Modeling & Inference in Ecological Problems

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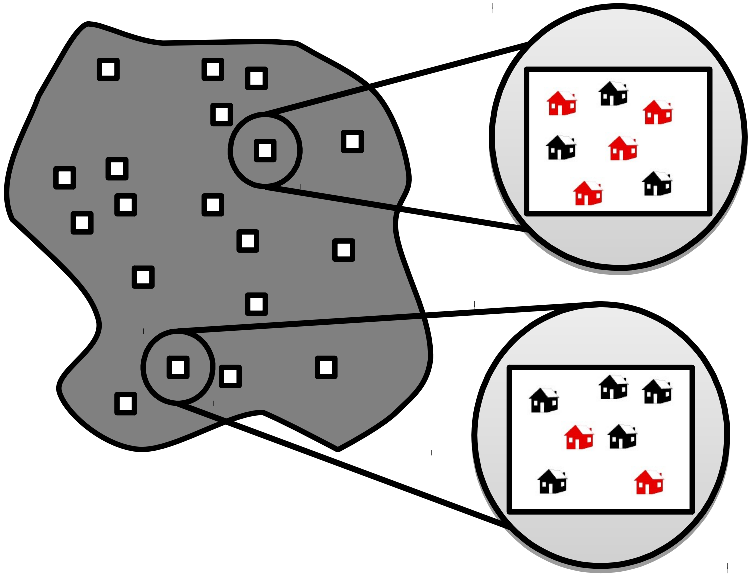
Sampling Biological Systems

- Vector & disease management
- Most likely available data will be counts:
  - Easy to collect.
  - Historical data sets.
- Population Time Series

Sampling Biological Systems

- What is a "Count".
  - A random variable.
  - The product of abundance and detection probability.
  - Many methods developed to correct counts for detection error.



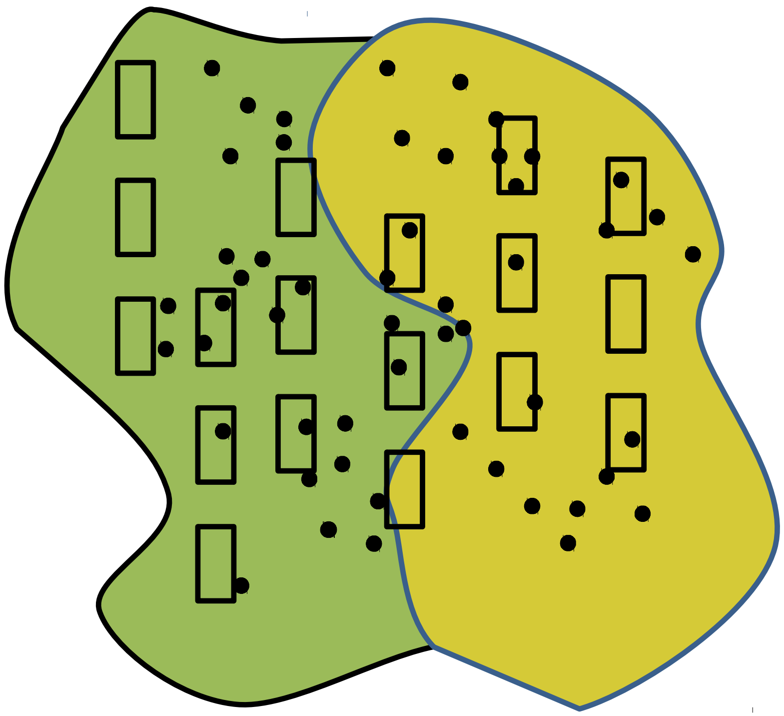
Count Model

$$E(C_{it}) = N_{it} * p_{it}$$

$$\hat{N}_{it} = C_{it} / \hat{p}_{it}$$

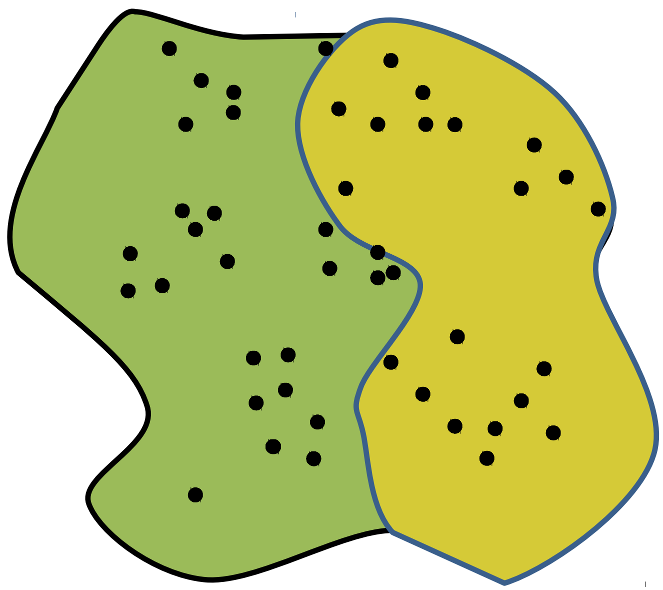
Sampling Biological Systems

- Observation Model.
  - Observation Model: quantifies probabilities of detection.
  - Describes the covered region, survey units, effort (observers/trap).
  - Randomness determined by survey design.



Sampling Biological Systems

- State Model
  - State Model: statistically describes the distribution of animals.
  - Who lives here and where are they?
  - Characteristic of the animal, such as group size, habitat preference, movement, exposure.



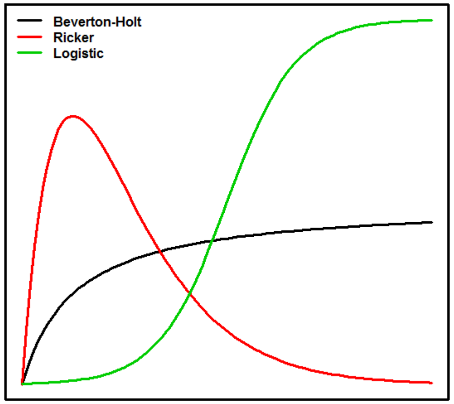
Simple spatial state model

$$\pi(x_{s1},\ldots,x_{sN}) = \prod_{i=1}^{N}\left[1-\phi_s\right]^{1-x_{si}}\phi_s^{x_{si}}$$

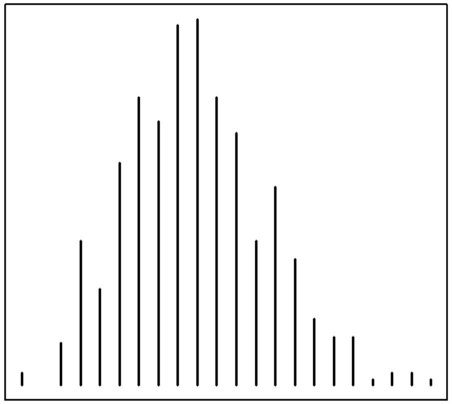
where ϕ = probability of being in woodland during survey *s*.

