DSM2 PTM, an Open Source Platform for Delta Fish Migration Behavior Research and Model Development

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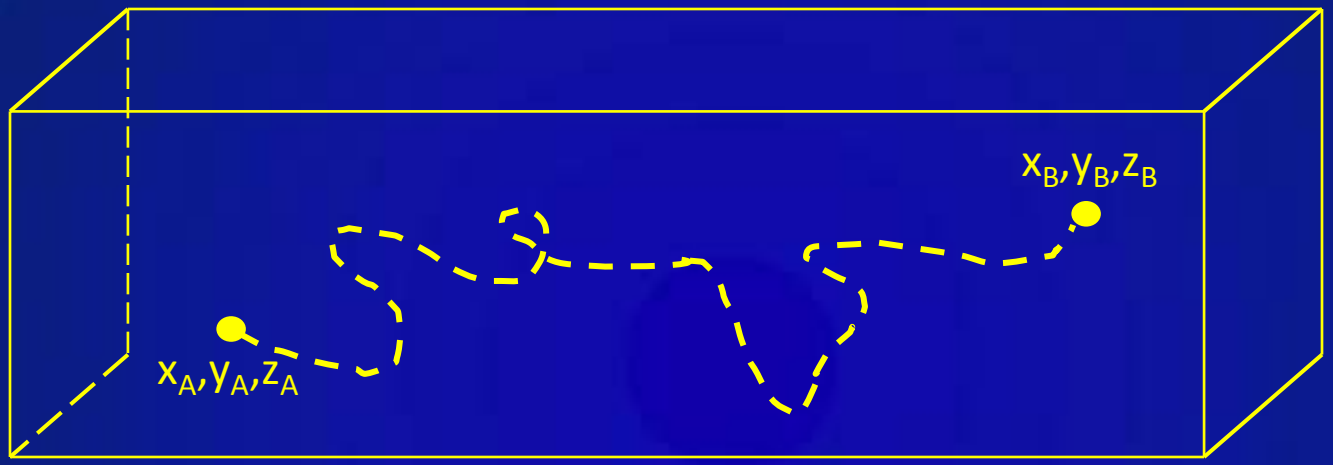
Goal

Develop a fish migration model to:

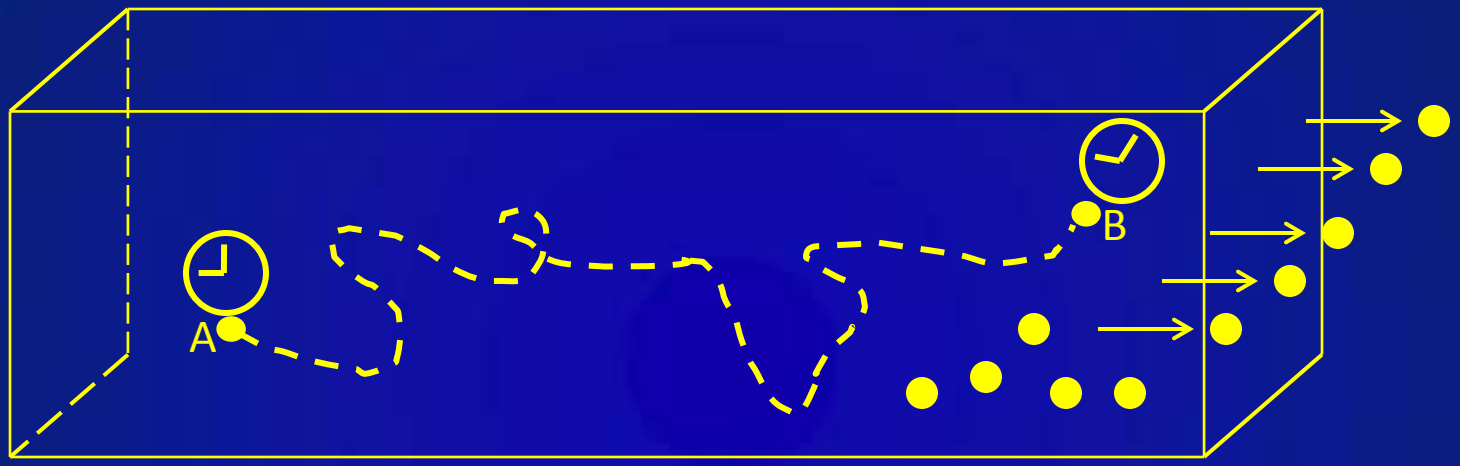
- Identify environmental factors that affect fish behaviors and survival
- Evaluate ecological impacts
- Assist management decision-making
- Guide field monitoring programs

Current PTM Features



- Tracking particle positions in 3D space
- Time step determined by user and flow Conditions
- Built-in random walk components

Current PTM Output



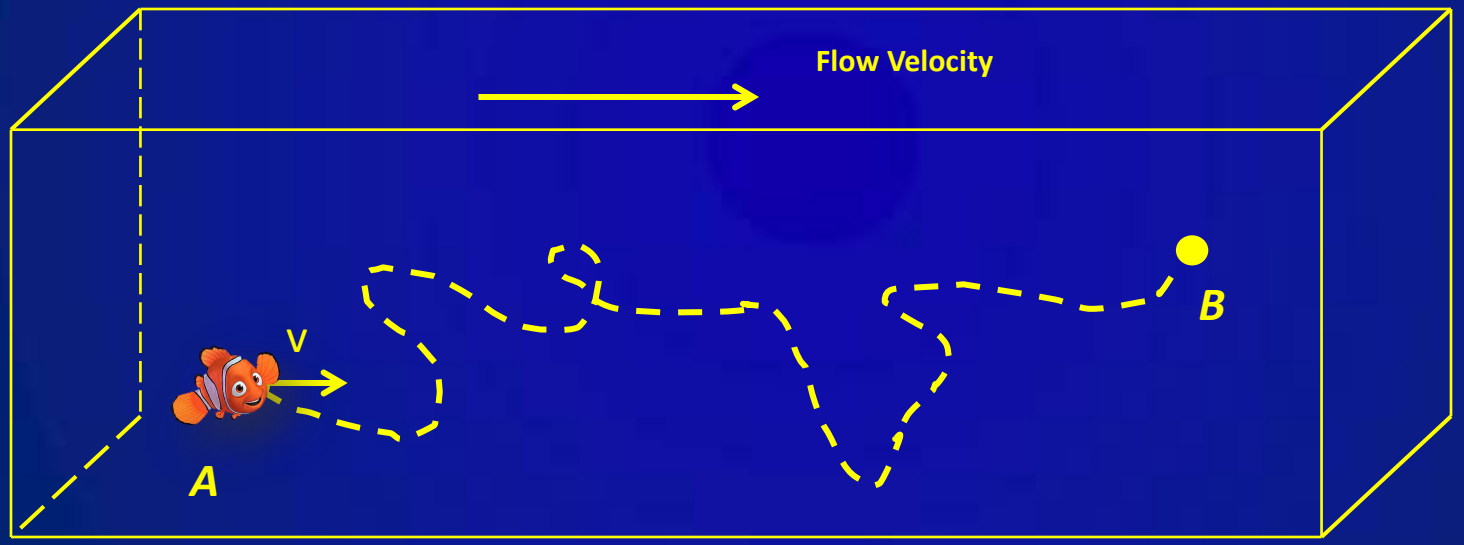
- Individual particle travel time from A to B
- Particle flux: # of particles passing specified location
- Particle concentration: # of particles in specified area

