Using Gaussian Process Models to Fit an Enhanced Particle Tracking Model to Acoustic Telemetry Data of Juvenile Salmon

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Coupled physical-biological models

- Physical models
  - Spatially explicit 1D – 3D hydrodynamics
- Biological models
  - Add “fishy” behaviors to neutrally buoyant particles
    - E.g., swimming velocity, holding during day
- Conduct simulation experiments
  - Water management actions
  - Patterns from fish behaviors and hydrodynamics

How Do We Determine Values of Behavioral Parameters?

- Theory
  - Hypotheses about fish behavior

- Trial and Error
  - “Pattern matching” to observed data

- Problems:
  - No uncertainty in parameter estimates
  - Somewhat subjective

Goals

- Develop methods to fit models to observed data
- Methods should be general
  - Applicable to any model
- Provide parameter estimates + uncertainty
- Allow assessment of different model structures

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Challenges

- Models are computationally burdensome
  - Traditional optimization routines take too long
- Models are stochastic
  - Direct search methods won’t work
  - Traditional stochastic methods take too long
- Two potential solutions
  - Gaussian process model + MCMC (this talk)
  - Particle Swarm Optimization (next talk)

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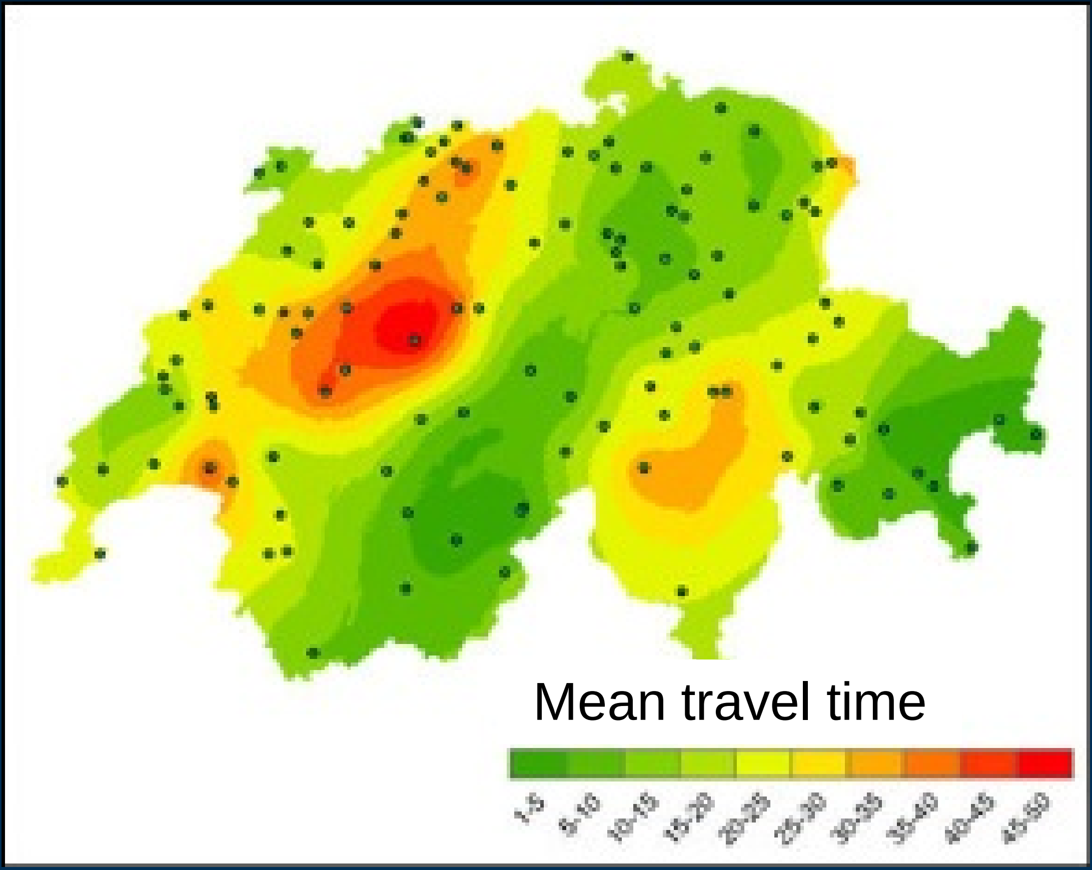
Gaussian Process Models

