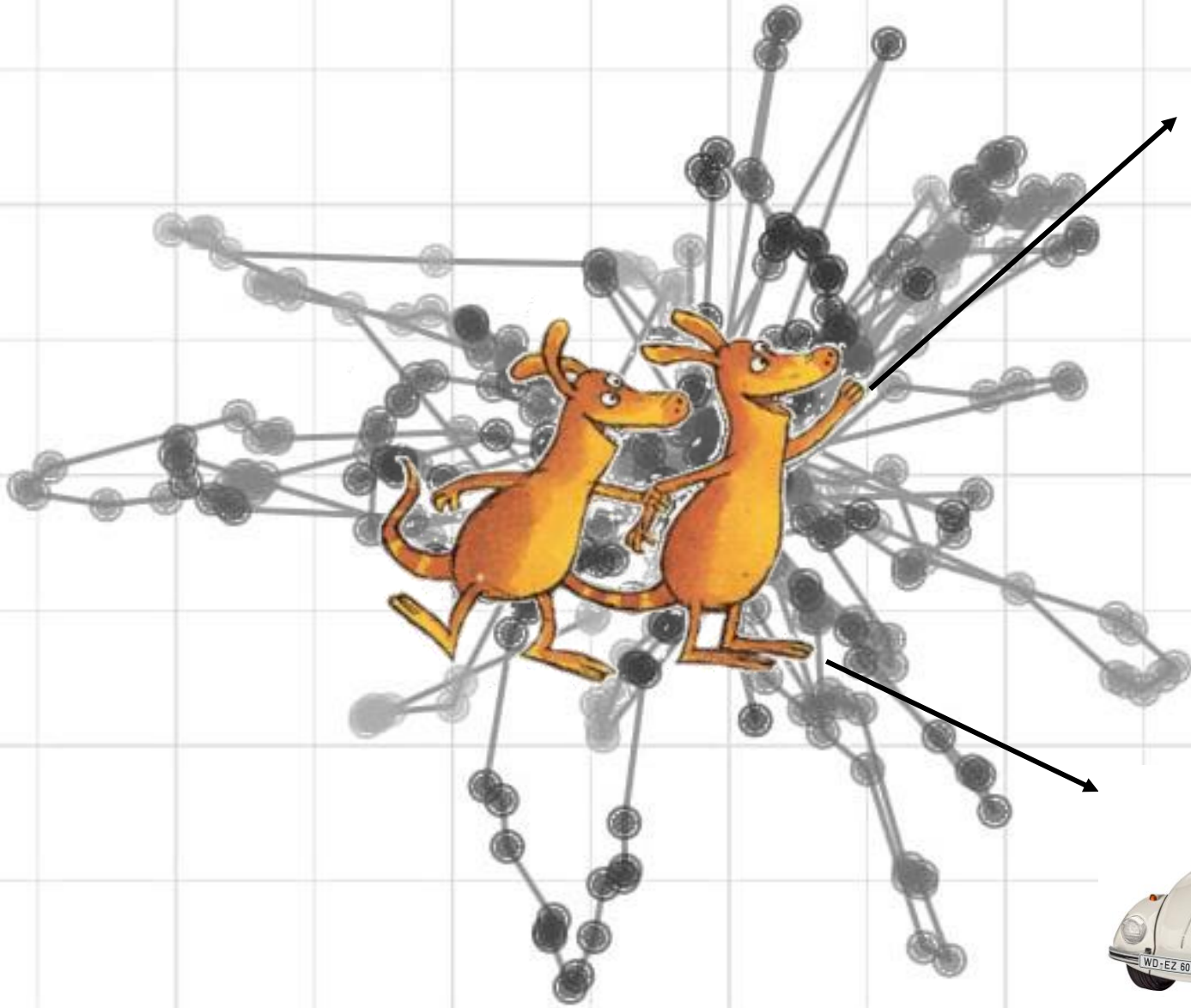
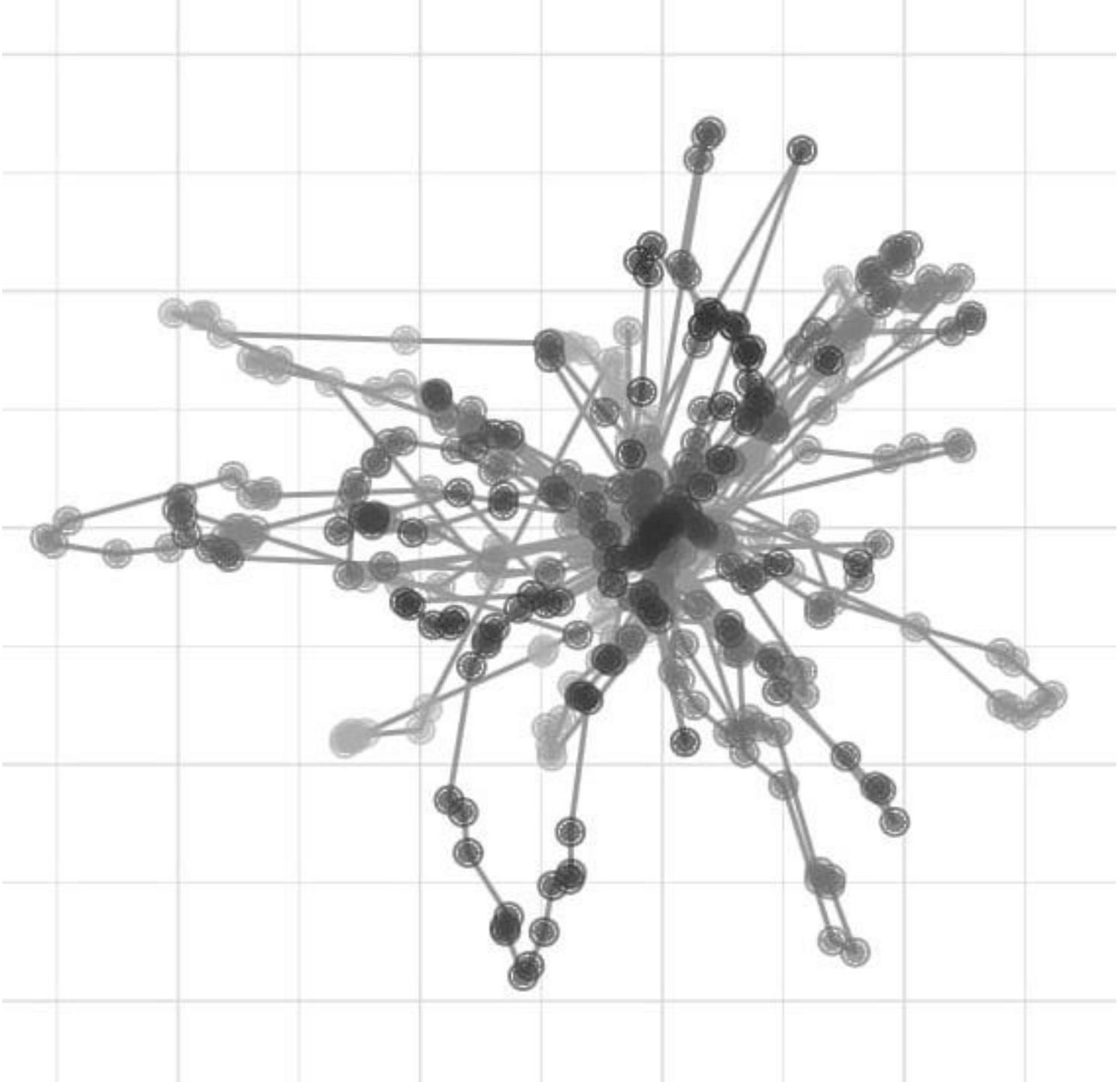
Approximate **B**ayesian **C**alibration of a Movement Model

