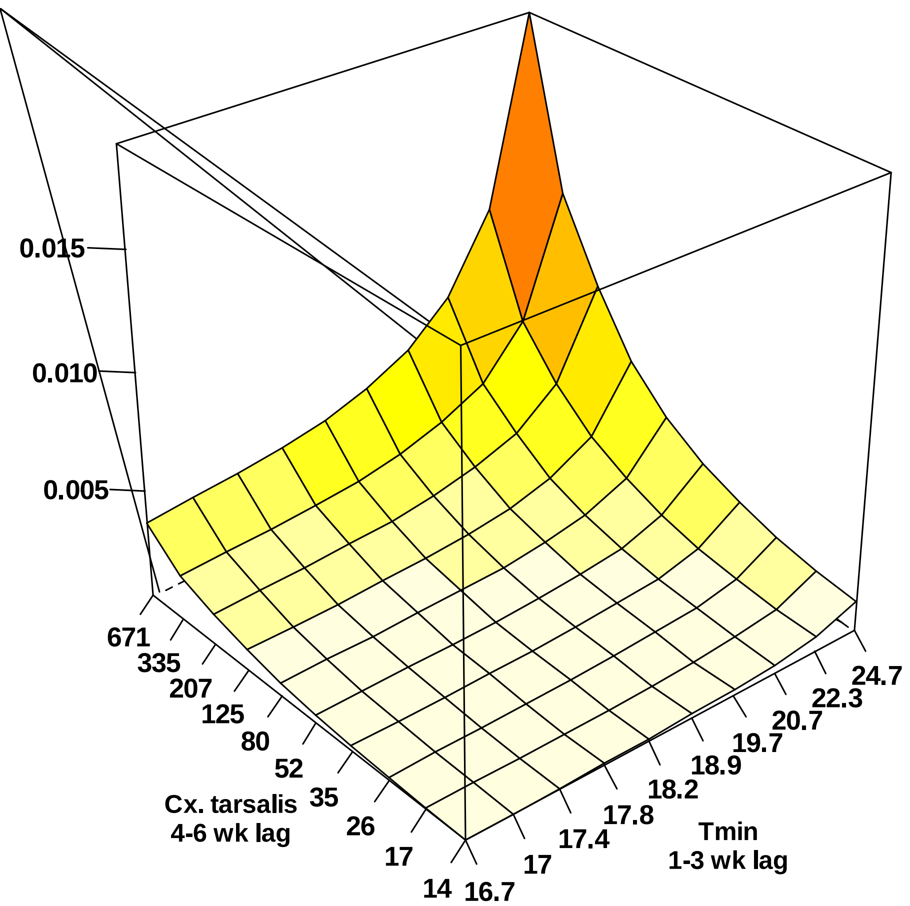
Central Valley

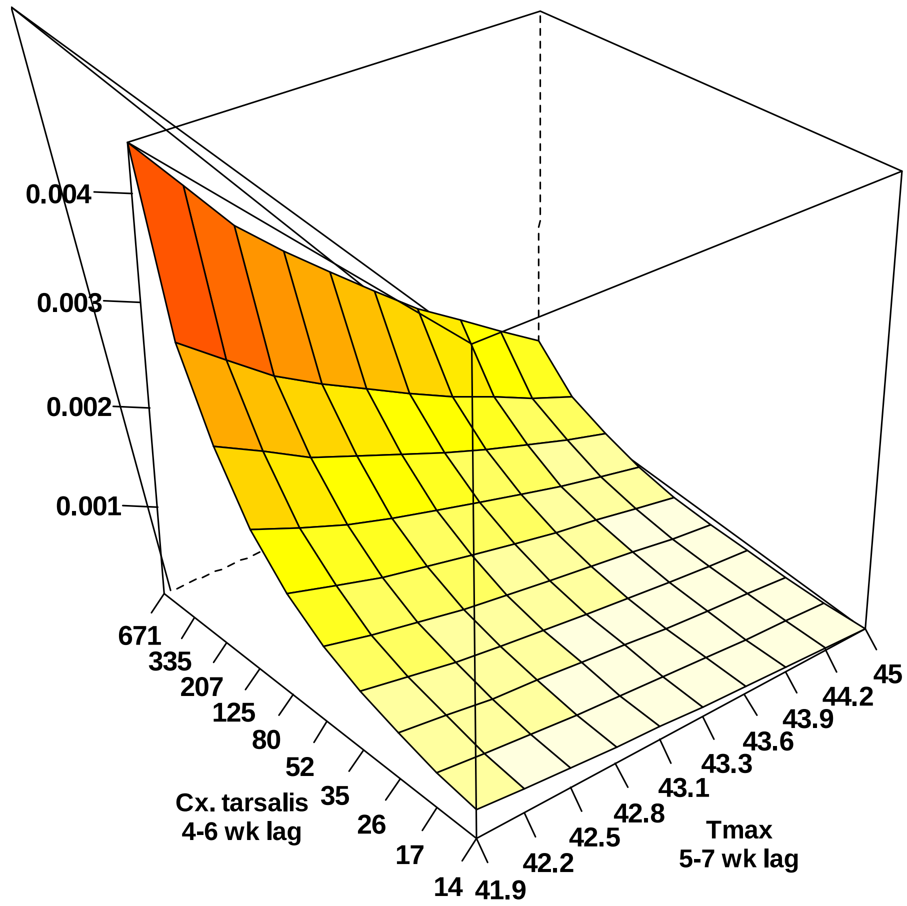




Probabilities of seroconversion

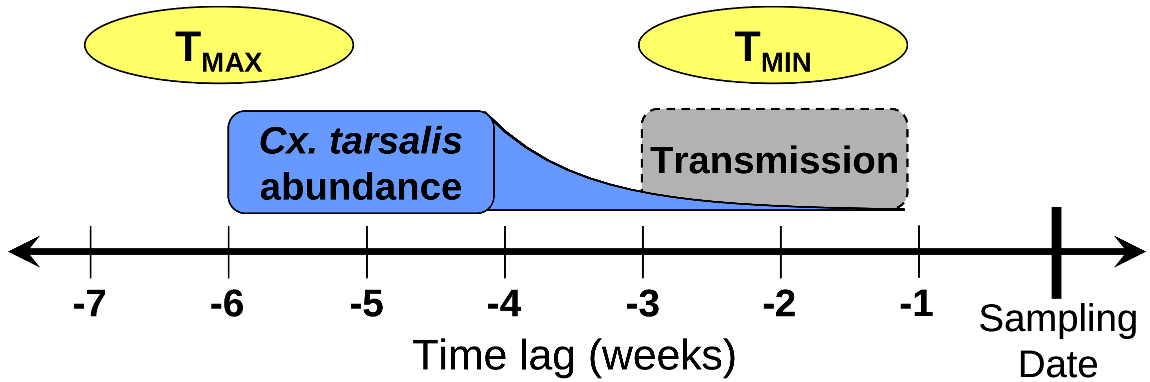
Coachella Valley





Probabilities of seroconversion

Conclusion

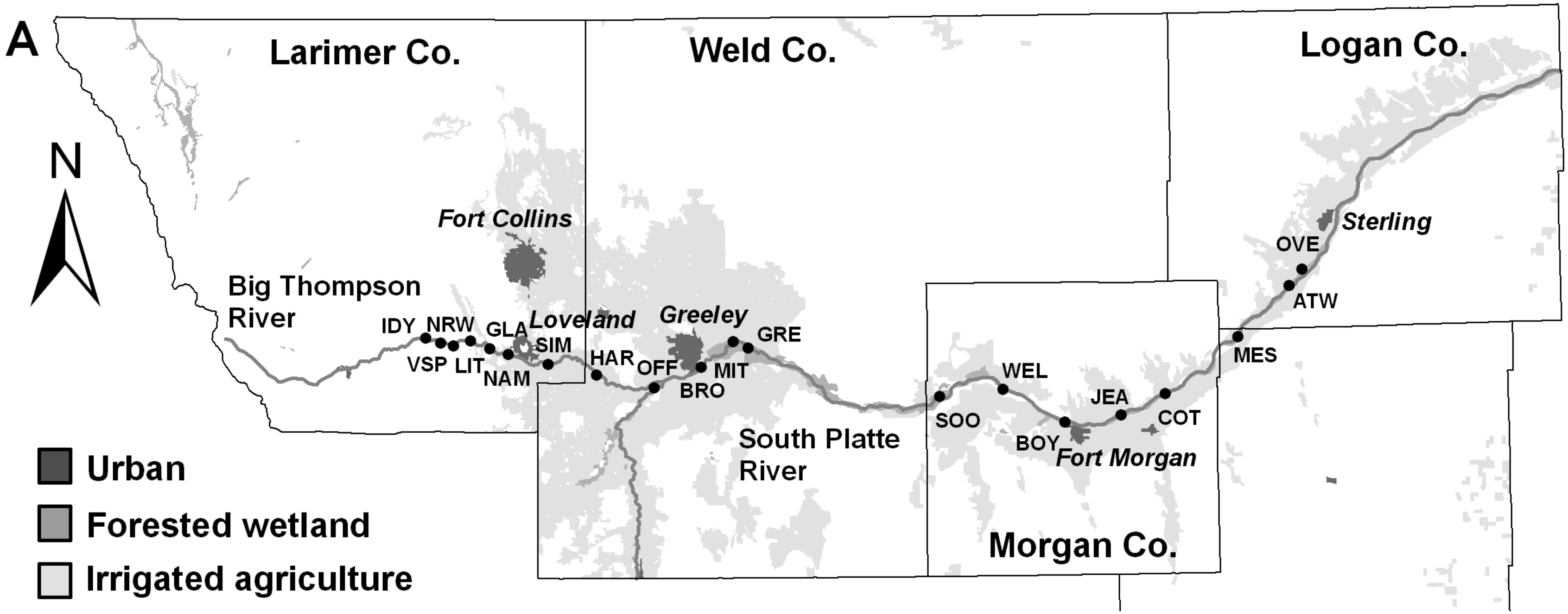


- Combination of warmer temperatures and elevated *Cx. tarsalis* abundance 4-6 weeks prior to the chicken sampling date (3-5 wks prior to the transmission event) resulted in the highest probability of virus transmission to sentinel chickens

Extension to other areas

- Colorado
  - Spatiotemporal models of mosquito abundance and WNV infection rates from Rocky Mountain foothills to plains
- Washington
  - Mosquito testing and reporting via the CalSurv Gateway (version 2 “pilot program”)
- Singapore?
  - Collaboration with NTU and NEA to share tools and models from the CA WNV decision support system to be adapted for dengue

Work with Colorado State University



- Mosquitoes and WNV sampled along a gradient from the Rocky Mountain foothills into the plains
- Models constructed using habitat/climate predictors, including TOPS temps, precip

Work with CDC

- **ArboNET**
  - WK Reisen is academic representative to ArboNET Evaluation Working Group
  - CA data regularly exported from CalSurv Gateway to ArboNET
- **New UCD/CDPH/CDC project on integrated population-based surveillance for WNV**
  - Compare surveillance measures as predictors of human West Nile cases at sentinel sites
  - CalSurv Gateway as model for data collection

Gateway 2.0

- Spatial capabilities of PostgreSQL and PostGIS
- Integration of Google Maps
- Will permit users to group and query data spatially using “point-and-click” polygon definition
- Currently used in Washington, will be delivered to all of California by the end of 2009