- Distance-weighted interpolation
- Uses multivariate normal distribution
  - e.g., Kriging

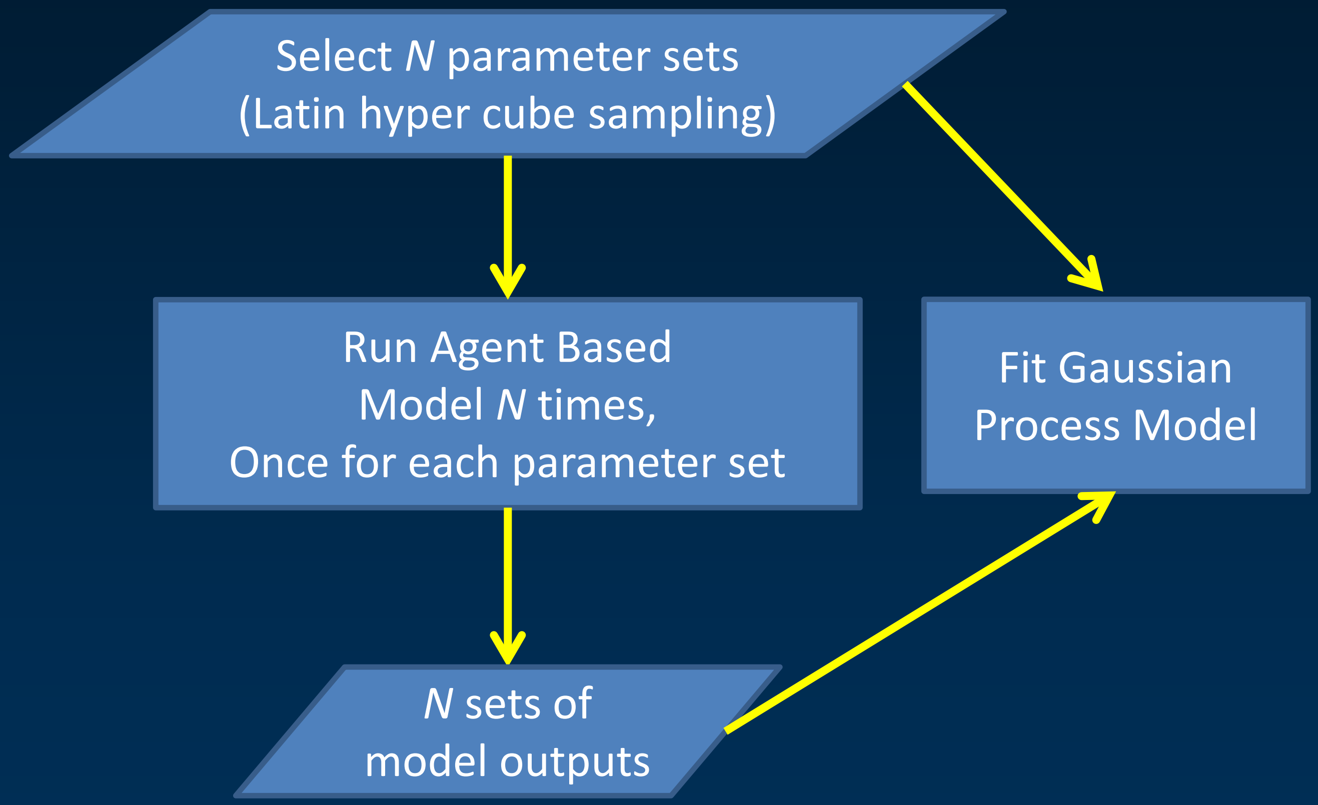
Probability of day-time migration



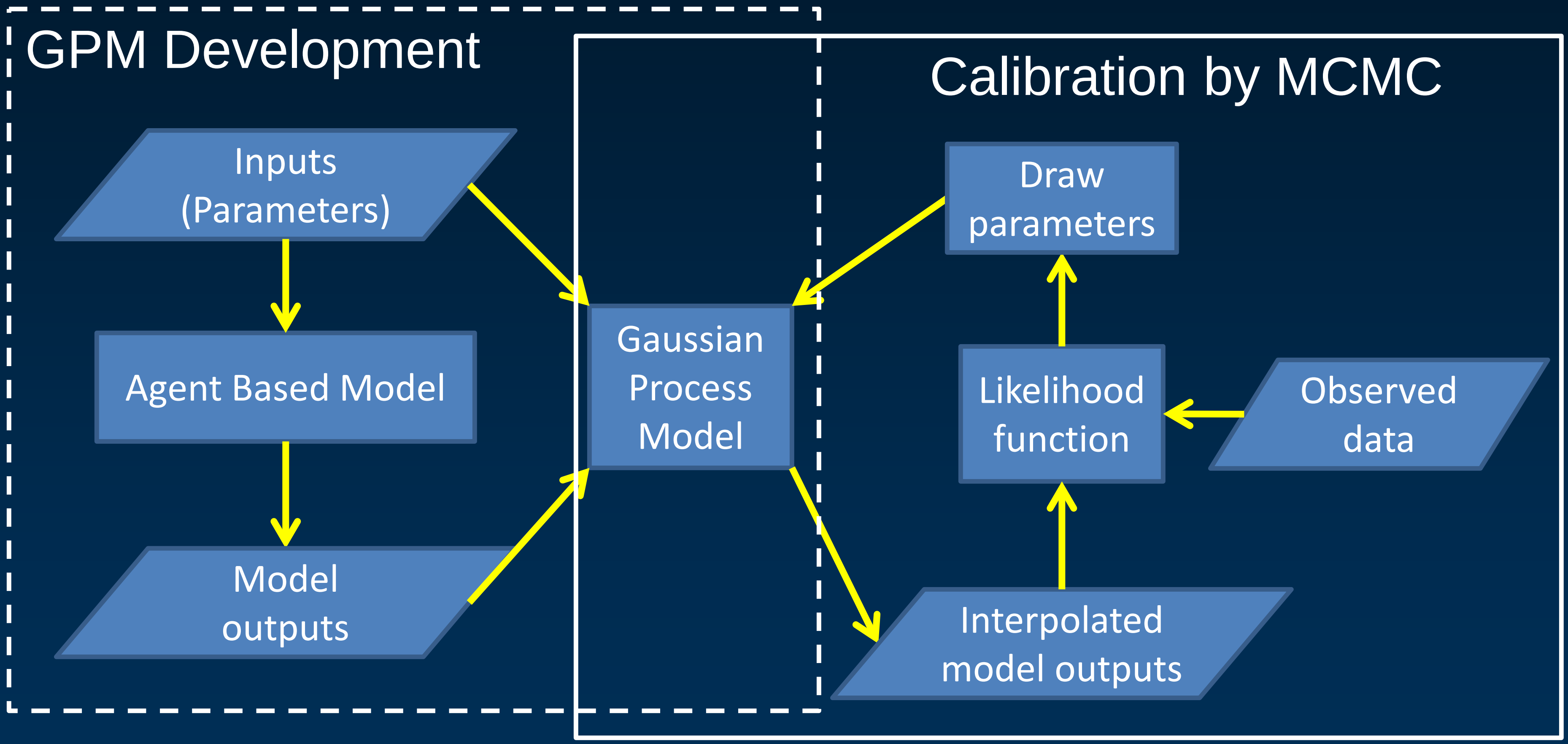
Swimming Velocity

Source: http://www.gitta.info/ContiSpatVar/en/image/kriging.jpg

Developing Gaussian Process Models (GPM)



Calibration using Gaussian Process Models (GPM)



