EVALUATING EXPERIMENTAL DESIGNS THROUGH SIMULATION ANALYSES

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NOUMÉA, NEW CALEDONIA

IATTC Tagging Workshop
La Jolla,
USA
Jan 2019

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Communauté du Pacifique

Outline of this presentation

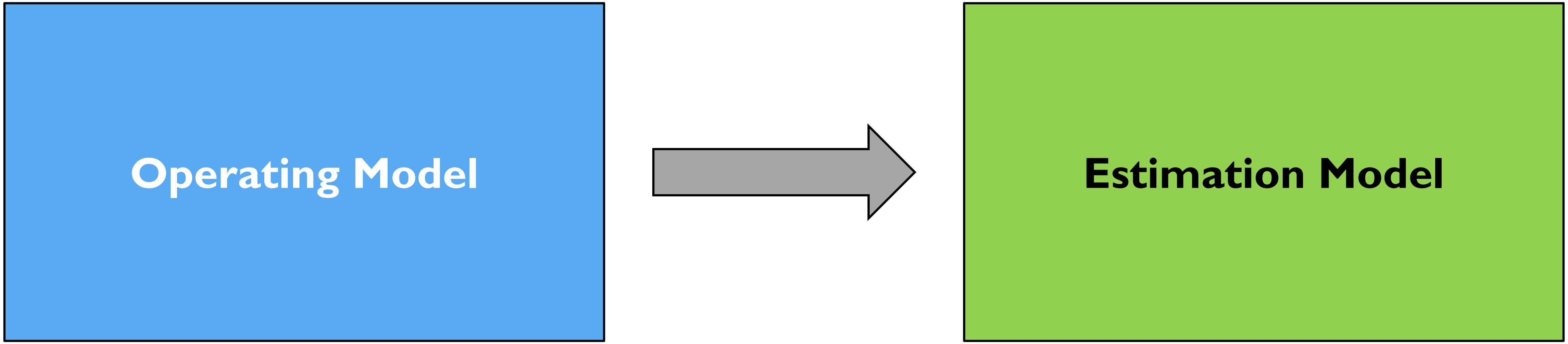
- Why use simulations?
- Choosing an simulation model
- Typical model assumptions and their problems
- Example: individual recapture probability
- WCPO tag simulations using Ikamoana

Why use simulation models?

Simulation models can be useful data generators for

- Experiment design
- Analytical design
- Understanding biases

Constructing a simulation experiment



Simulation of "reality"

- Various behavioural hypotheses
- Various fishing/environmental scenarios
- Various tagging strategies/assumptions

Estimate emergent properties of operating model data

- Omniscient measurements
- Quantify measurement error
- Sensitivity of parameter estimates to hypotheses

Mark-recapture fundamentals

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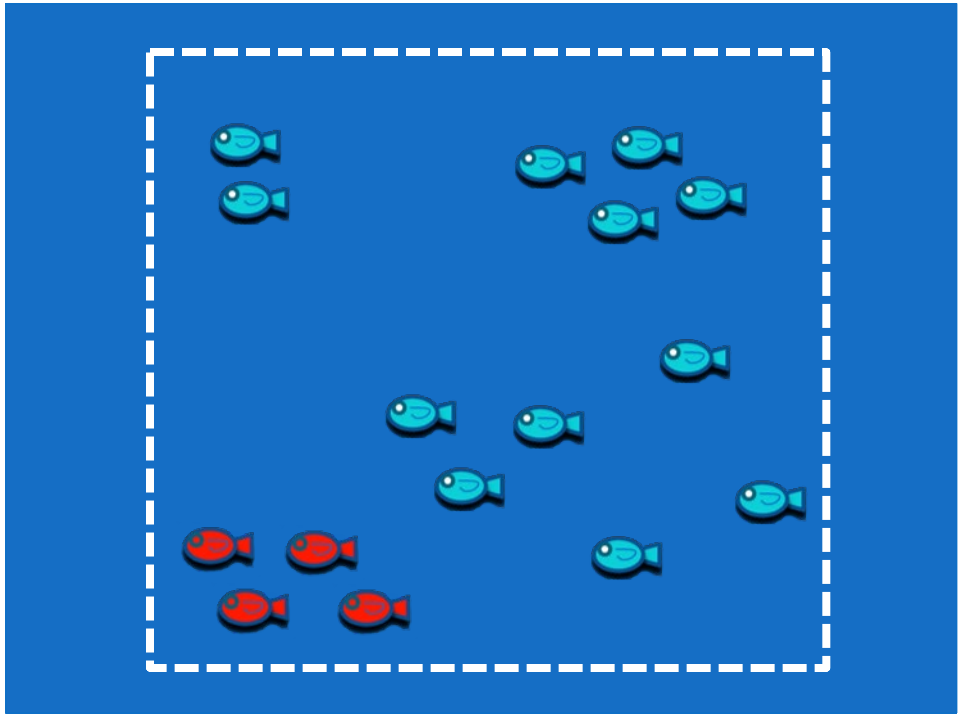
Mark-recapture tagging assumes that a marked subset of the population is representative of that population in a region

- Tagged sample is released
- Period of time passes ("mixing period")...
- Those tagged individuals distribute themselves relative to the untagged population in the region
- Subject to the same processes as untagged individuals