CalSurv California Vectorborne Disease Surveillance System

Gateway 2.0

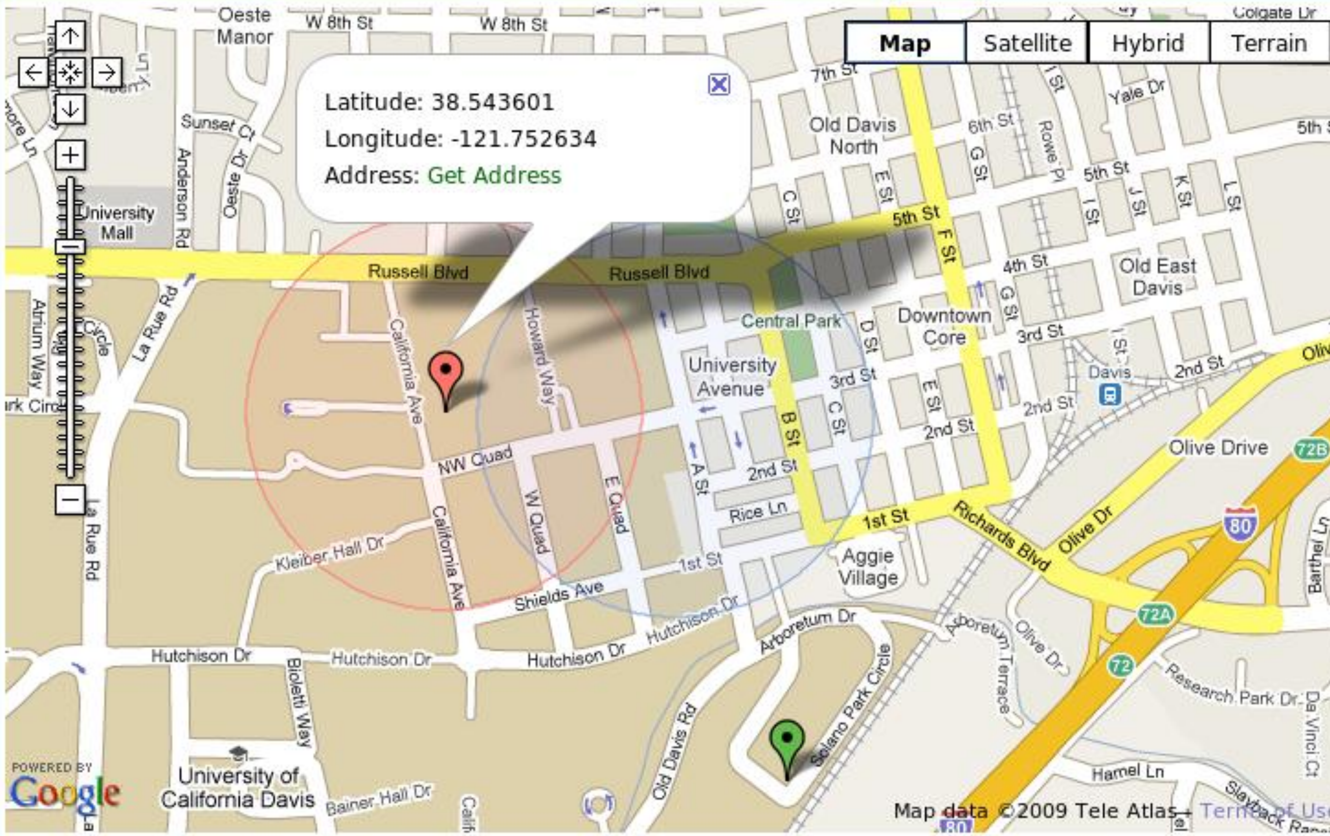
Site Information

***Site Code** **CVEC** 1006

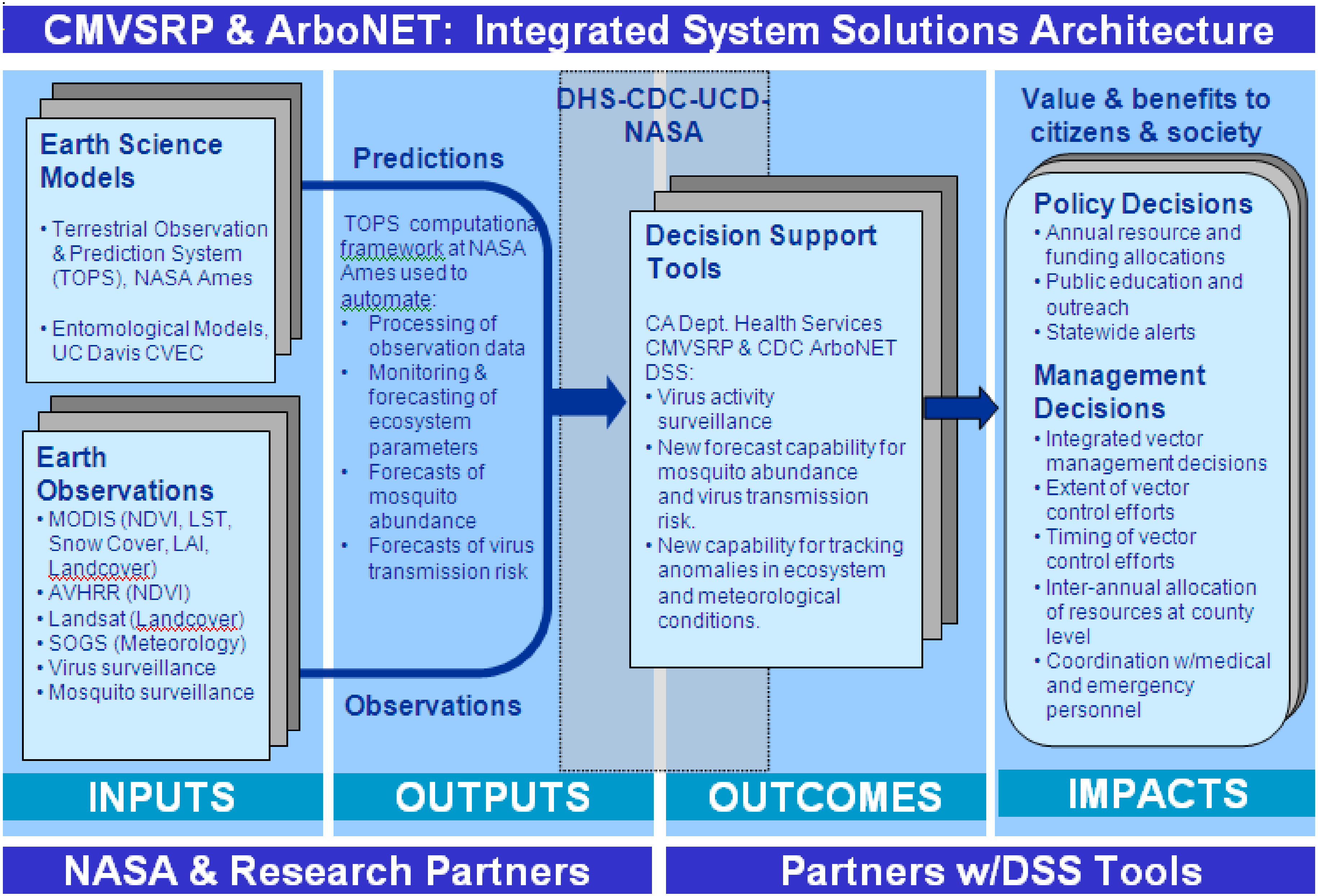
Site Name Salt Water Taffy

Coordinates

Decimal Degrees | Degrees Minutes Seconds | Degrees Minutes | **Map**



Geocode | Fix Map


CMVSRP & ArboNET: Integrated System Solutions Architecture
Earth Science Models
• Terrestrial Observation & Prediction System (TOPS), NASA Ames
• Entomological Models, UC Davis CVEC
Earth Observations
• MODIS (NDVI, LST, Snow Cover, LAI, Landcover)
• AVHRR (NDVI)
• Landsat (Landcover)
• SOGS (Meteorology)
• Virus surveillance
• Mosquito surveillance
Predictions
TOPS computational framework at NASA Ames used to automate:
• Processing of observation data
• Monitoring & forecasting of ecosystem parameters
• Forecasts of mosquito abundance
• Forecasts of virus transmission risk
Observations
DHS-CDC-UCD-NASA
Decision Support Tools
CA Dept. Health Services CMVSRP & CDC ArboNET DSS:
• Virus activity surveillance
• New forecast capability for mosquito abundance and virus transmission risk.
• New capability for tracking anomalies in ecosystem and meteorological conditions.
Value & benefits to citizens & society
Policy Decisions
• Annual resource and funding allocations
• Public education and outreach
• Statewide alerts
Management Decisions
• Integrated vector management decisions
• Extent of vector control efforts
• Timing of vector control efforts
• Inter-annual allocation of resources at county level
• Coordination w/medical and emergency personnel
INPUTS
OUTPUTS
OUTCOMES
IMPACTS
NASA & Research Partners
Partners w/DSS Tools

Final year plans

- Months-in-advance forecasting of mosquito abundance using TOPS, RS data
- Gateway 2.0
  - BK Park invited to present Gateway at Southeast Regional Public Health & Vector Management Conference in Florida
- Survey of vector control and public health agencies re: usage of response plan and CalSurv Gateway