Application to DSM2-ePTM

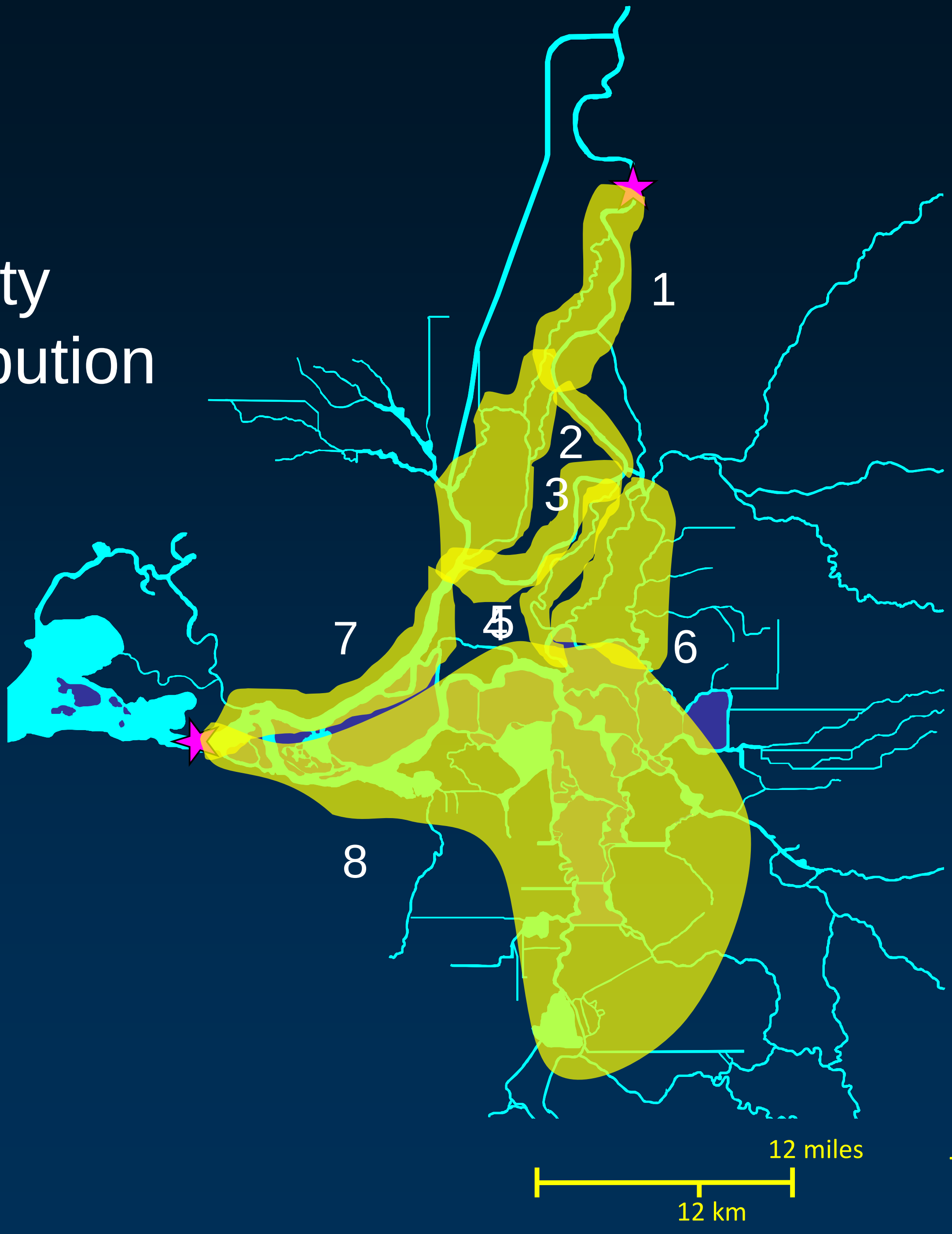
- 7 parameters (per reach)
- Swimming behaviors
  - Swimming velocity (mean + SD)
  - Daytime holding probability
  - Velocity holding threshold
    - Selective tidal stream transport
  - Probability of mis-assessing downstream direction
    - Function of mean velocity relative to SD velocity
- XT Survival model (Anderson et al. 2005)
  - λ, mean distance between predator-prey encounters
  - ω, random encounter velocity

Acoustic Telemetry Data

- USFWS (Delta Action 8 study)
- Late-fall Chinook salmon
- Vemco acoustic telemetry
- 1,583 Acoustic tagged fish
- 4 Years (2007 – 2010)
- 8 unique release groups
- 9 reaches
- Migrated between December and February