Neutral Buoyant Particle = Fish ?

- Move passively with flow, no active swimming velocity
- Make route choice based on flow split
- Always stay alive

Add Swimming Behavior

Fish movement velocity = flow velocity +
constant swimming velocity (v)



Estimate Constant Swimming Velocity

- Obtain observed fish travel time data from acoustic telemetry fish studies
- Run PTM simulations to generate simulated travel times
- Maximize likelihood function to estimate the velocity

Obtain Observed Fish Travel Times

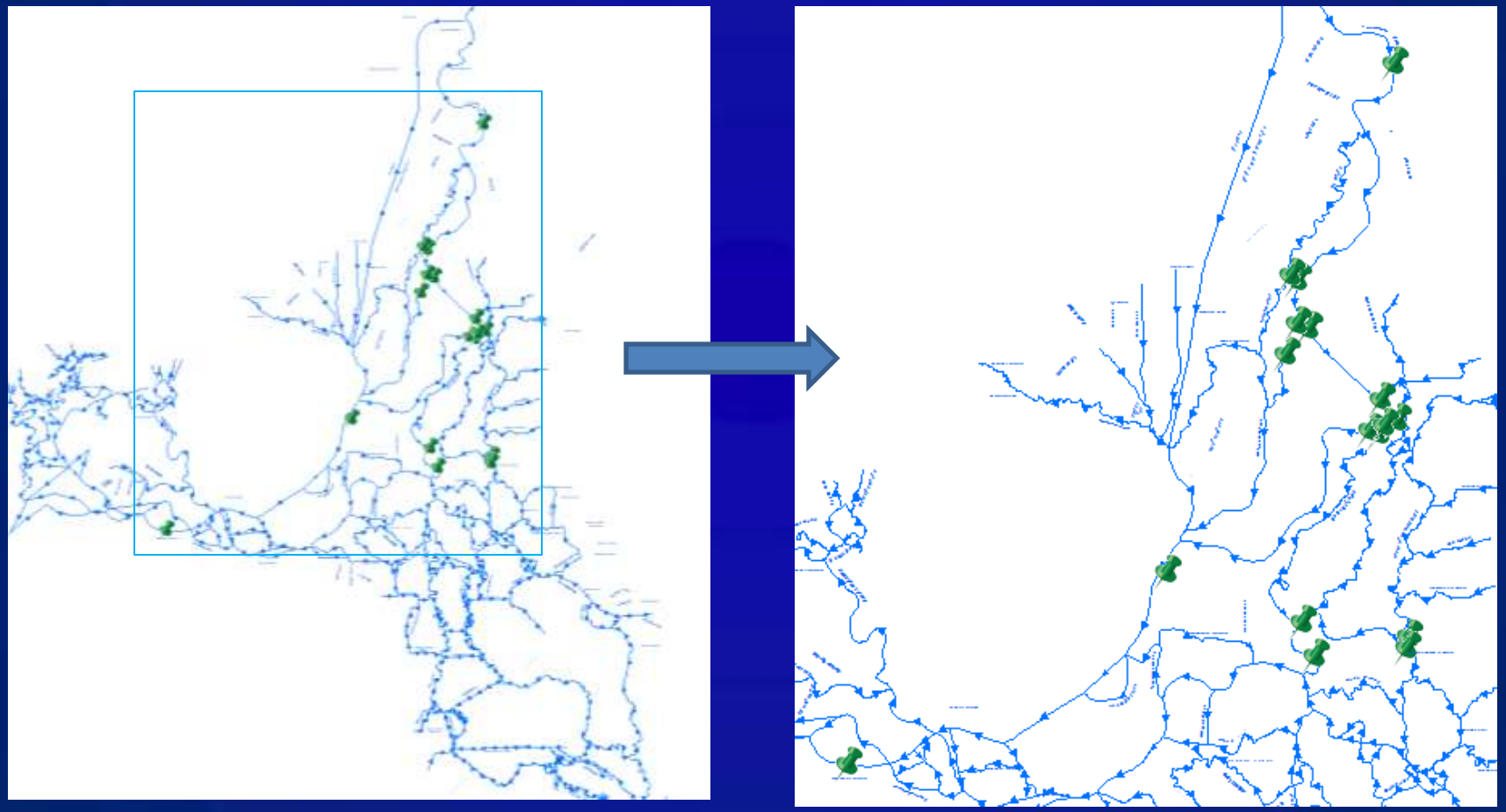
Studies

Acoustic telemetry fish studies:

- Collected by USFWS
- Late-fall Chinook from Coleman NFH
- Tagged and released in DEC – JAN 2007-2010
- Total sample size: 1147