Time 0 → Time X

Typical operating models

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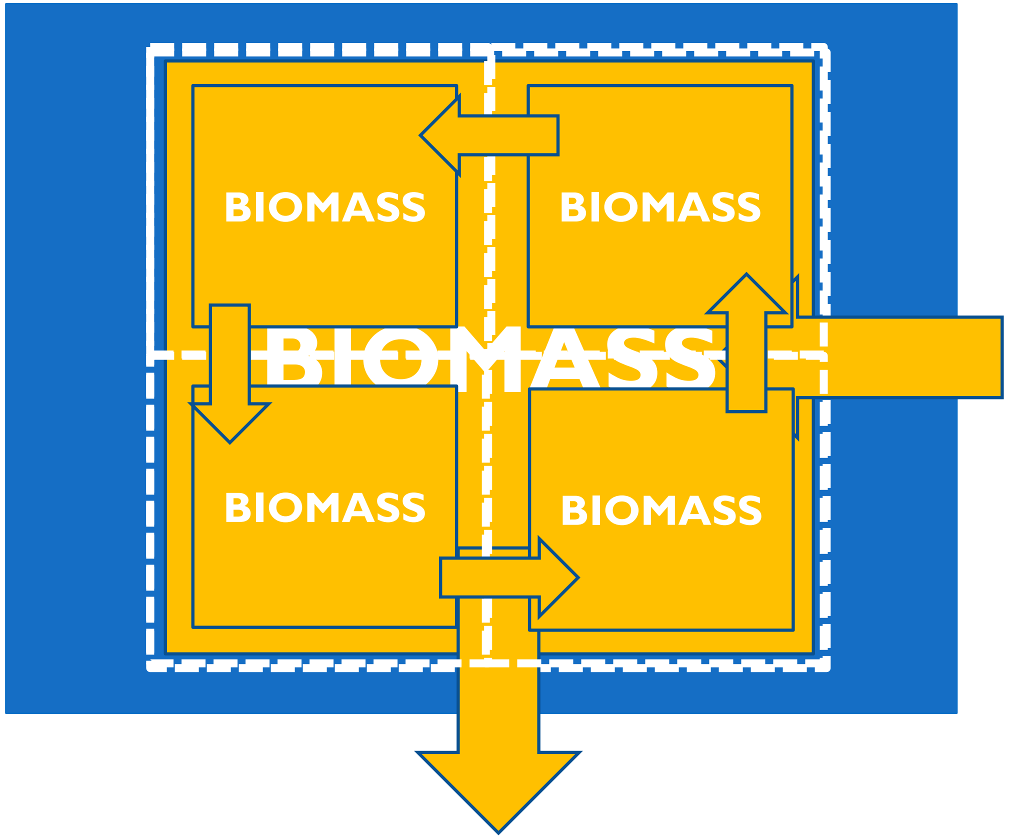
Individuals often abstracted to discrete spatial packets of biomass

After mixing period

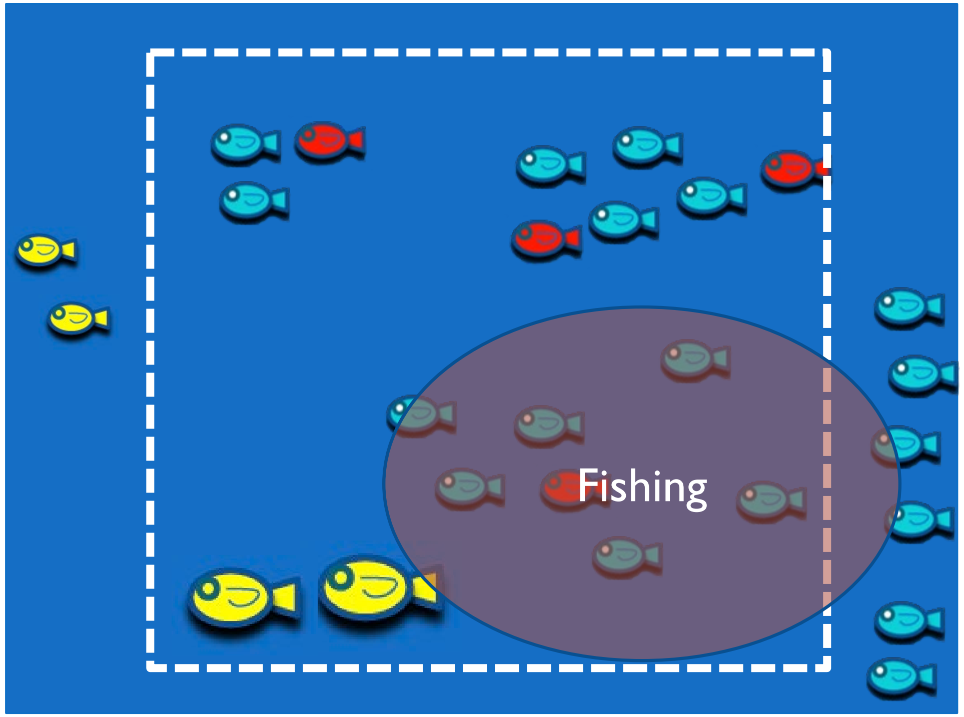
- Tagged and un-tagged fish homogenously distributed within closed region
- Potential immigration/emigration rates
- Multiple regions with transfer rates between them
- Generate an expected capture probability per time interval, region



Mark-recapture realities

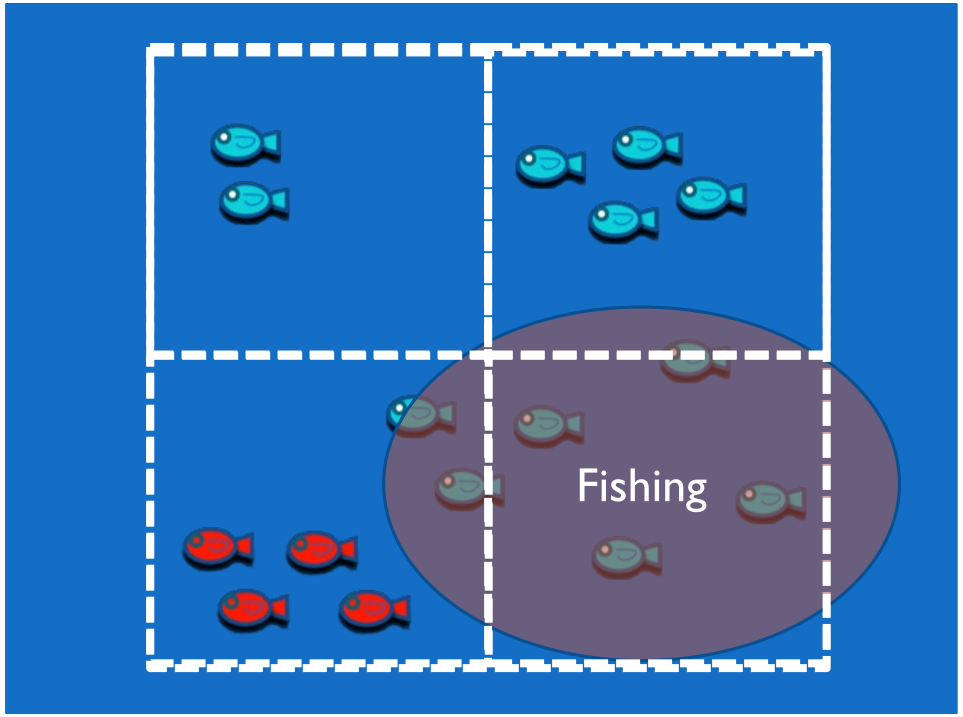
In practice, there are many processes that undermine the assumptions mark-recapture tagging of mobile animals