Reaches

For each reach:
- Survival probability
- Travel time distribution



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Gaussian Process Model

- 2000 parameter sets
  - – Run for each reach and release
  - – 144,000 ePTM model runs!
    - Ran in parallel on Amazon cloud

- Model outputs for each reach and release
  - – Survival probability
  - – Proportion of fish in 20 travel time bins
  - – Flexible distribution shapes (e.g., bi-modal)

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Likelihood Function

- Multistate mark-recapture model
  - Perry et al. (2010)
  - Survival, detection, routing
- Multinomial distribution for travel times
  - Proportion of fish in 20 travel time bins
  - Observed number in each bin

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Compare Two Fitted Models

- “Simple” Model
  - Daytime swim probability and Hold Threshold
    - Turned Off
  - All other parameters set equal among reaches
- “Complex” Model
  - Hold threshold turned off
  - Daytime swim probability and ω
    - Different for riverine, transitional, and tidal reaches
  - Probability of mis-assessing direction
  - All other parameters reach-specific
- Compare using WAIC

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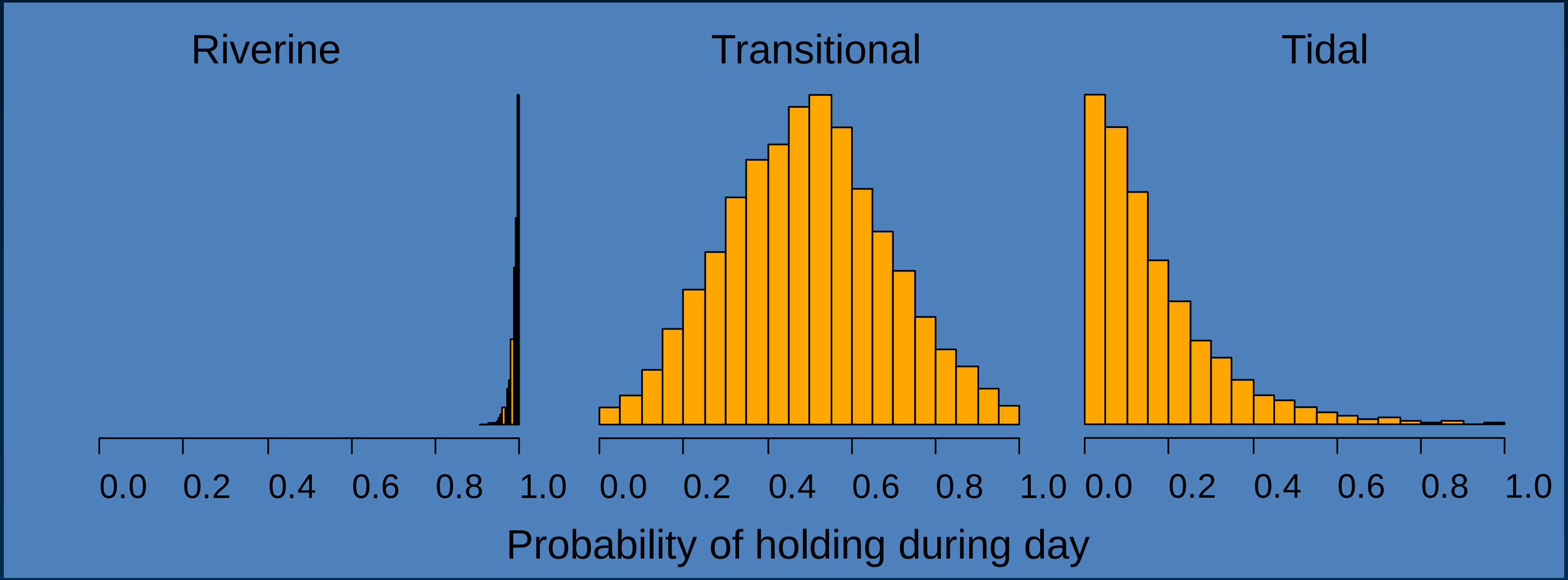
Model Selection