Variability & Uncertainty

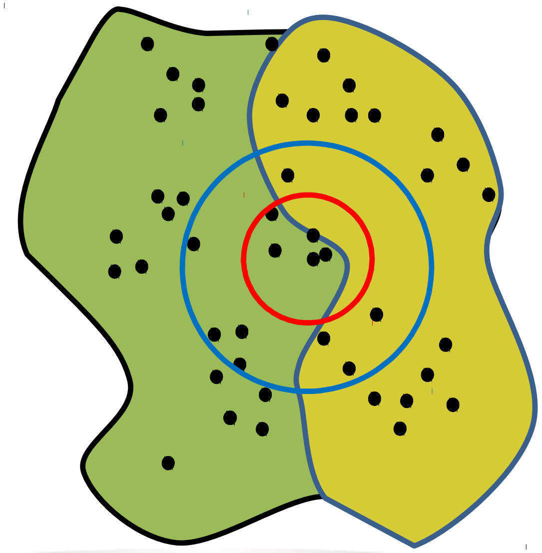
Model Error



Process Error

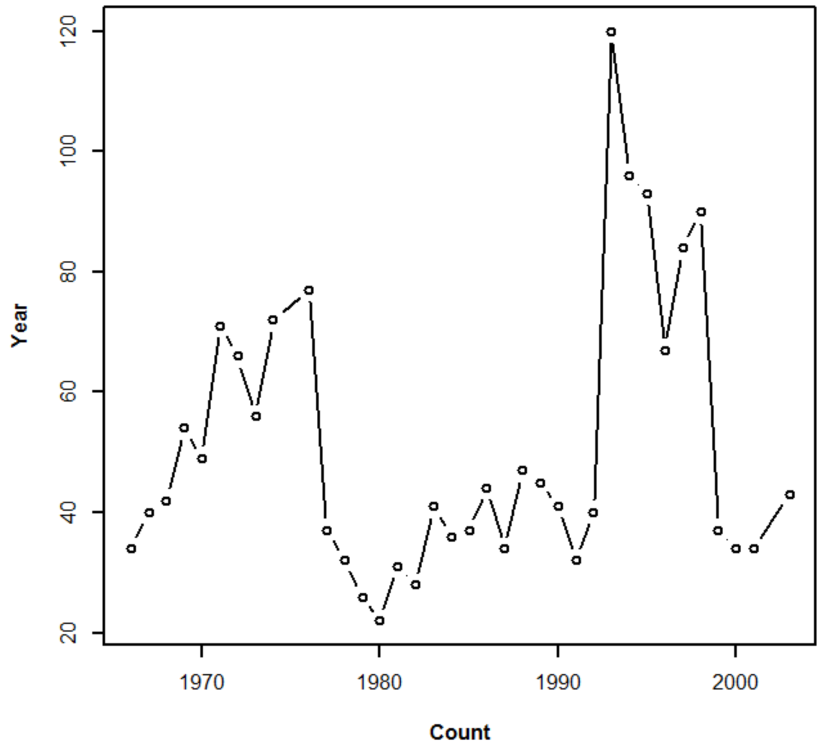


Observation Error

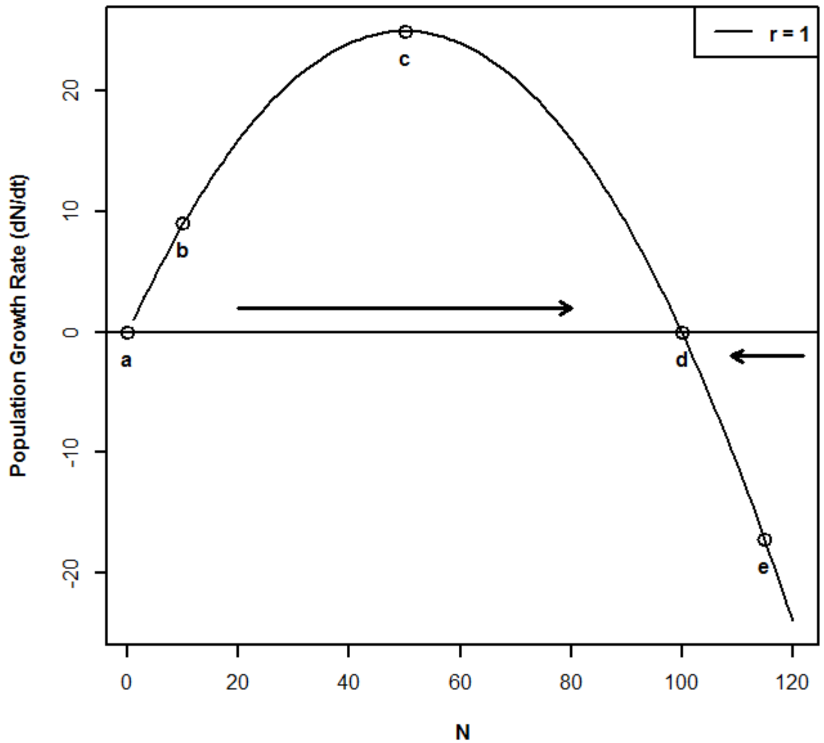


Model Paradigms

Empirical



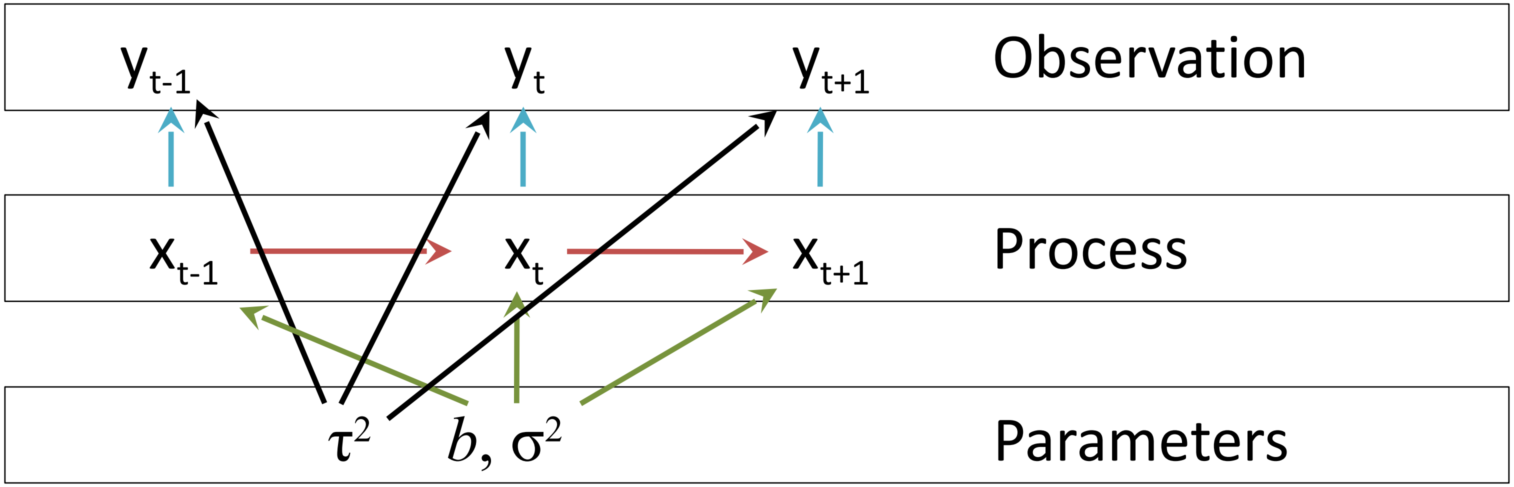
Theoretical



Hierarchical View

Hierarchical View: Philosophical middle ground between "Observation" & "Process" driven approaches.

Model-based estimation can be decomposed into "process" & "observation" levels through hierarchical modeling.



[observation|process,parameters][process|parameters][parameters]

Hierarchical View

- *Implicit* process
  - Collection of random effects.
  - Lack a biological interpretation.
- *Explicit* process
  - Describes realization of an actual ecological process.
  - Maintain distinction between process and observation models.