- — Size classes/life stage have distinct distributions/behaviours
- —Low dispersion of tags
- —Low numbers of tags
- —Influx of untagged individuals
- —Heterogeneity of fishing (capture probability)



Individual capture probability

At fine spatiotemporal scales, tagged individuals are unlikely to be subject to the same processes as untagged individuals



- Each fishes' capture probability is unique
- Can include many regions and small time-steps
- Requires more tag releases to accurately estimate parameters

Ikamoana: a movement model

Individual-based Kinesis, Advection and Movement of Ocean ANimAls (Ikamoana)

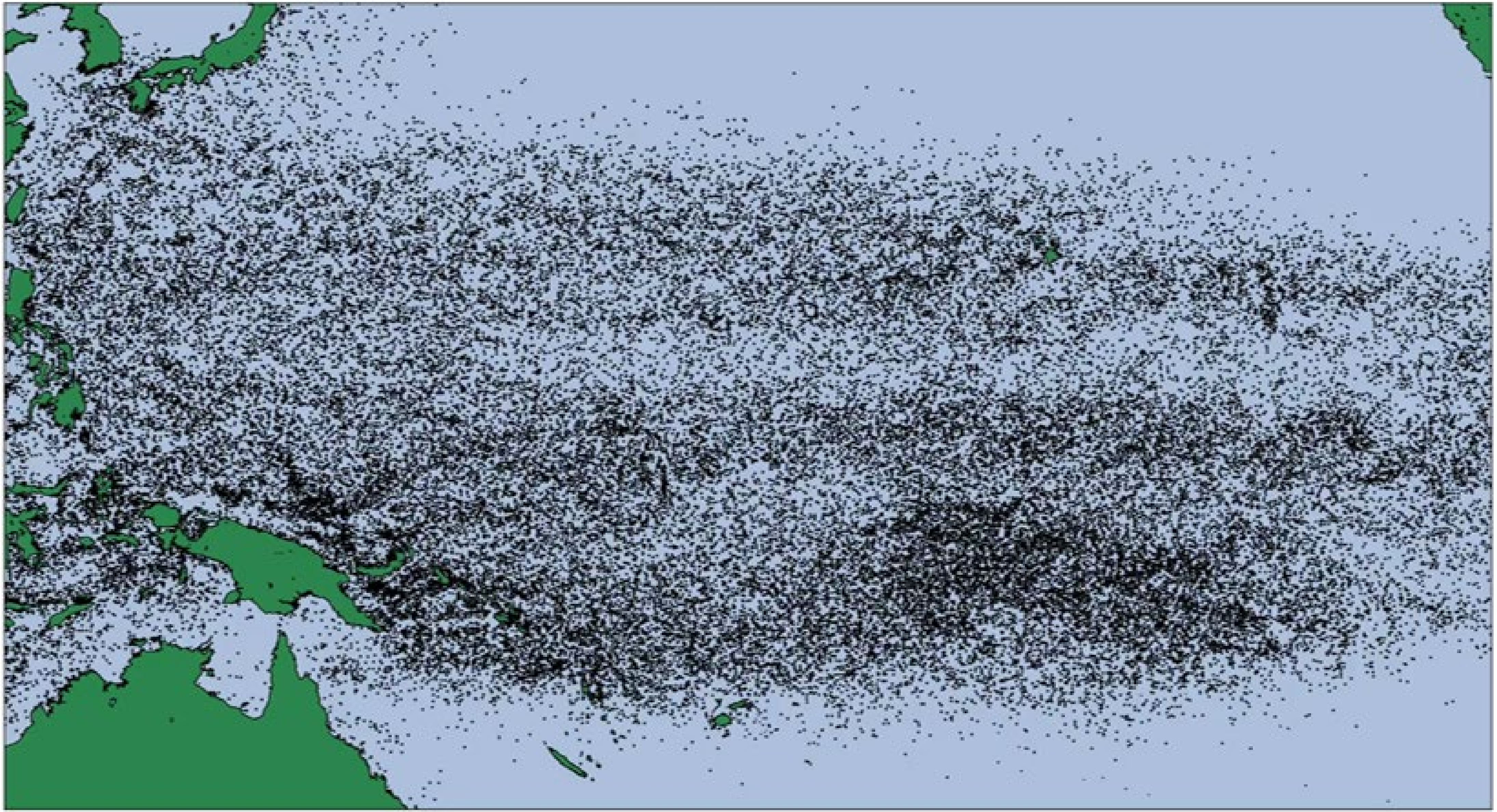
— Extends a recently developed Lagrangian particle simulator (Parcels) which **advects** individuals using physical forcing

— Adds non-directional **kinesis** movements, such as Lagrangian diffusion, random walks, internal states of individuals etc.