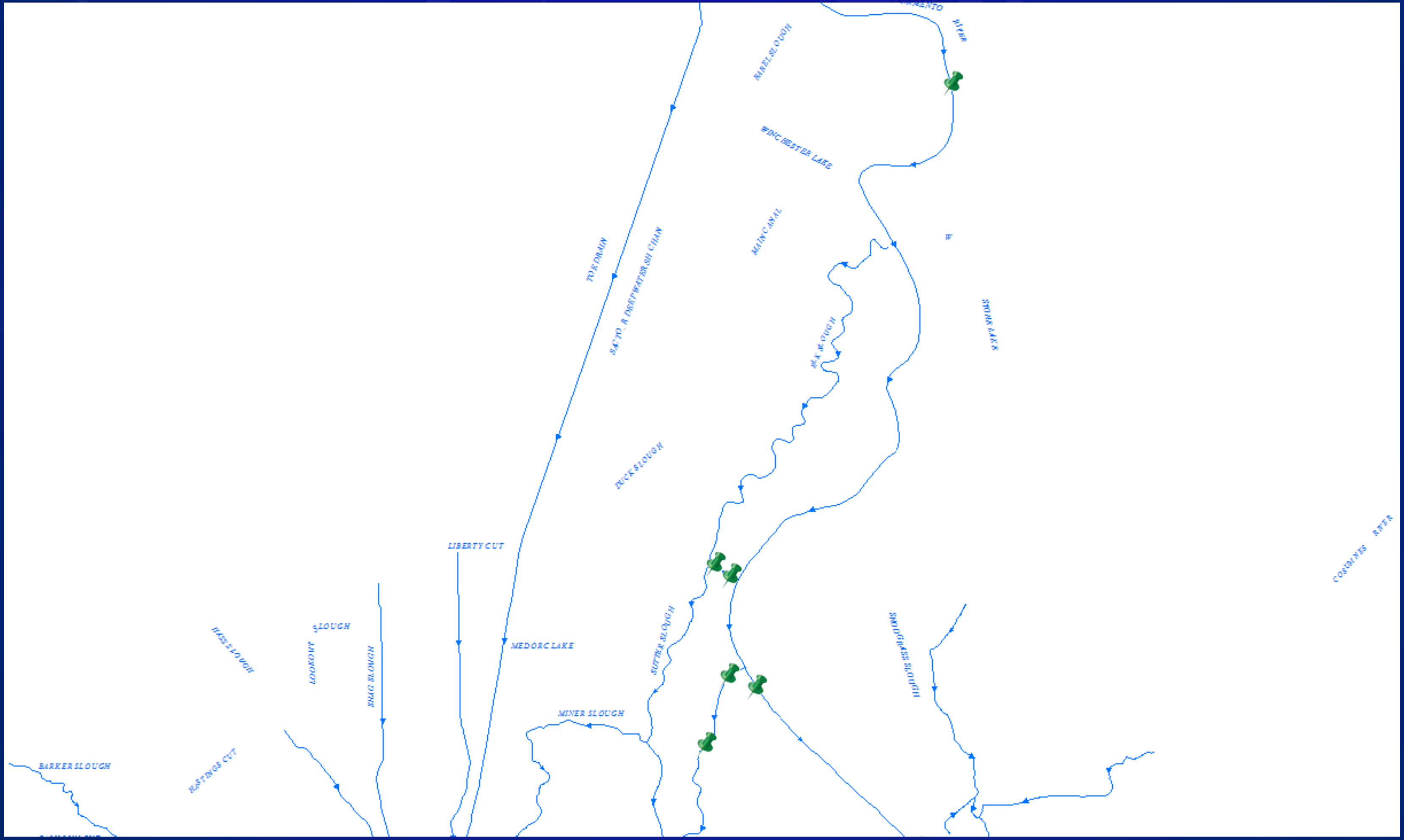
Obtain Observed Fish Travel Times

Detection Stations

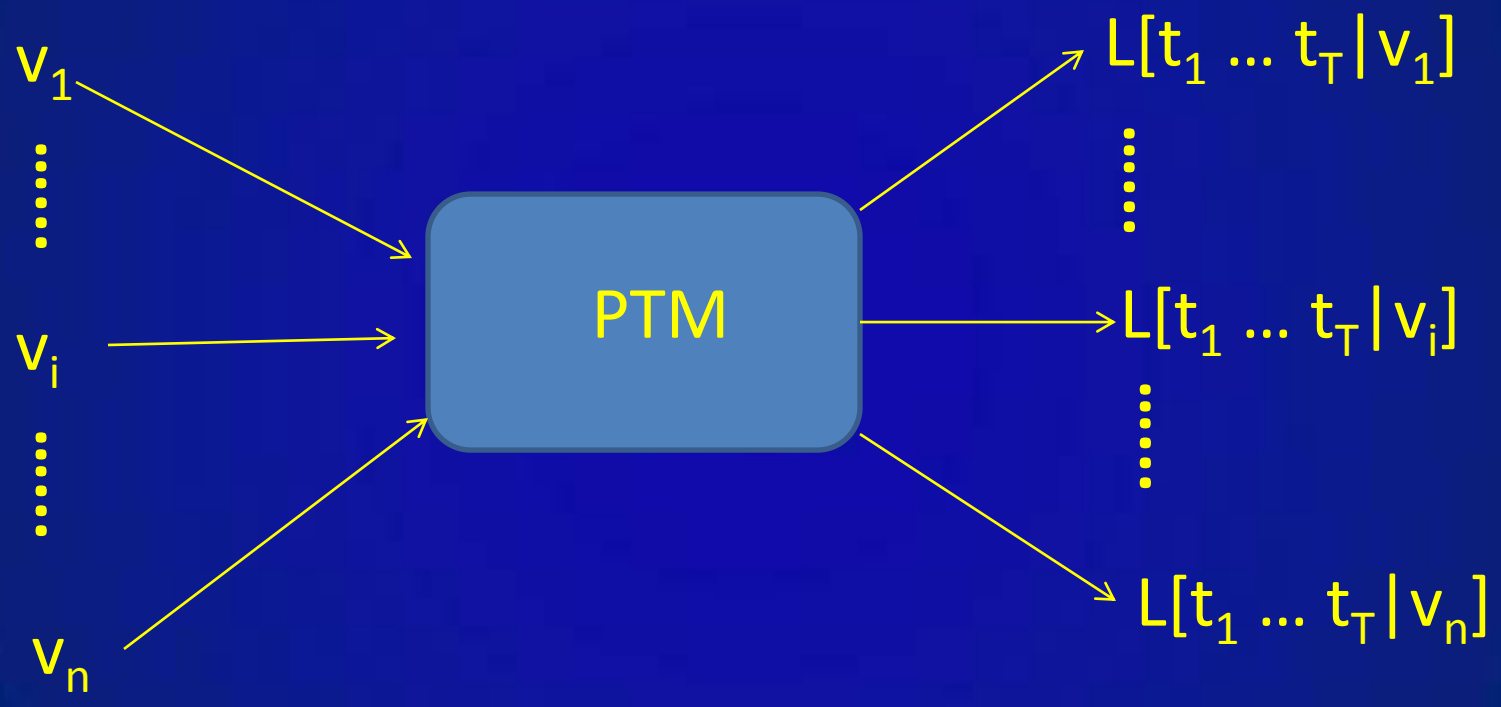


Obtain Observed Fish Travel Times