The covariance between replicate counts of the same local population is:

$$Cov\left(y_{i1}, y_{i2}\right) = p^2\lambda = \sigma_{12}$$

σ simply tells us there is some correlation between replicated counts.
p^2 tells us how detection probability is changing between replicated counts.

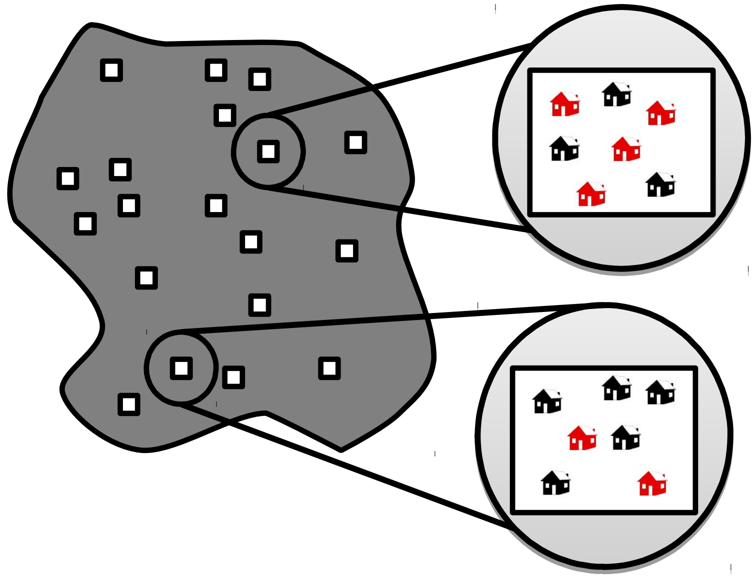
Ecological Model

- Simple ecological model:
  - Geometric growth

$$N_{t+1} = r_t \cdot N_t$$

where r_t is growth rate.

- State-space model to separate the process & observation models



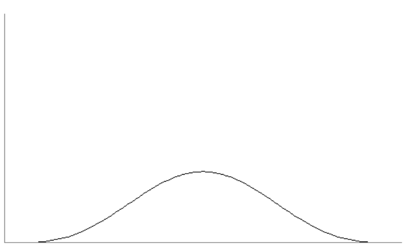
The Bayes rule

Expertise

Prior Knowledge

Model
Parameters, state variables ϕ,
Likelihoods $[y|\phi]$

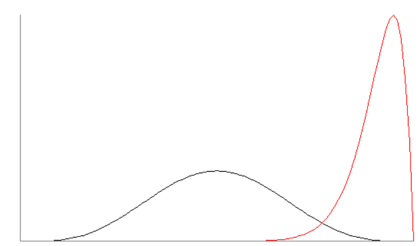
Prior



Bayes rule

$$[\phi \mid y] = \frac{[\phi]\cdot[y \mid \phi]}{\int [\phi]\cdot[y \mid \phi]\, d\phi}$$