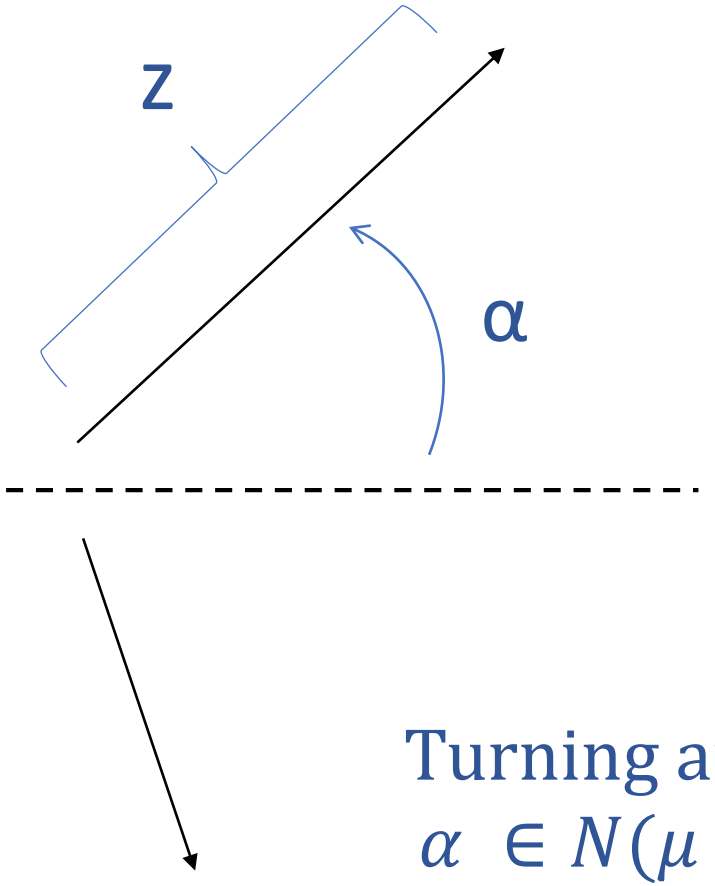


Movement model

Laziness
Basket size
Food radius
Concentration



Movement model



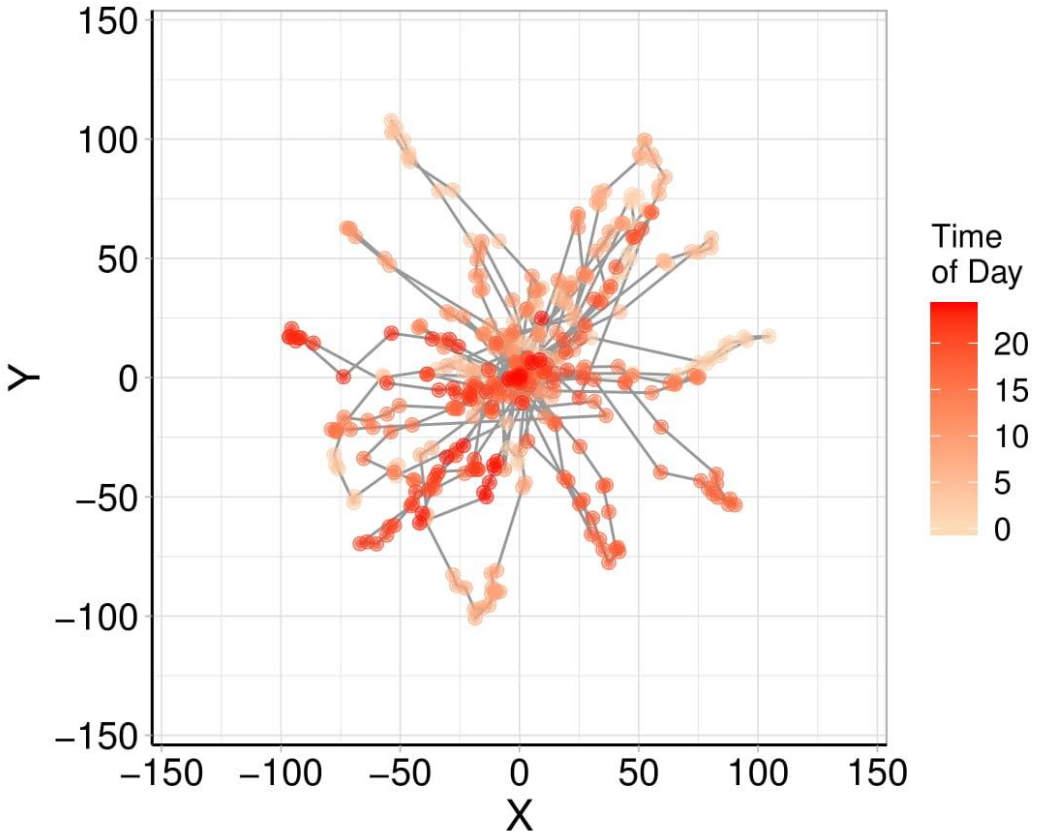