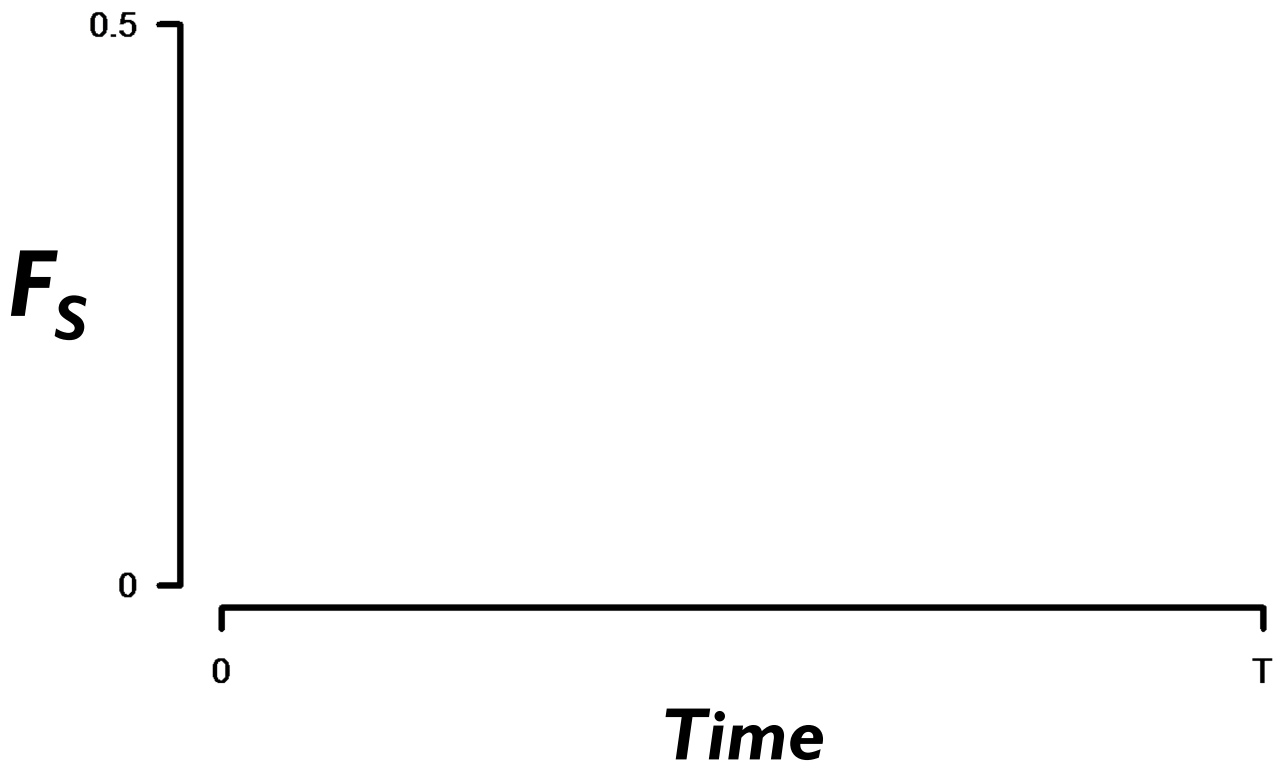
— Active **movements** that cause individuals to follow habitat gradients, or move in response to other individuals, environment etc.

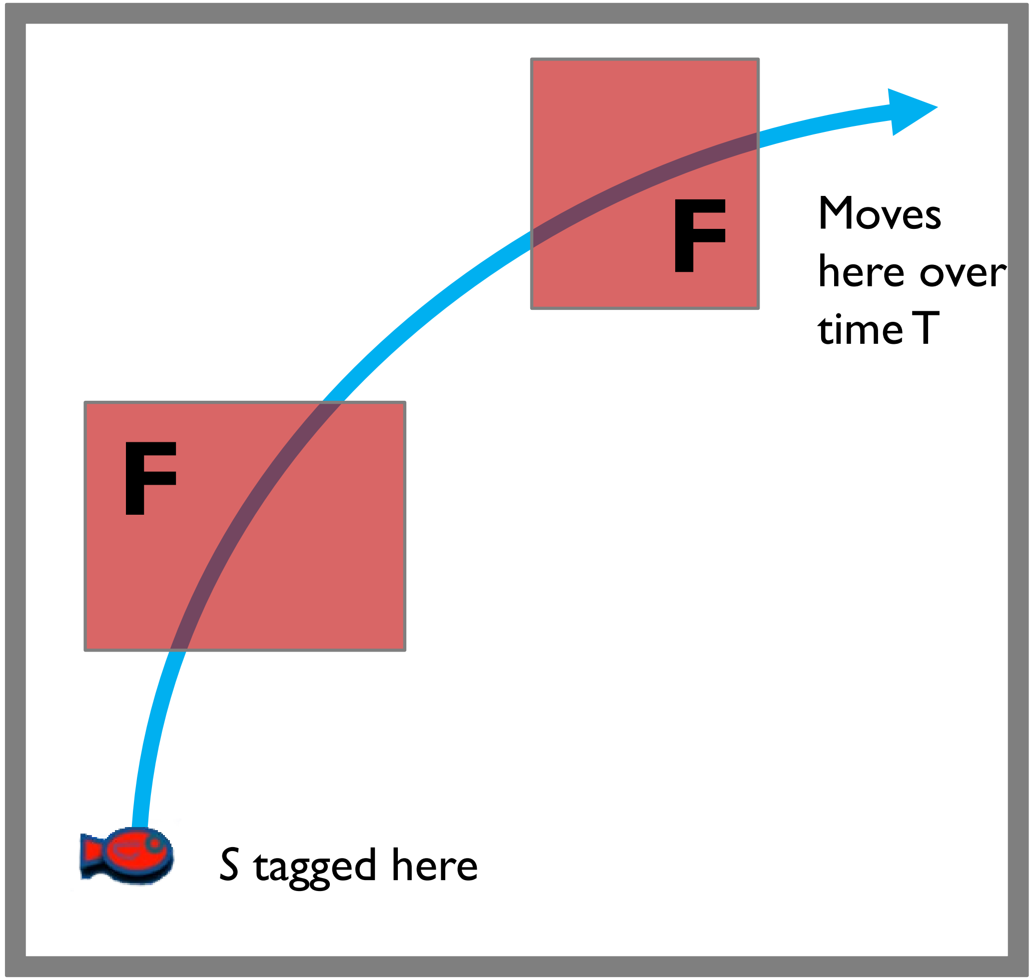
— Ikamoana is a movement mode, not a population dynamics model!