Detection Stations

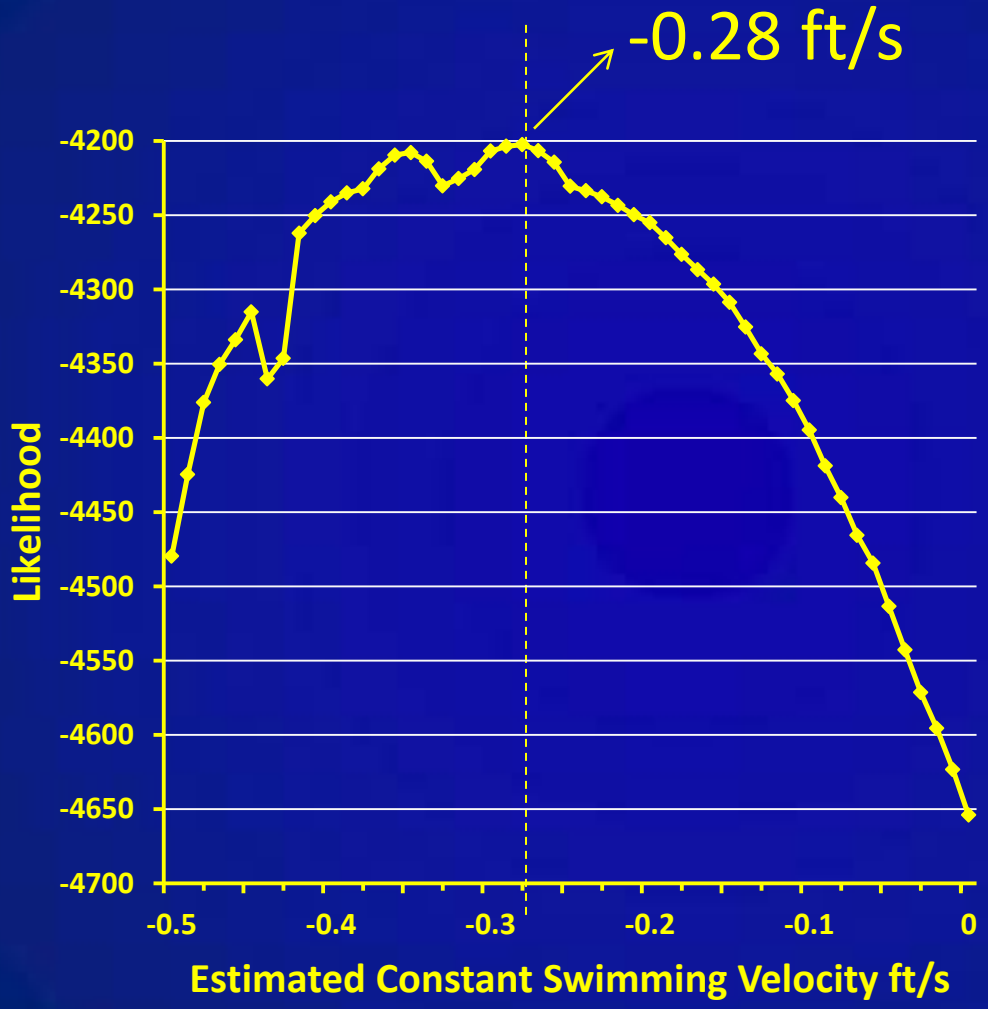


Run PTM Simulations



Observed $t_1 \ldots t_T$

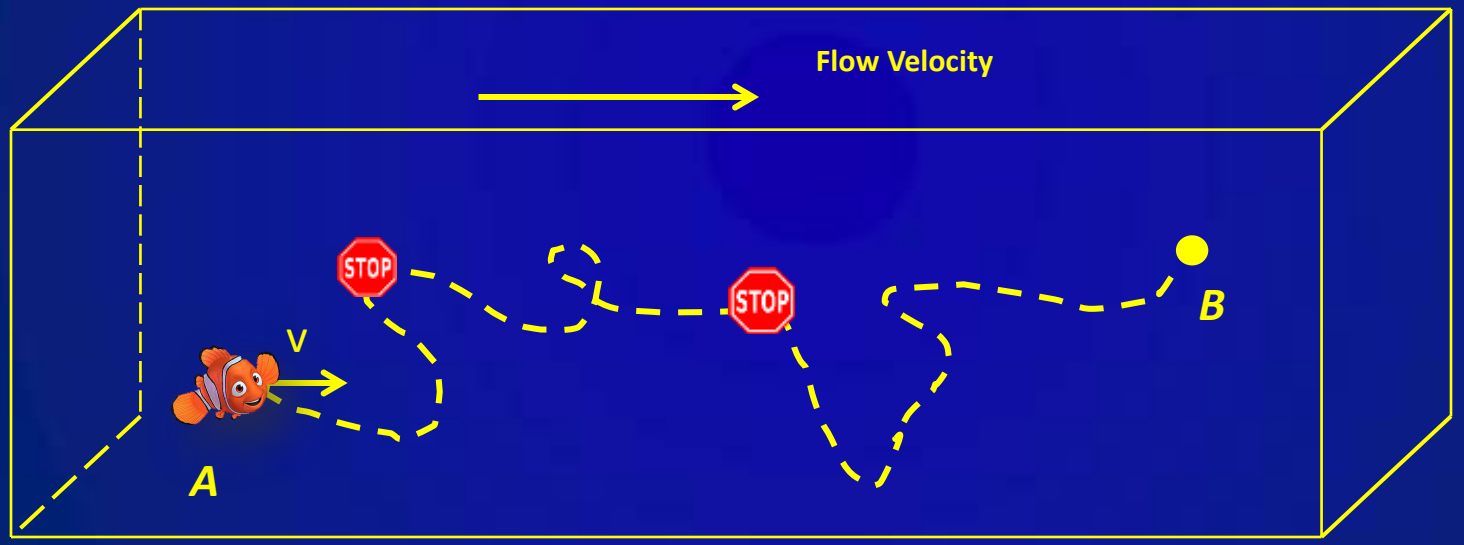
Maximize Likelihood Function