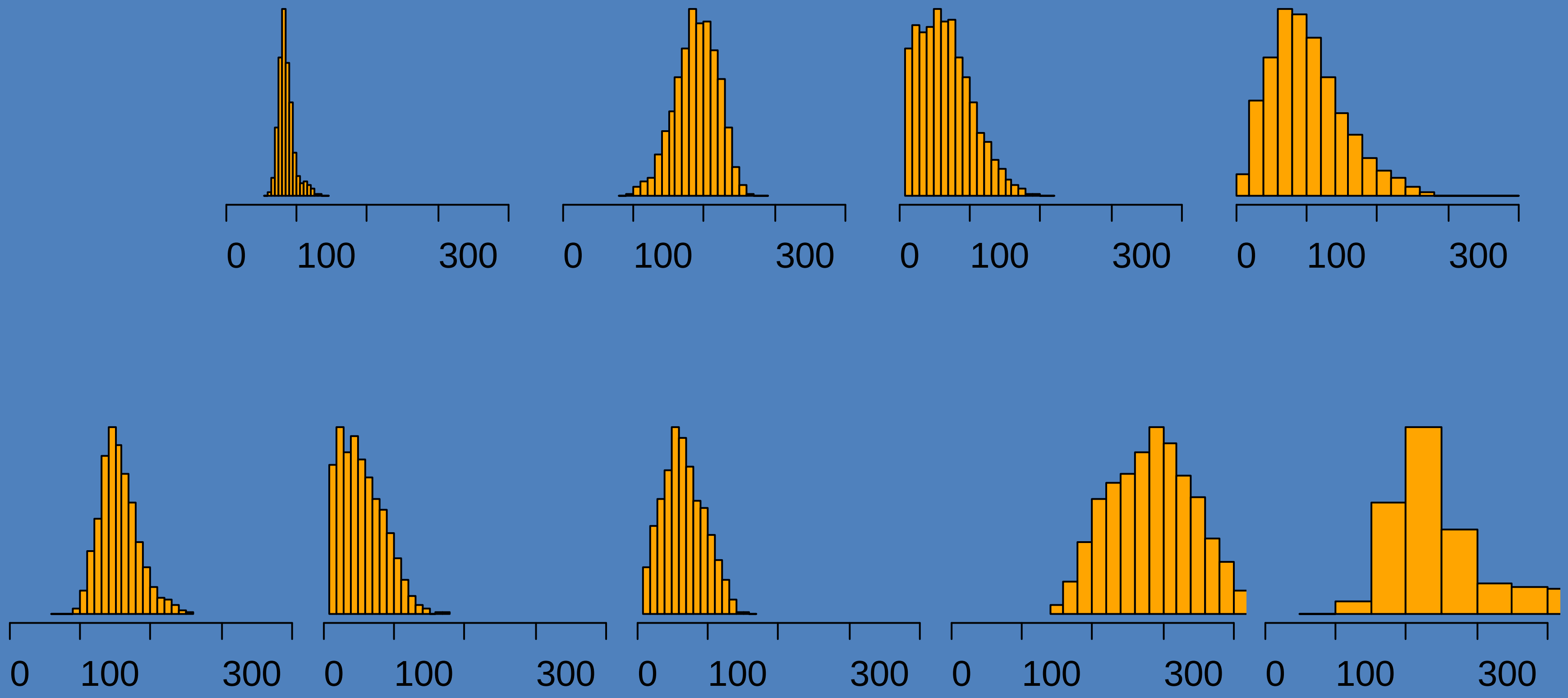
- “Simple” Model
  - 5 parameters
  - WAIC = 505,988
- “Complex” Model
  - 34 parameters
  - WAIC = 423,856
- Difference of 82,131
- Complex model is better fit

Posterior Distributions



Posterior Distributions

λ, Mean distance (km) between predator-prey encounters
Median λ: 52 – 287 km



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Conclusions

- Advantages
  - Fully parametric
  - Posterior distributions of parameters
  - Full accounting of uncertainty due to:
    - PTM stochasticity
    - Error due to GPM interpolation of PTM
    - Sampling uncertainty in observed data

- Disadvantages
  - Many steps in process
  - Not “off the shelf”
  - Not using PTM directly