Ikamoana: SEAPODYM behavioural model

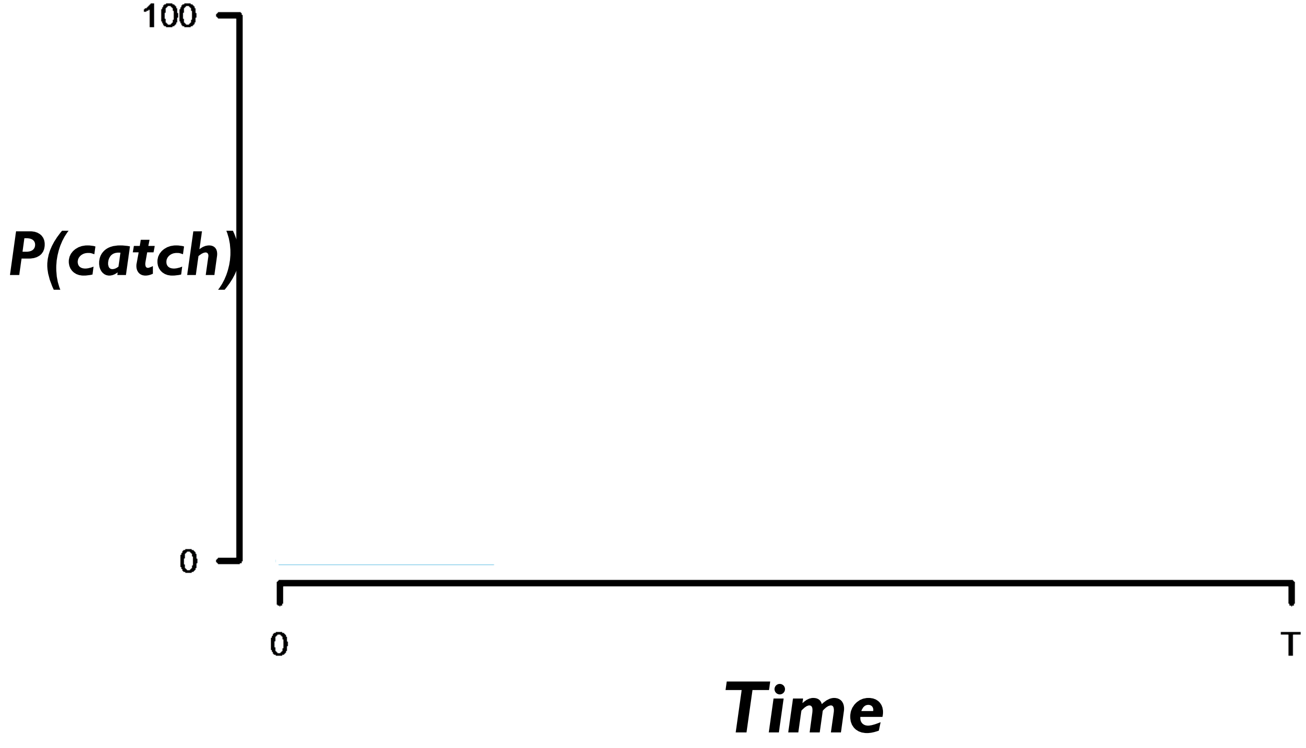


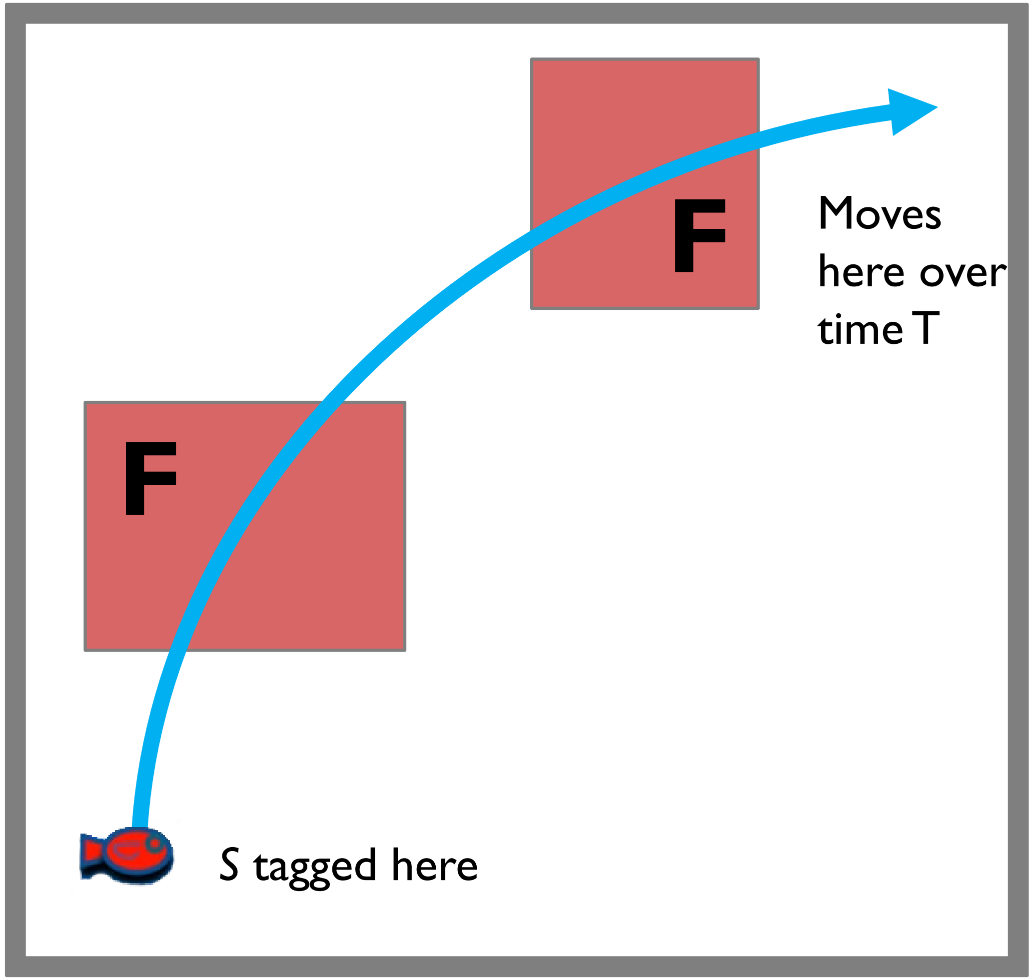
Individual capture probability





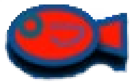
Individual capture probability

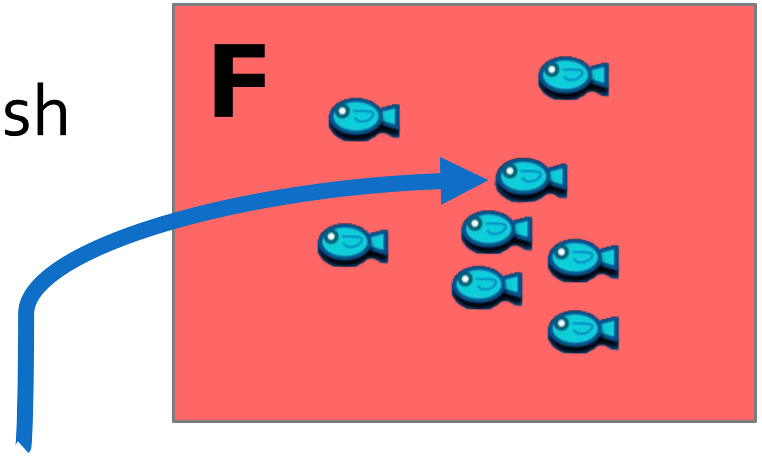




Individual capture probability

$$depletion = \left(1 - e^{-(M_t+F_t)\Delta t}\right)N$$

Assuming uniform probability of capture for all fish within cell, for an individual fish: 