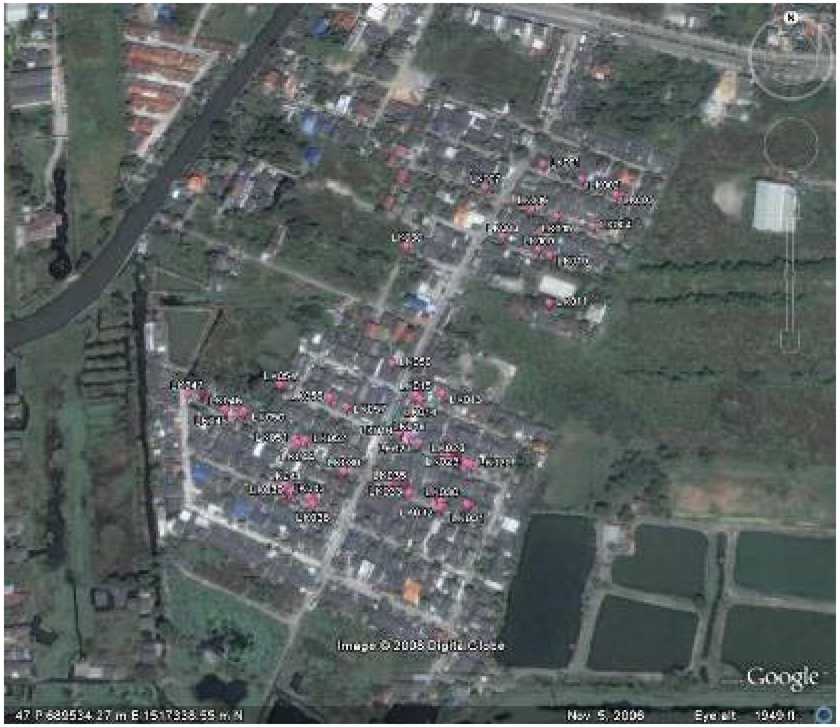
Posterior



Data $Y = y$

Field Evaluation

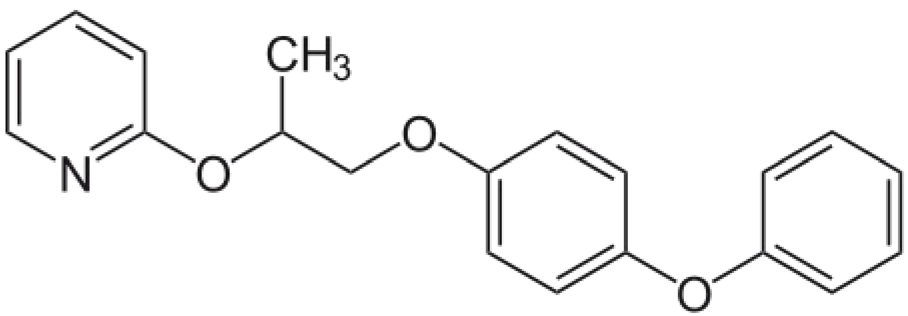
Ponlawat A., Fansiri T., Kurusarttra S., Pongsiri A., McCardle P.W., Evans B.P. and Richardson J.H. 2013. *Development and evaluation of a pyriproxyfen-treated device to control the dengue vector, Aedes aegypti (L.)(Diptera: Culicidae).* Southeast Asian J. Trop. Med. Public Health. 44:167-178.



Pyriproxyfen

Pyriproxyfen (4-phenoxyphenyl (RS)-2-(2-pyridyloxy) propyl ether)

- **A juvenile hormone mimic**
- **Affects the physiology of morphogenesis, reproduction and embryogenesis of arthropods**

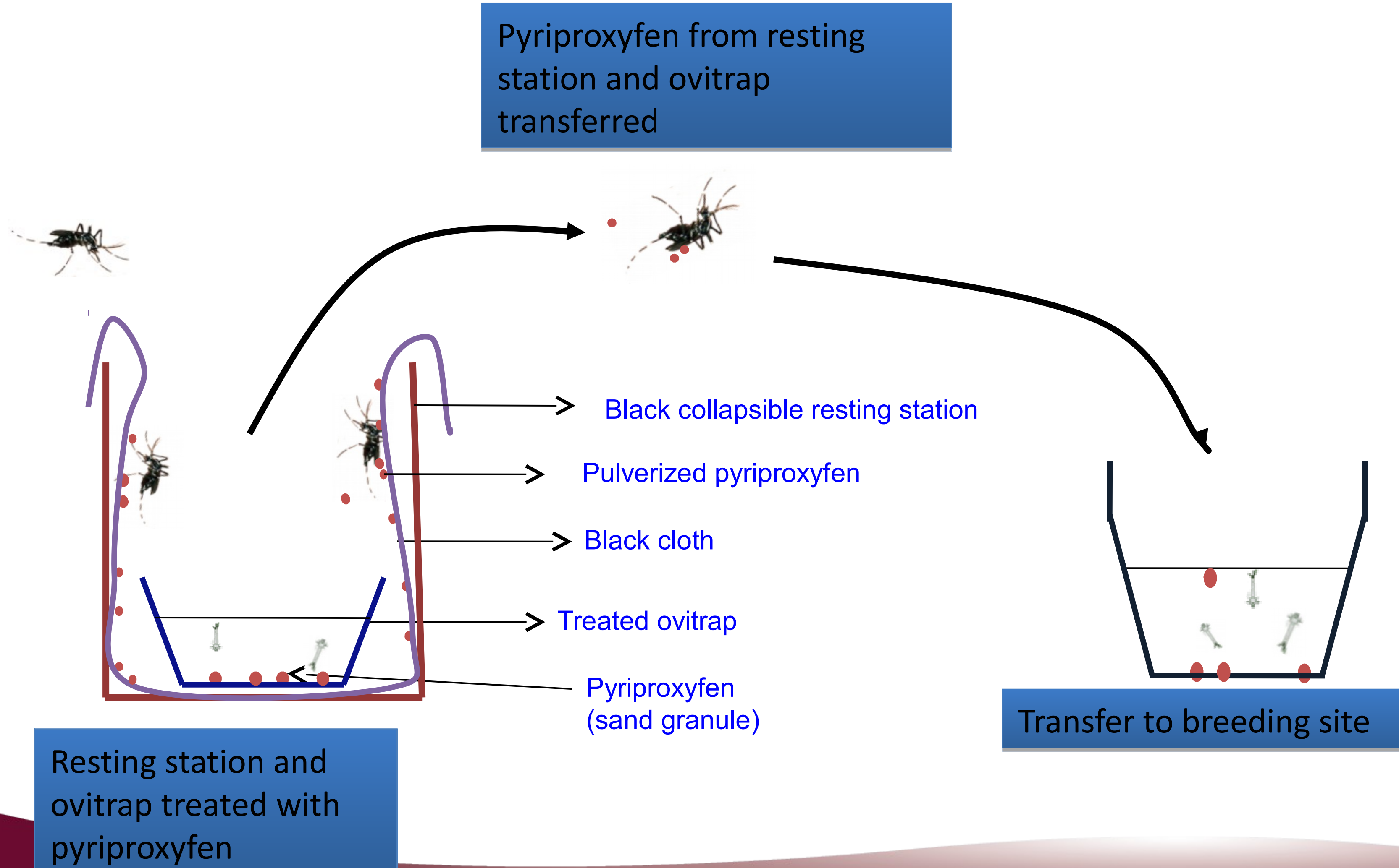


Pyriproxyfen 0.5% Granule (w/w)