Fish hold and move slower than flow!

Fish Holding Behavior

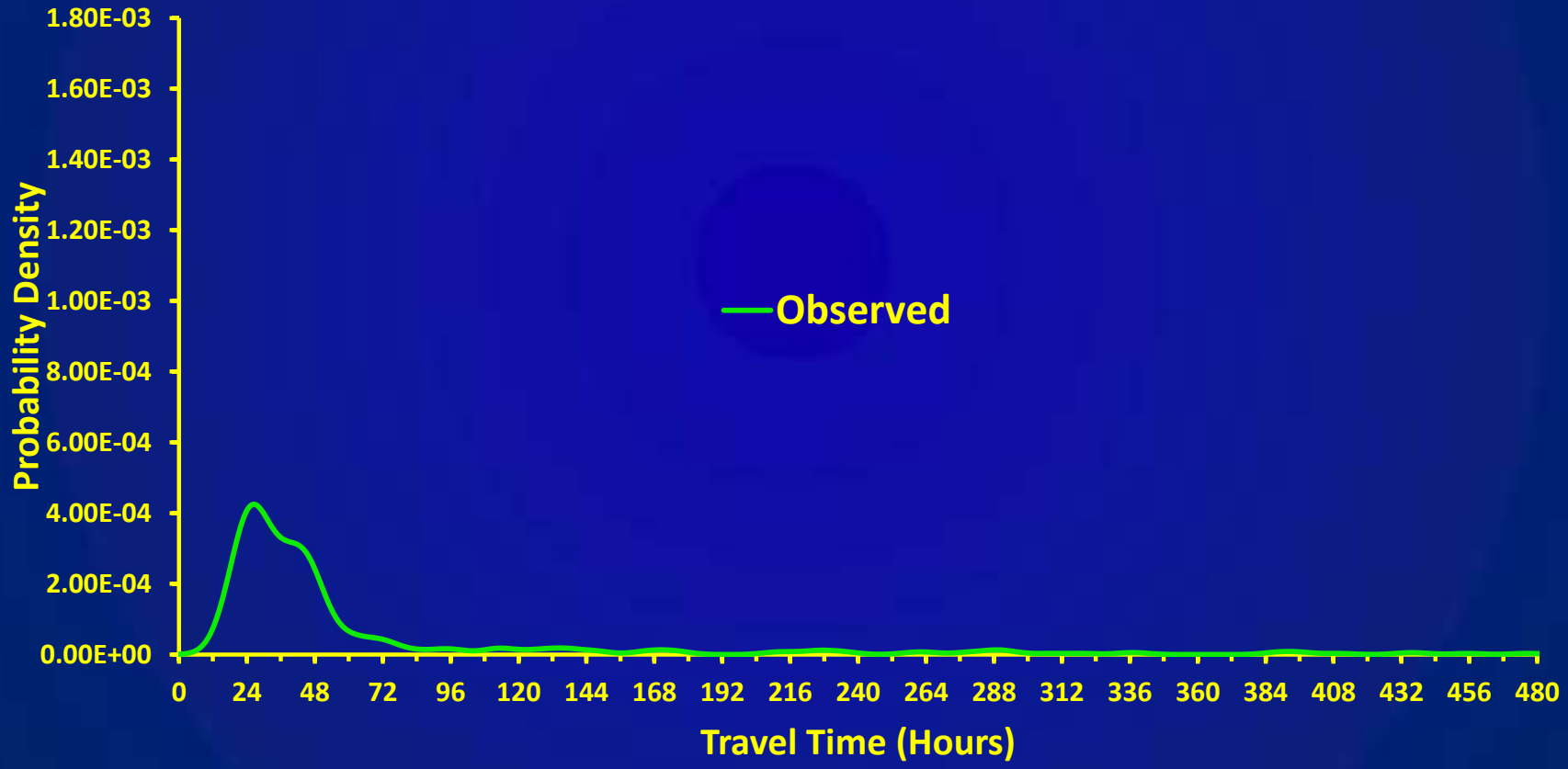
Fish movement velocity = flow velocity +
constant swimming velocity (-0.28)