$$P_t(mor) \ = \left(1 - e^{-(M_t+F_t)\Delta t}\right)P_t(surv)$$

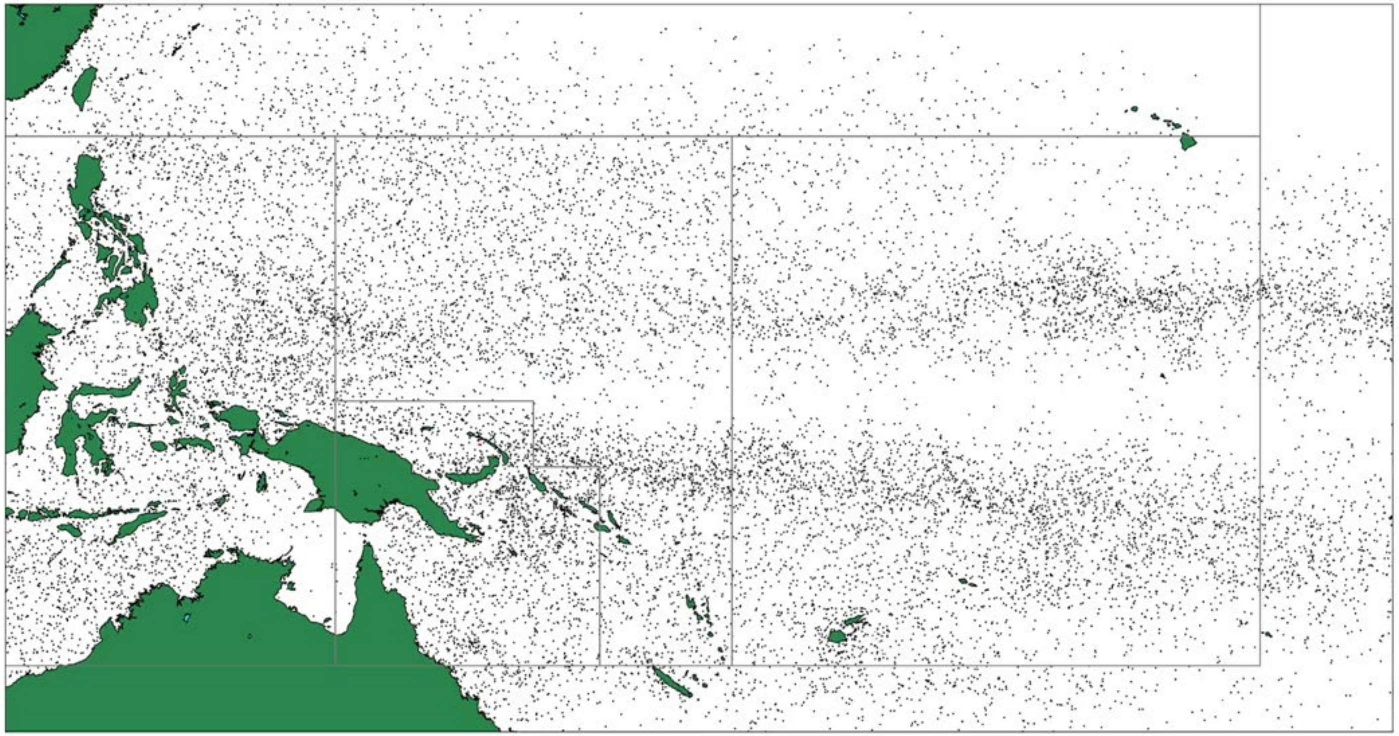
$$P_t(surv) = \prod_{n=0}^{t} 1 - P_n(mor)$$

$$P_t(catch) = \frac{F_t}{M_t + F_t} P_t(mor \Bigg)$$

Tagging simulation with Ikamoana

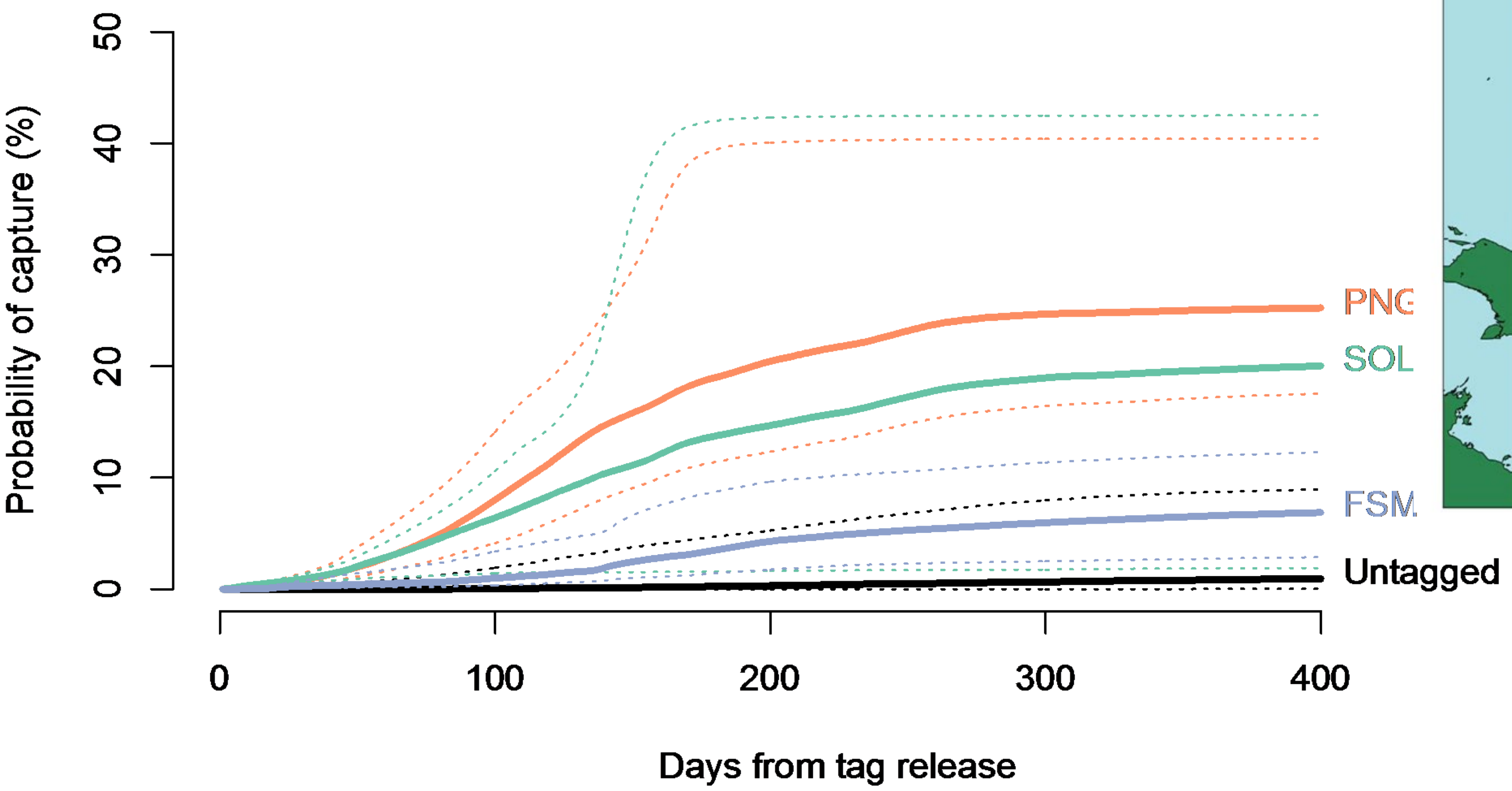
Using Ikamoana:

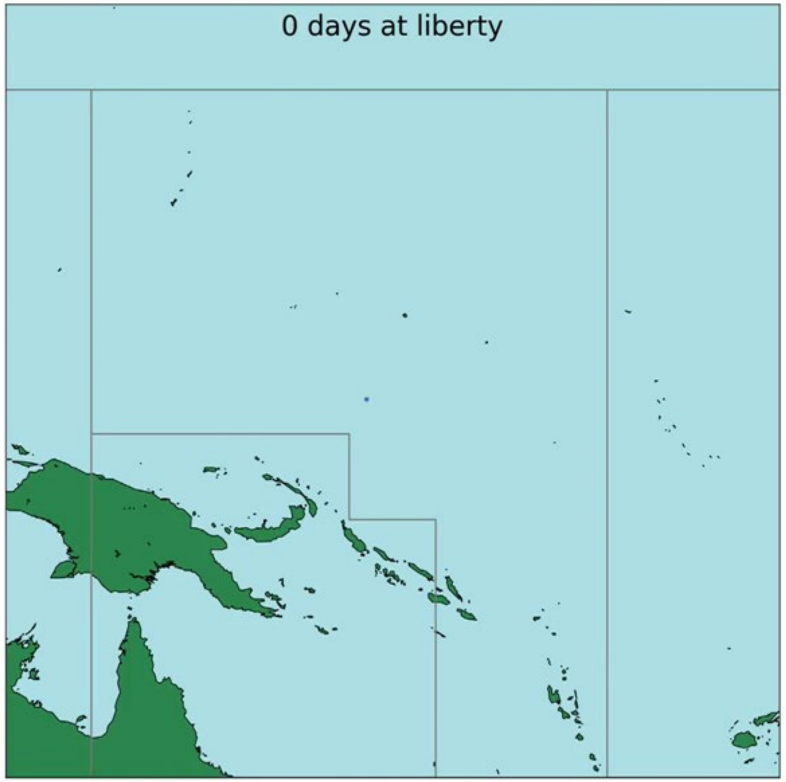
- Simulate both tagged fish and untagged cohort
- Changes across release scenarios
  - Temporal (ENSO, seasons etc.)
  - Location
- Record probability of capture
- For simulated tagged fish vs untagged fish, compare:
  - Connectivity
  - Capture history