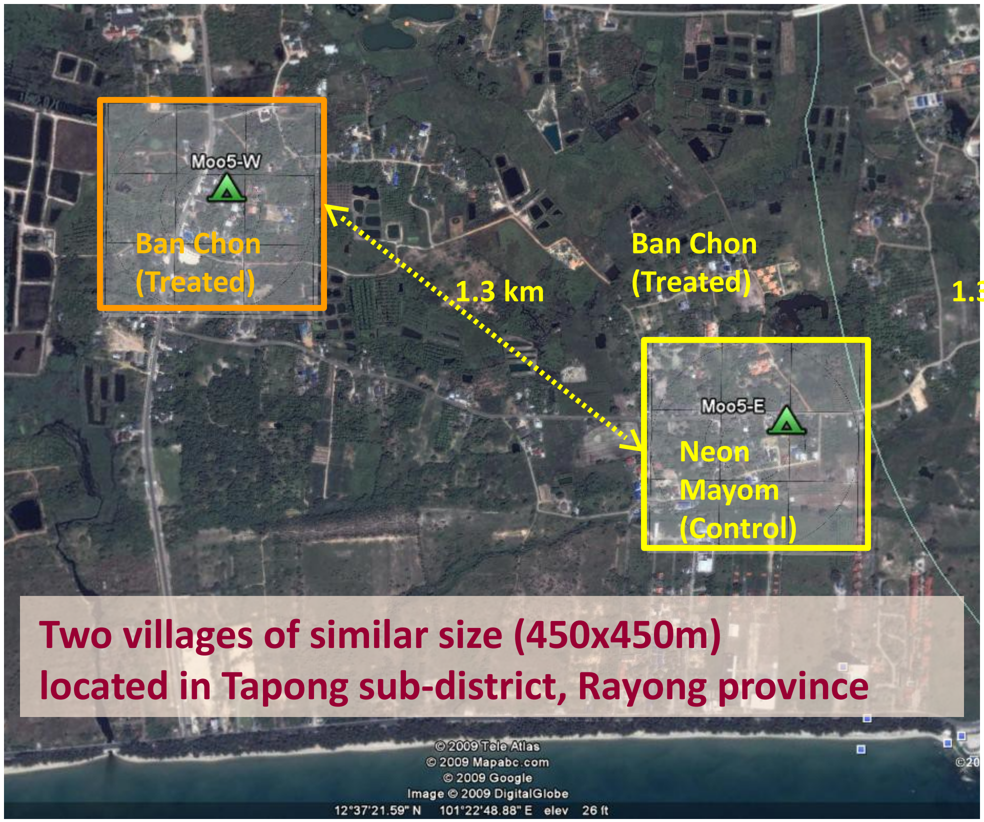
pupae not emerged

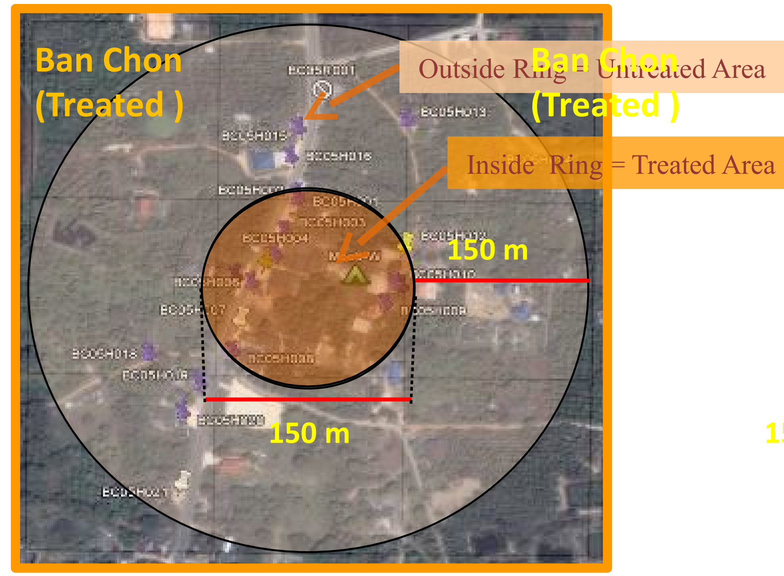
adult not fully eclosed

Pyriproxyfen Transfer



Study Area


Moo5-W
Ban Chon
(Treated)
1.3 km
Ban Chon
(Treated)
1.3 km
Moo5-E
Neon
Mayom
(Control)
Two villages of similar size (450x450m)
located in Tapong sub-district, Rayong province
© 2009 Tele Atlas
© 2009 Mapabc.com
© 2009 Google
Image © 2009 DigitalGlobe
12°37'21.59" N 101°22'48.88" E elev 26 ft


Ban Chon
(Treated)
Outside Ring = Untreated Area
Ban Chon
(Treated)
Inside Ring = Treated Area
150 m
150 m