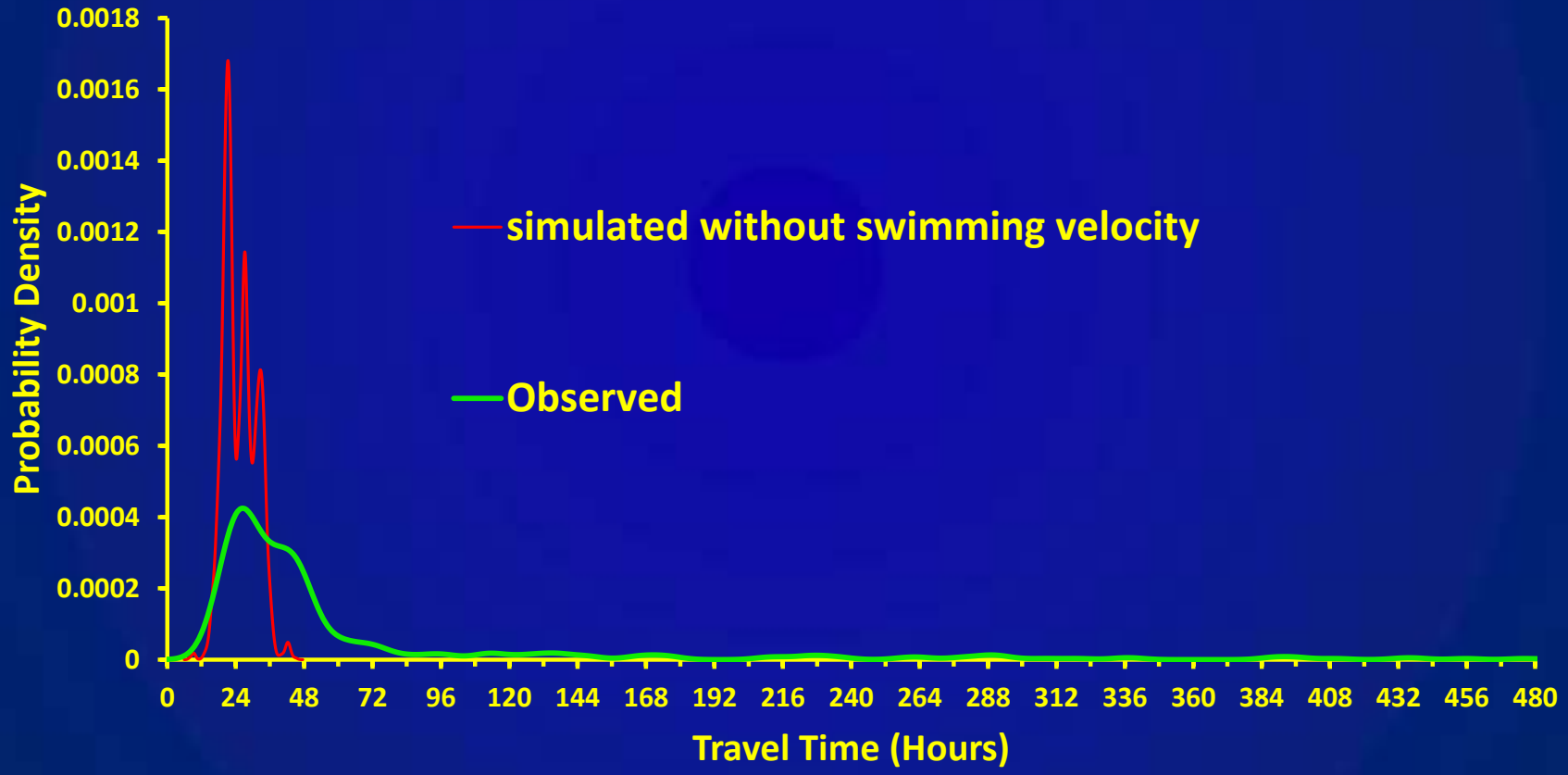
STOP Nocturnal migration, diurnal holding