steplength

$z \in Exp(\lambda)$

Turning angle

$\alpha \in N(\mu = 0, sd = concentration)$

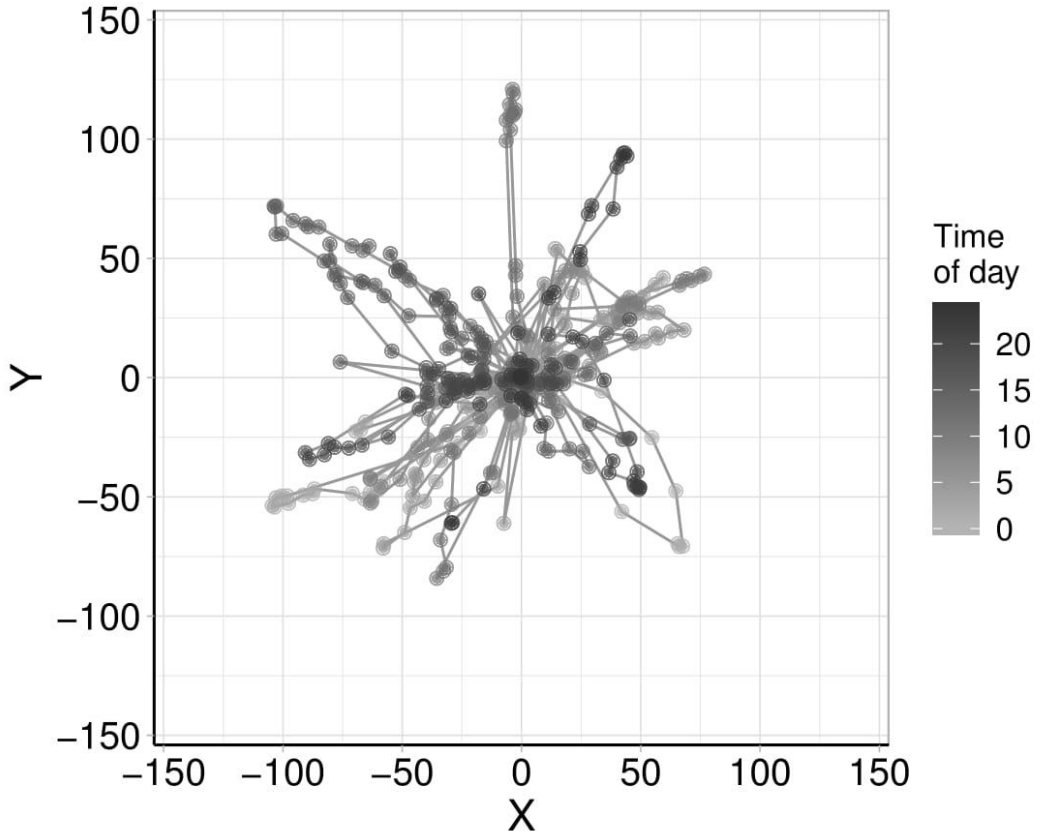
Observed data: y_{obs}



?