Between Neon Mayom & Ban Chon

- **Process Model:**

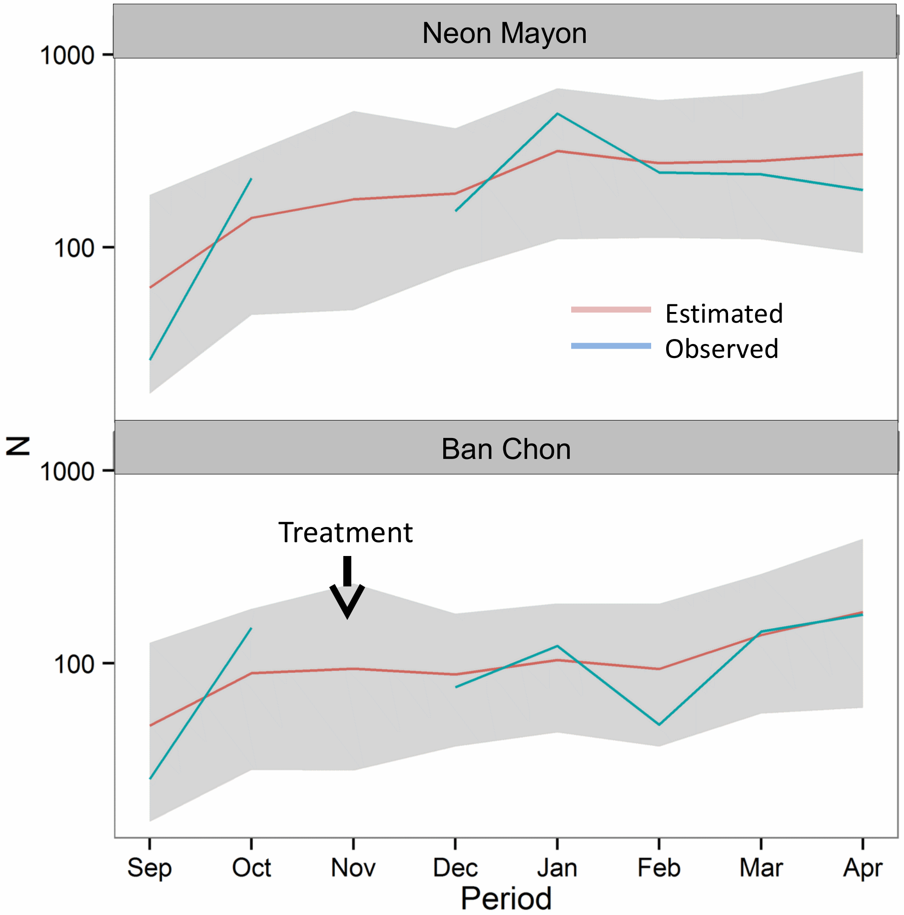
$$\log(N_{t+1}) = \log(N_t) + r_t$$

$$r_t \sim N(\bar{r}, \sigma_r^2)$$

- **Observation Model:**

$$y_t = \log(N_t) + \varepsilon_t$$

$$\varepsilon_t \sim N(0, \sigma_y^2)$$



Between Neon Mayom & Ban Chon

- **Process Model:**

$$\log\left(N_{t+1}\right) = \log\left(N_t\right) + r_t$$

$$r_t \sim N\left(\overline{r}, \sigma_r^2\right)$$

- **Observation Model:**

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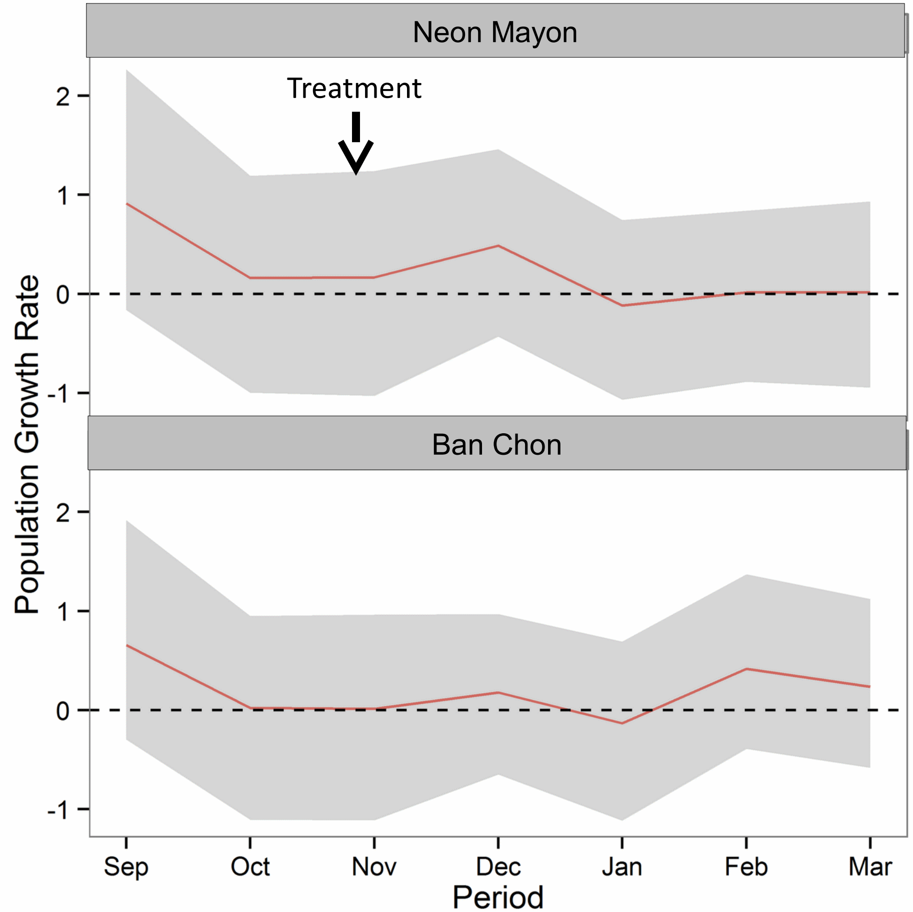

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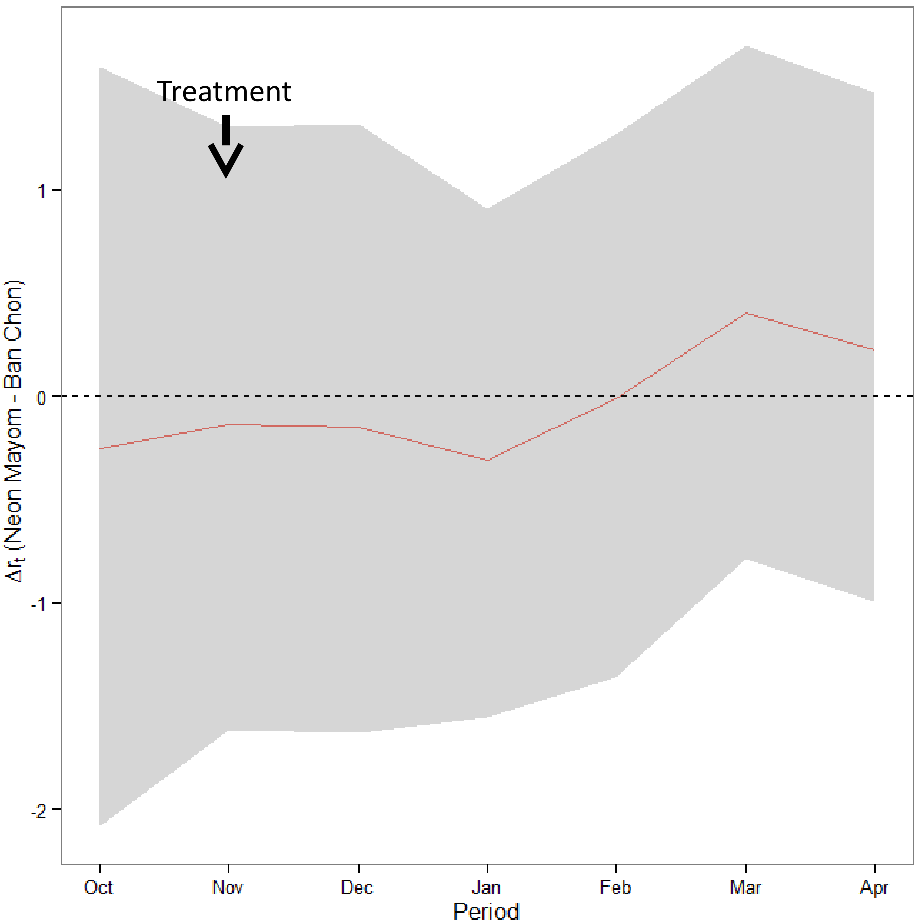