STOP Selective tidal stream transport , holding during flood tides

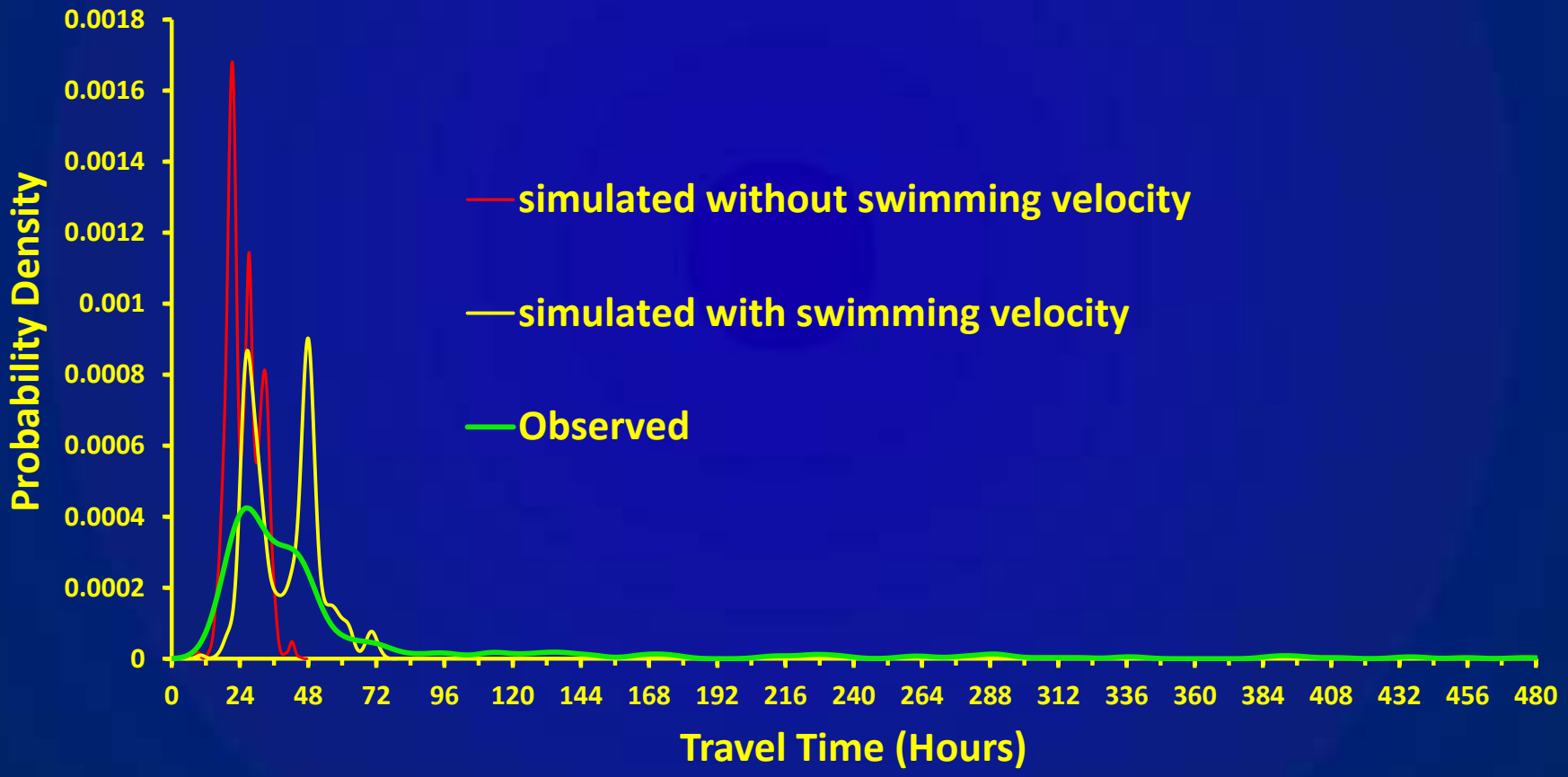
Travel Time Distribution



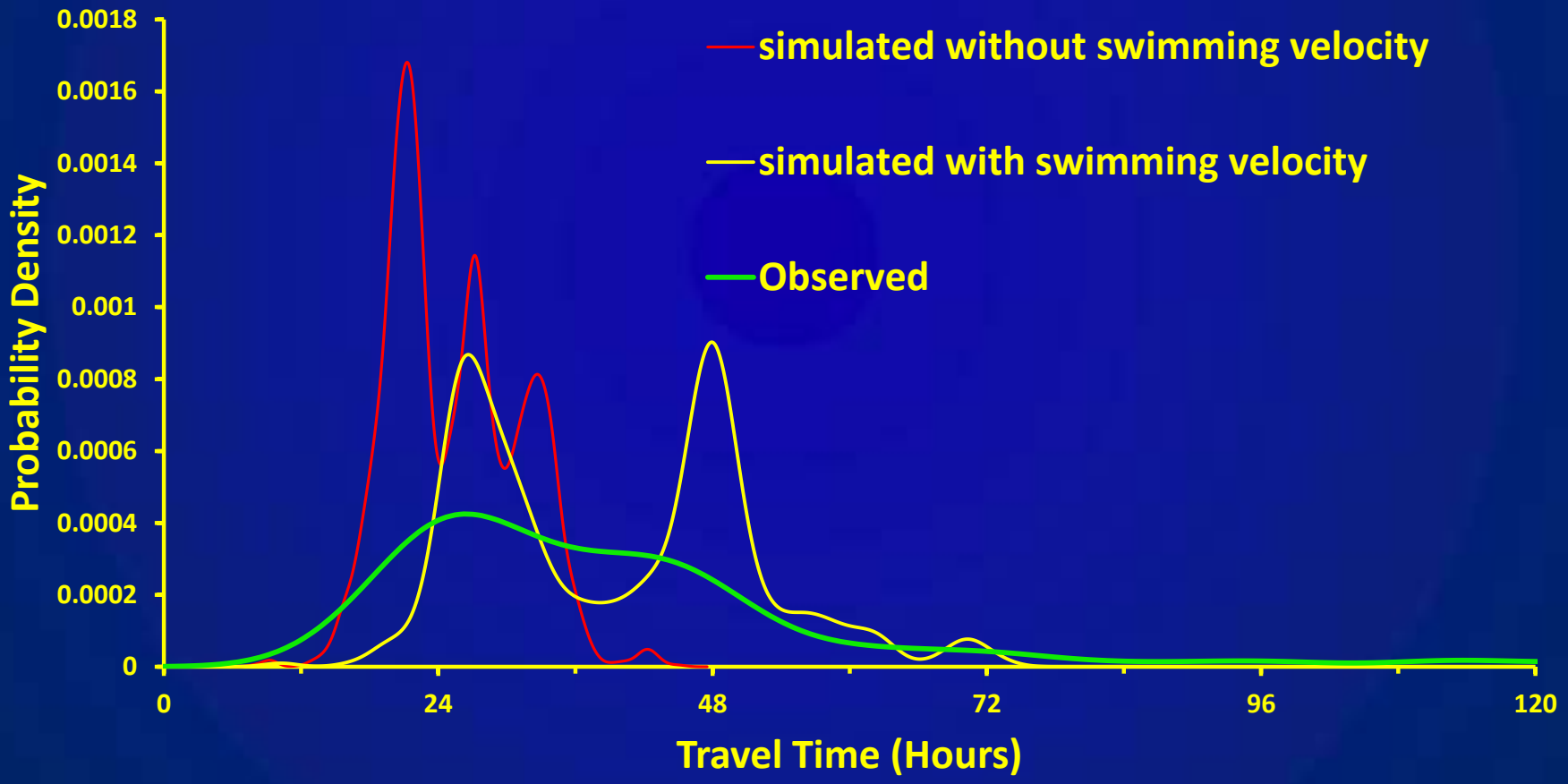
Travel Time Distribution



Travel Time Distribution



Travel Time Distribution



Future Work: Statistical Analysis

- Swimming behaviors
  - Explore other parameters that affect travel time distribution, such as tidal/diurnal holding behavior
  - Incorporate more telemetry data sets
  - Estimate swimming velocities for other river reaches

Future Work: Statistical Analysis

- Route and survival behaviors
  - Analyze multi-station/multi-year acoustic telemetry tag data
  - Develop routing models for route choice probabilities
  - Develop survival models for survival probabilities

Future Work: PTM

- Implement behavioral models
- Modify PTM to take 3D velocities from a 3D flow model
- Build an open-source platform to facilitate collaborative model development