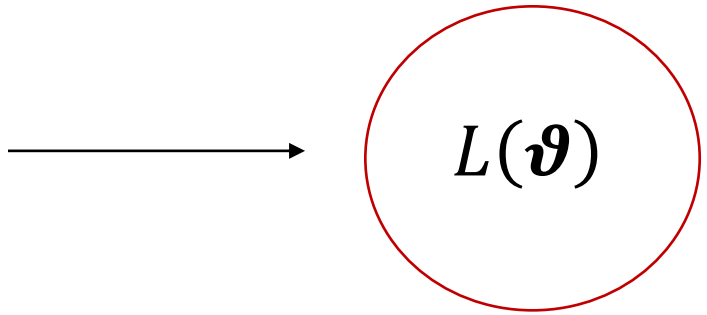
=

Model simulations: y_{sim}



Distance metric:

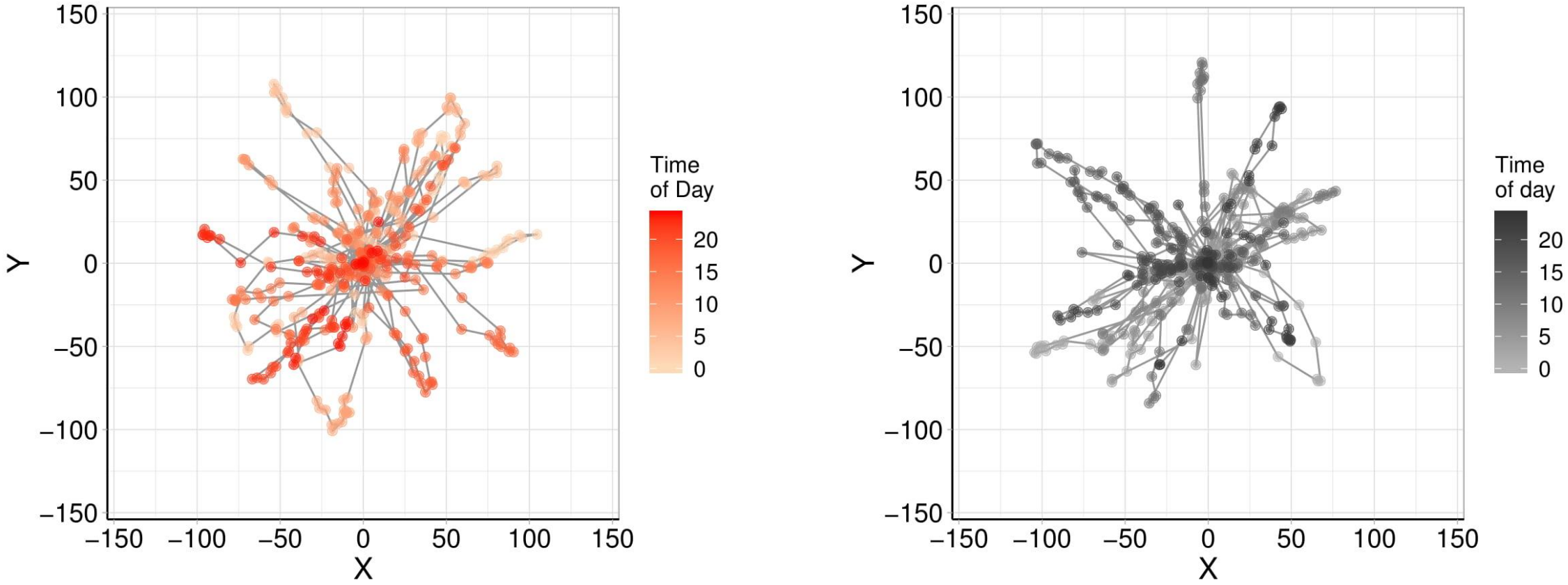