Within Ban Chon

- Process Model:

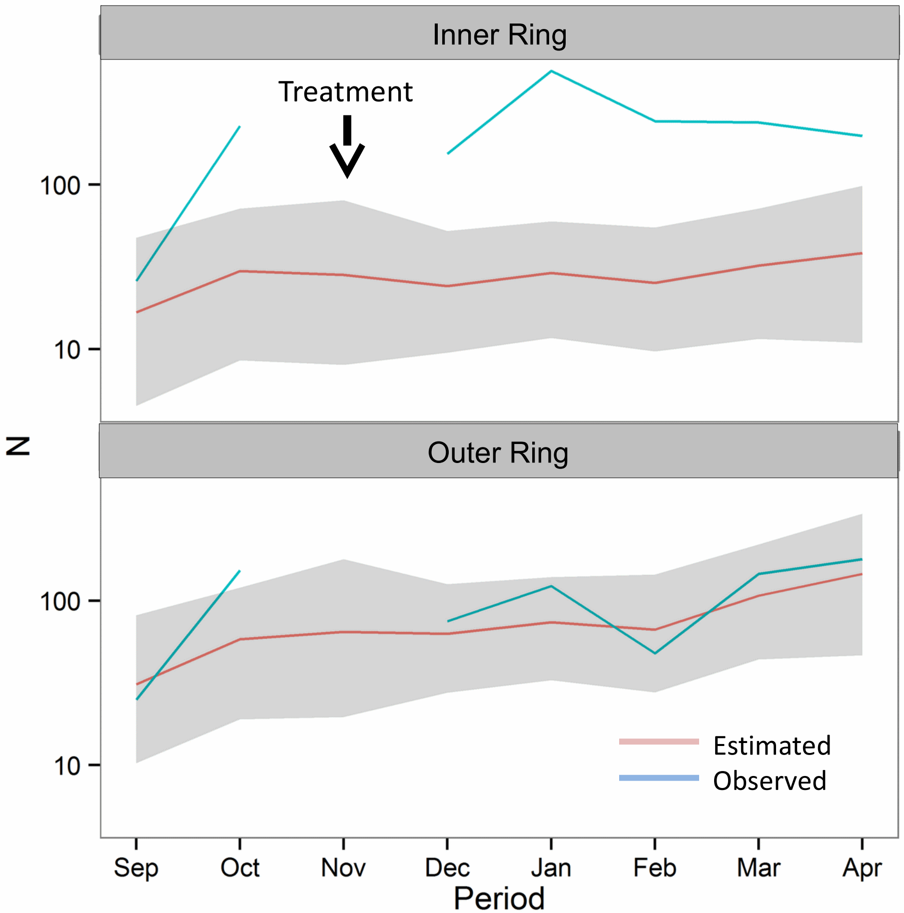
$$\log\left(N_{t+1}\right) = \log\left(N_t\right) + r_t$$

$$r_t \sim N\left(\bar{r}, \sigma_r^2\right)$$

- Observation Model:

$$y_t = \log\left(N_t\right) + \varepsilon_t$$

$$\varepsilon_t \sim N\left(0, \sigma_y^2\right)$$



Within Ban Chon

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$$\log\left(N_{t+1}\right) = \log\left(N_t\right) + r_t$$

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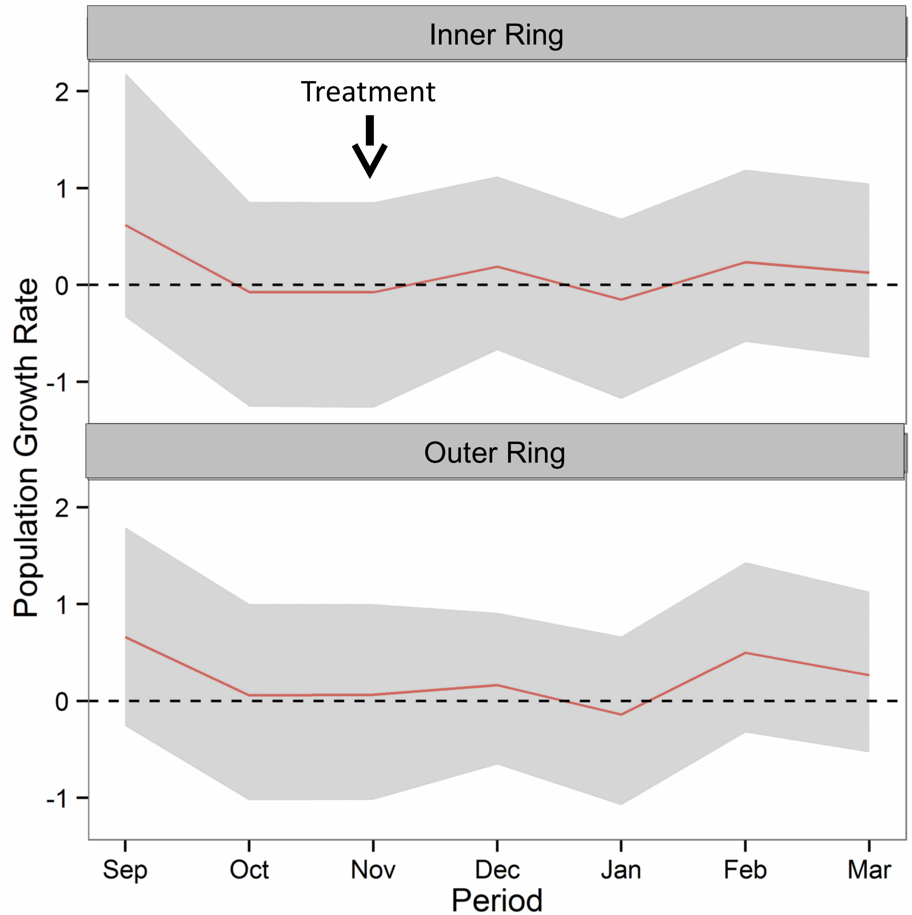