Acknowledgement

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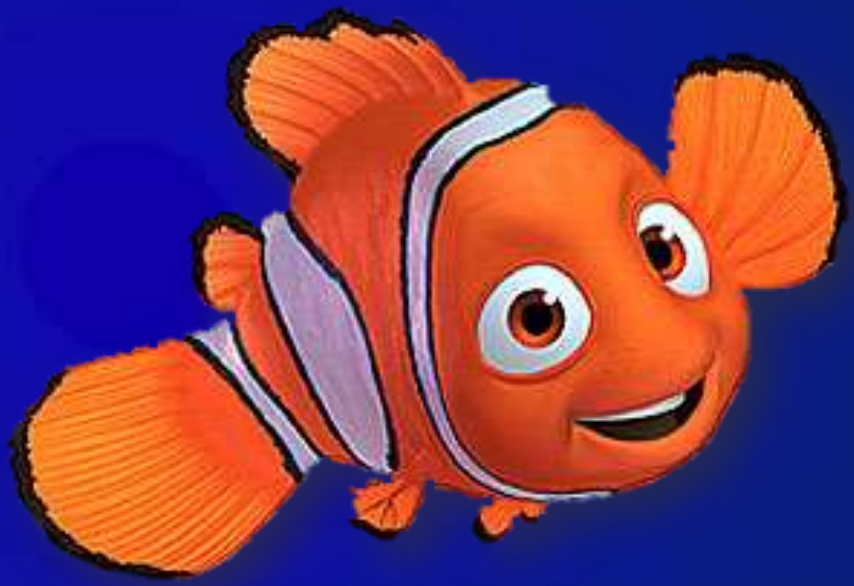
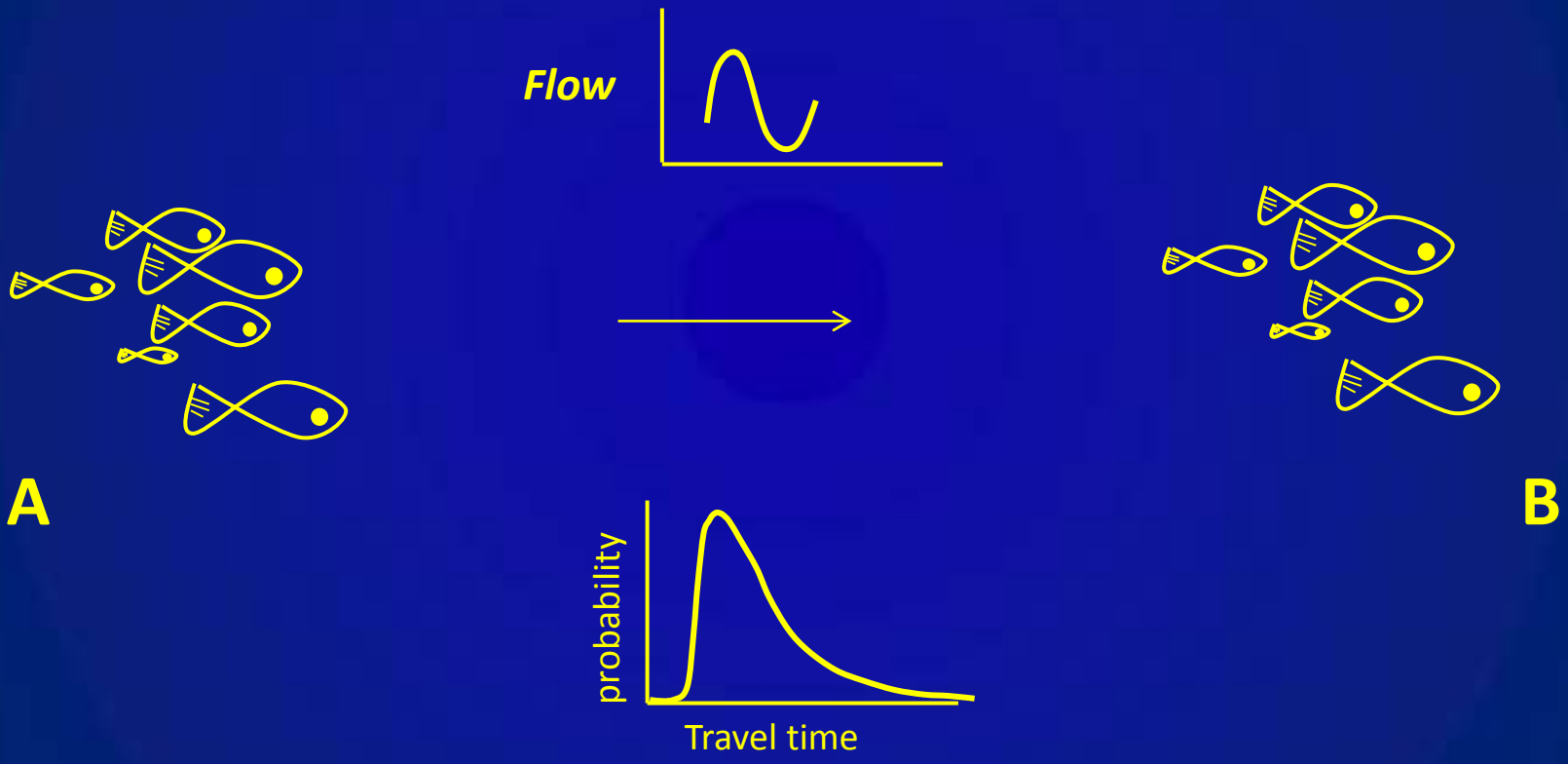


Maximize Likelihood Function

Travel Time Distribution (Gurarie et al., 2009)



Inverse Gaussian Reciprocal Normal Distribution

Maximize Likelihood Function

Calculate Likelihood

$$L(\mu_r, \sigma_r, \sigma_w | t, x) = \sum_{i=1}^{T} \log\left[\frac{x}{\sqrt{2\pi(\sigma_r^2 t_i + \sigma_w^2){t_i}^3}} \times e^{-\frac{(x-\mu_r t_i)^2}{2(\sigma_r^2 t_i + \sigma_w^2)t_i}}\right]$$

$(\mu_r, \sigma_r, \sigma_w)$ ~ estimated from simulated travel times and is function of Swimming velocity v ⟹ $\left(\hat{\mu}_r(v), \hat{\sigma}_r(v), \hat{\sigma}_w(v)\right)$

$$\hat{l}(\mu_r, \sigma_r, \sigma_w | t, x, v)$$

$$= \sum_{i=1}^{T} \log \frac{1}{S} \sum_{j=1}^{S} \left[\frac{x}{\sqrt{2\pi\left(\hat{\sigma}_{rj}^2(v) t_i + \hat{\sigma}_{wj}^2(v)\right){t_i}^3}} \times e^{-\frac{\left(x-\hat{\mu}_{rj}(v) t_i\right)^2}{2\left(\hat{\sigma}_{rj}^2(v) t_i + \hat{\sigma}_{wj}^2(v)\right)t_i}}\right]$$