Tagging simulation with Ikamoana

Probability of capture at time *t*





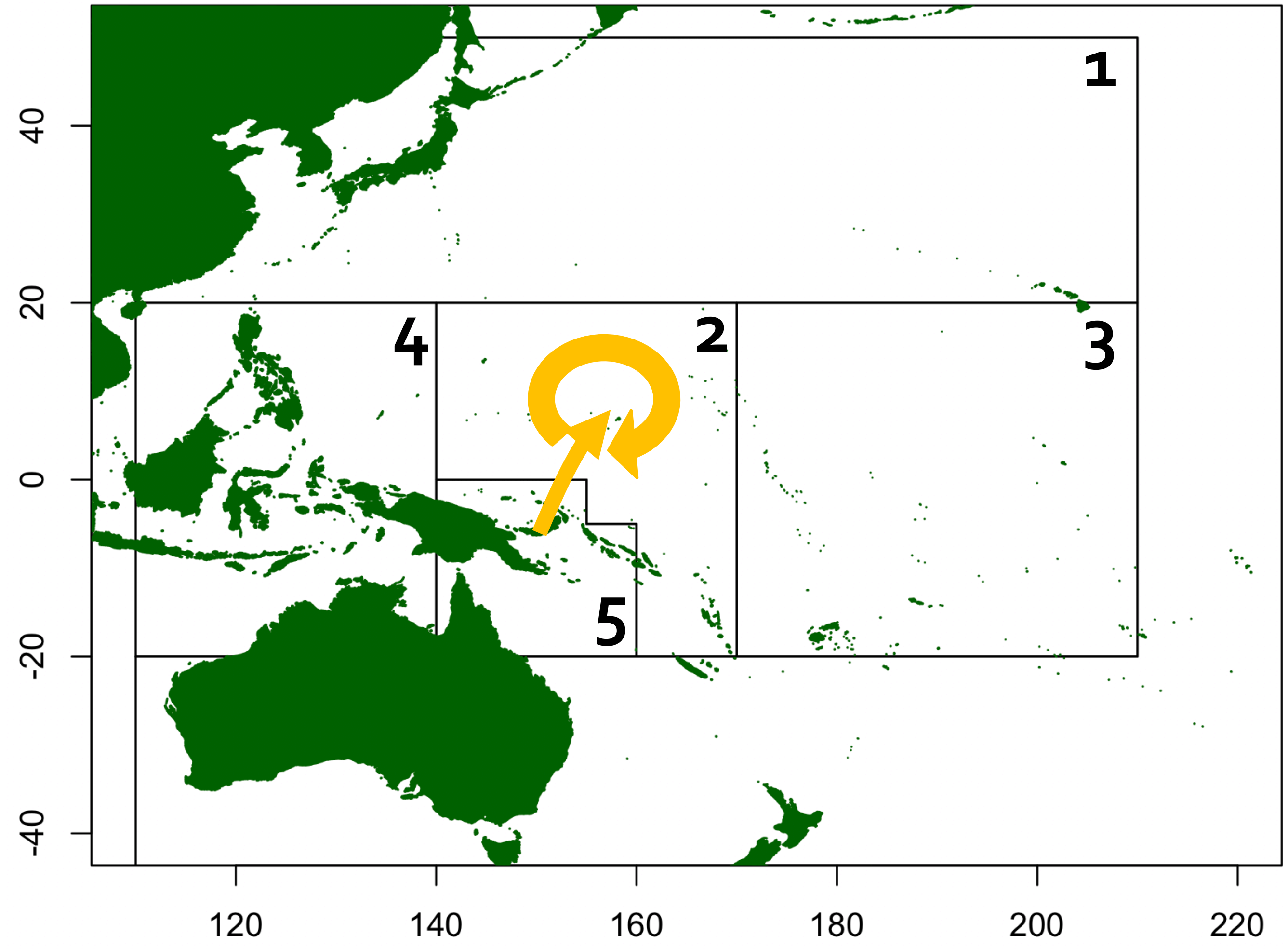
Tagging simulation with Ikamoana

Connectivity of PNG releases

- Assuming 1 month mixing period
- Assuming 3 month mixing period

Ratio Tag/Untagged
Ratio Tag/Untagged

	1	2	3	4	5	6
1	0	0	0	0	0	0
2	0	0.906	0.228	0.121	1.434	0
3	0	0	0	0	0	0
4	0	0	0	0	0	0
5	0	1.368	0.296	2.262	0.839	0
6	0	0	0	0	0	0



Next steps for WCPO tag simulation

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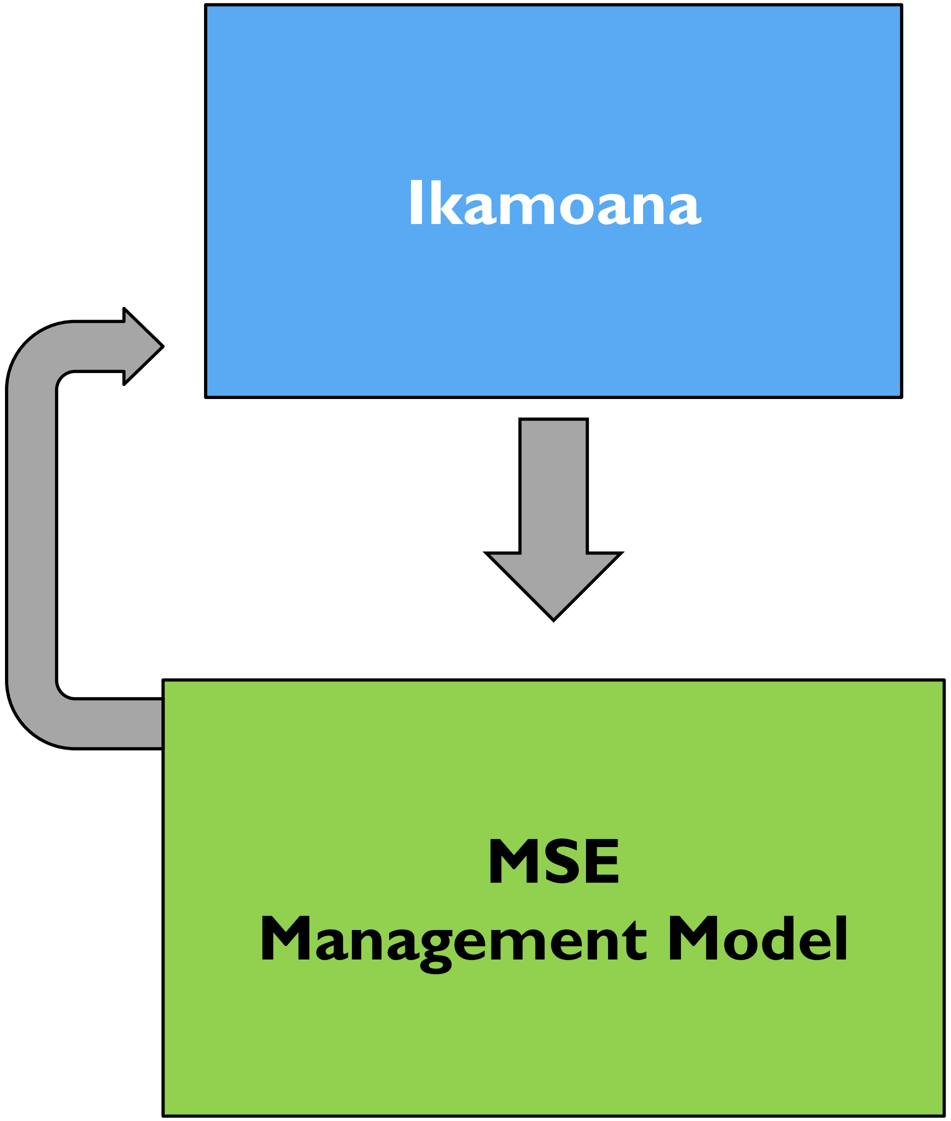
- Add further scenarios
  - Tag shedding/tag reporting rates
  - Alternative behavioural models
  - Alternative fishing effort models
  - Multiple releases

- Generate data for estimation model
  - Brownie tag-return model
  - Tagging data for MF-CL



Considerations

- What simulation model would best support current hypotheses for dynamics?

- What are the aims of the tagging programme?
  - Population size
  - Connectivity
  - Growth
  - Survivability

- How will parameters be estimated from tagging data?
  - Directly
  - Brownie tag-returns model
  - Full population dynamics model

- Logistics are everything

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