Within Ban Chon

- Process Model:

$$\log\left(N_{t+1}\right) = \log\left(N_t\right) + r_t$$

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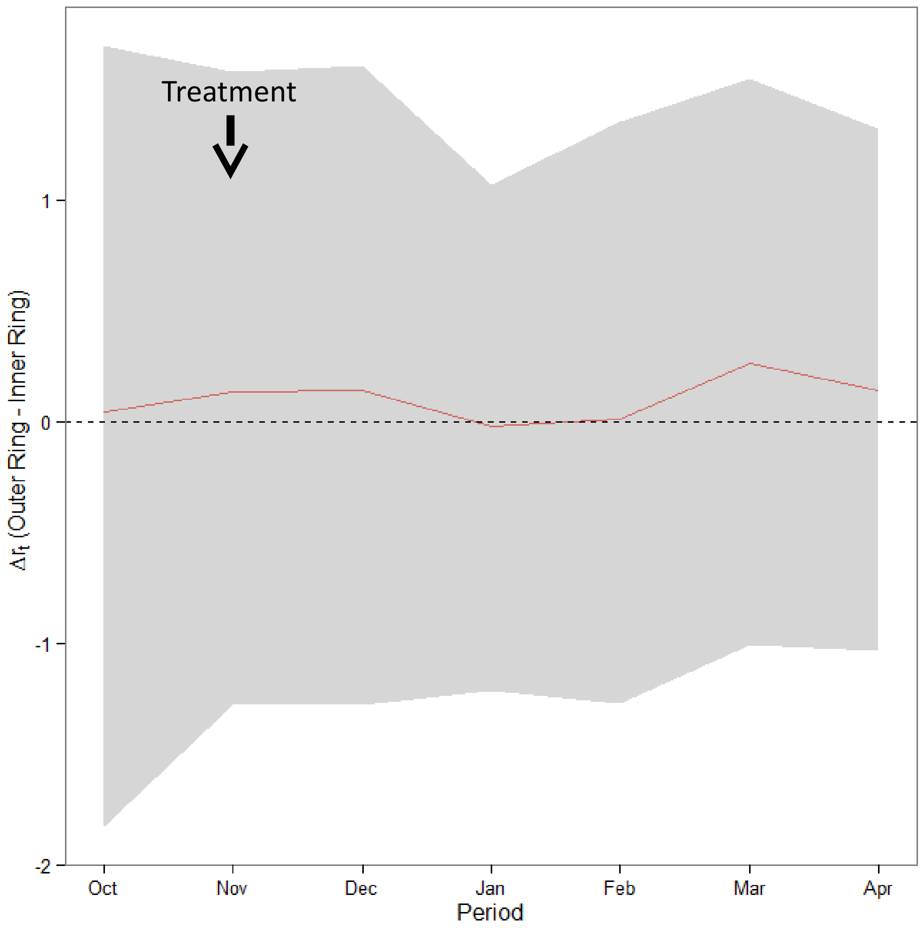
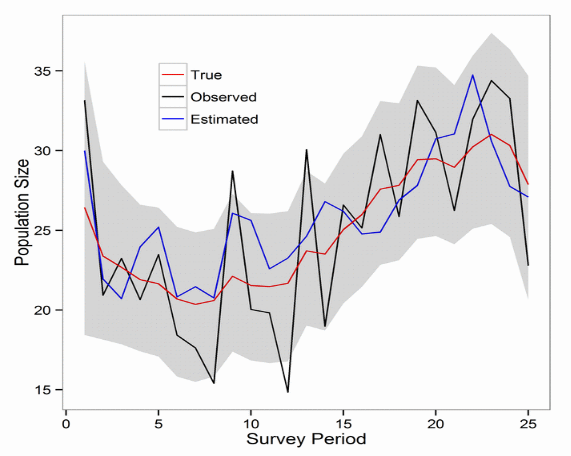
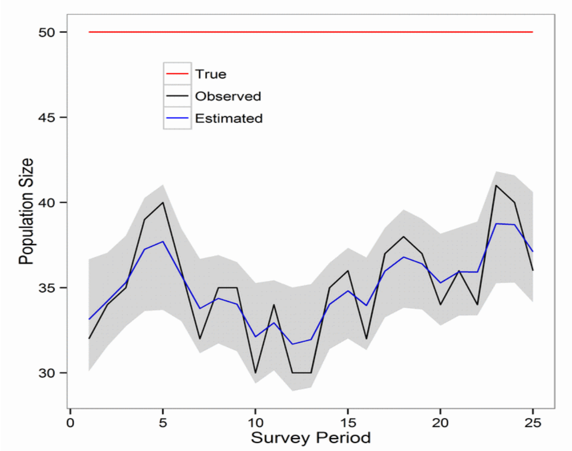
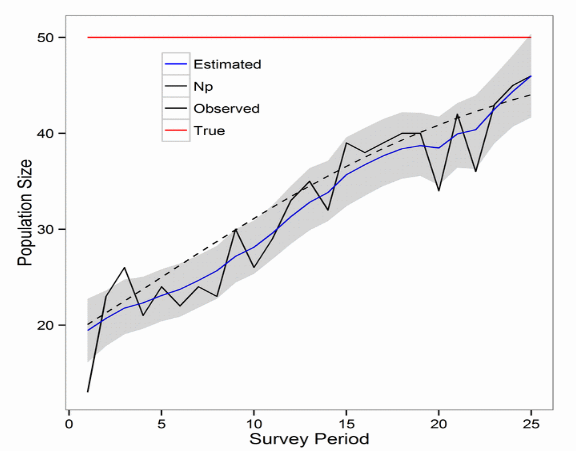


Assumption


True
Observed
Estimated
Population Size
Survey Period
35
30
25
20
15
0
5
10
15
20
25


True
Observed
Estimated
Population Size
Survey Period
50
45
40
35
30
0
5
10
15
20
25


Estimated
Np
Observed
True
Population Size
Survey Period
50
40
30
20
0
5
10
15
20
25

Models in Science

- There has never been a straight line nor a Normal distribution in history, and yet, using assumptions of linearity and normality allows, to a good approximation, to understand and predict a huge number of observations.

William J. Youden

Literature Cited

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