$$\min(\mathrm{d}(y_{obs} - y_{sim}))$$



Likelihood

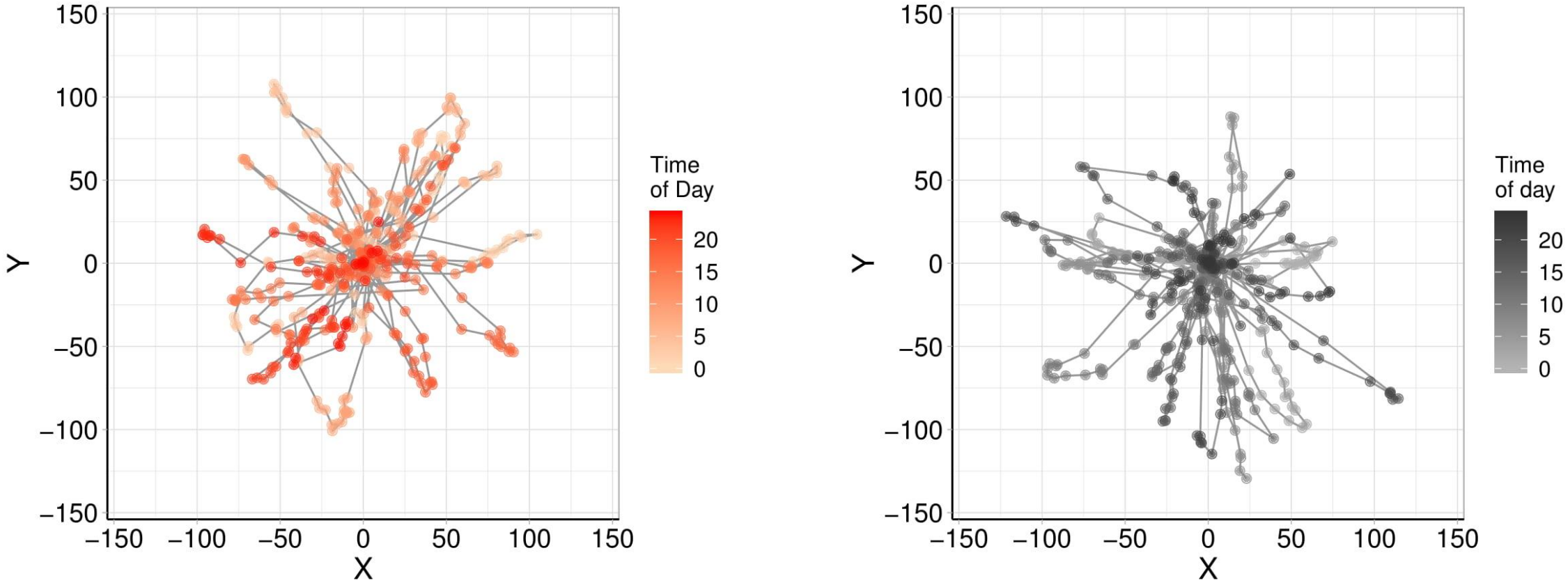
Distance metric:

$$\min(\mathrm{d}(y_{obs} - y_{sim})) \longrightarrow ?$$



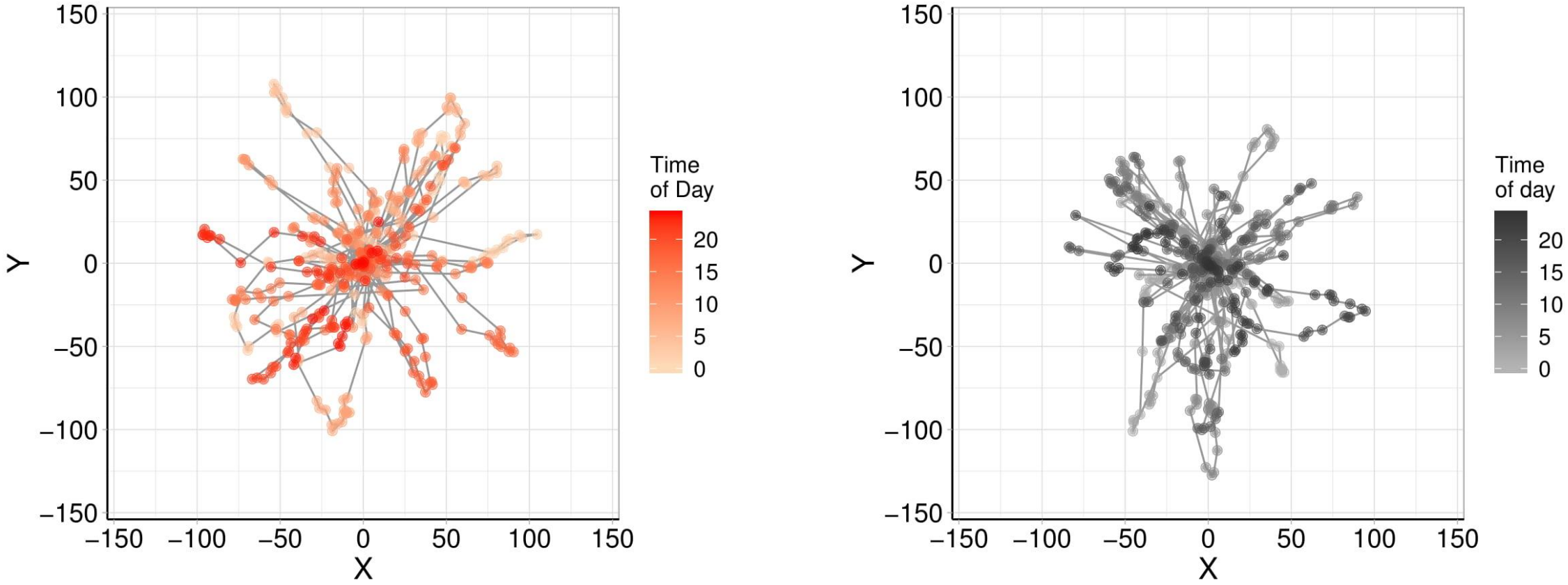
Distance metric:

$$\min(\mathrm{d}(y_{obs} - y_{sim})) \longrightarrow ?$$



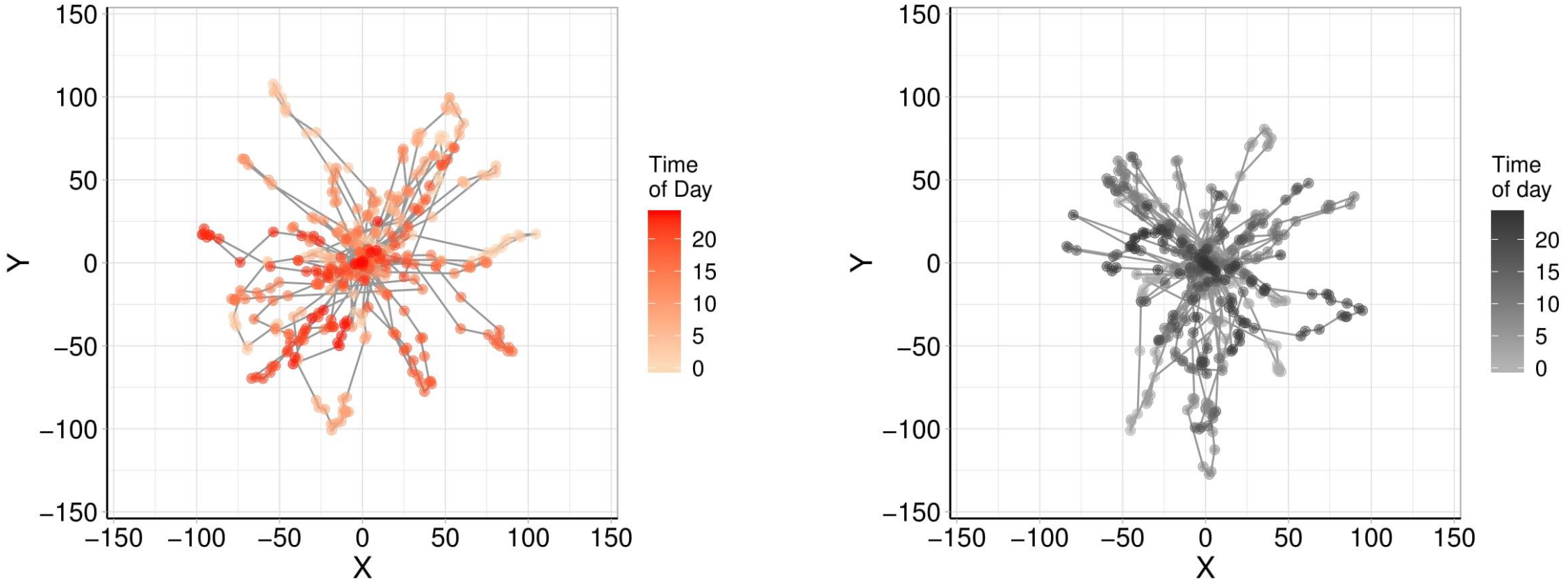
Distance metric:

$$\min(\mathrm{d}(y_{obs} - y_{sim})) \longrightarrow ?$$



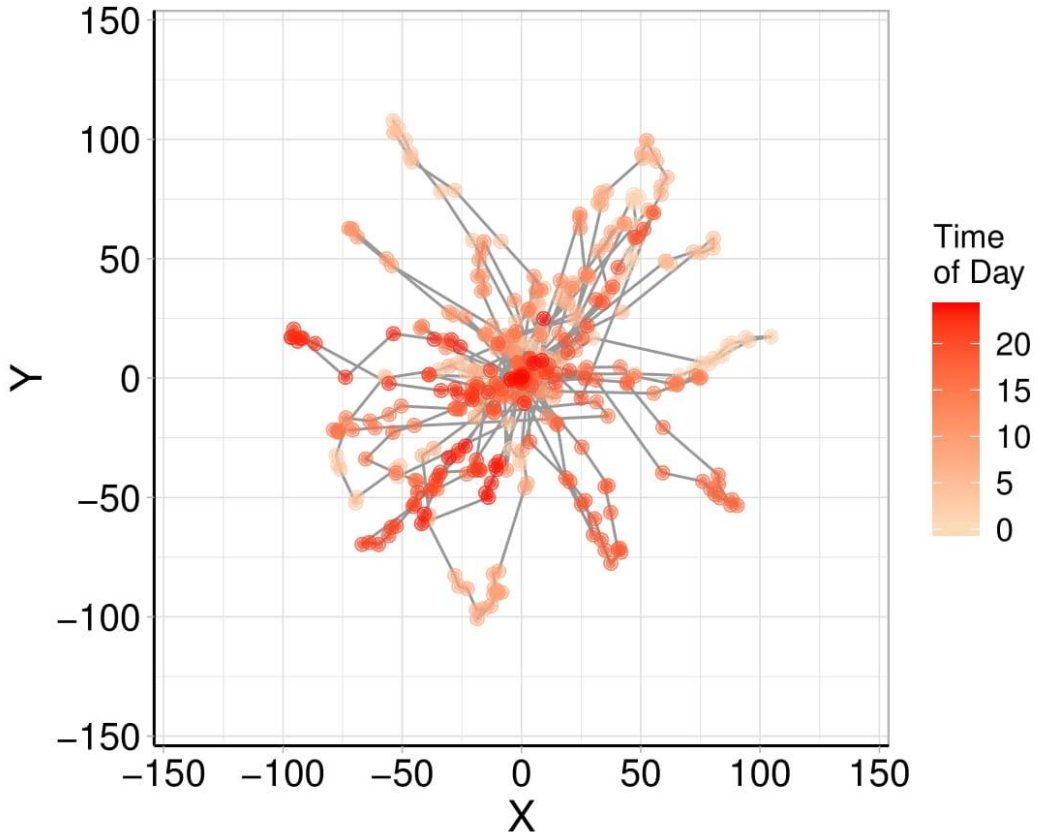
Summary statistics s :

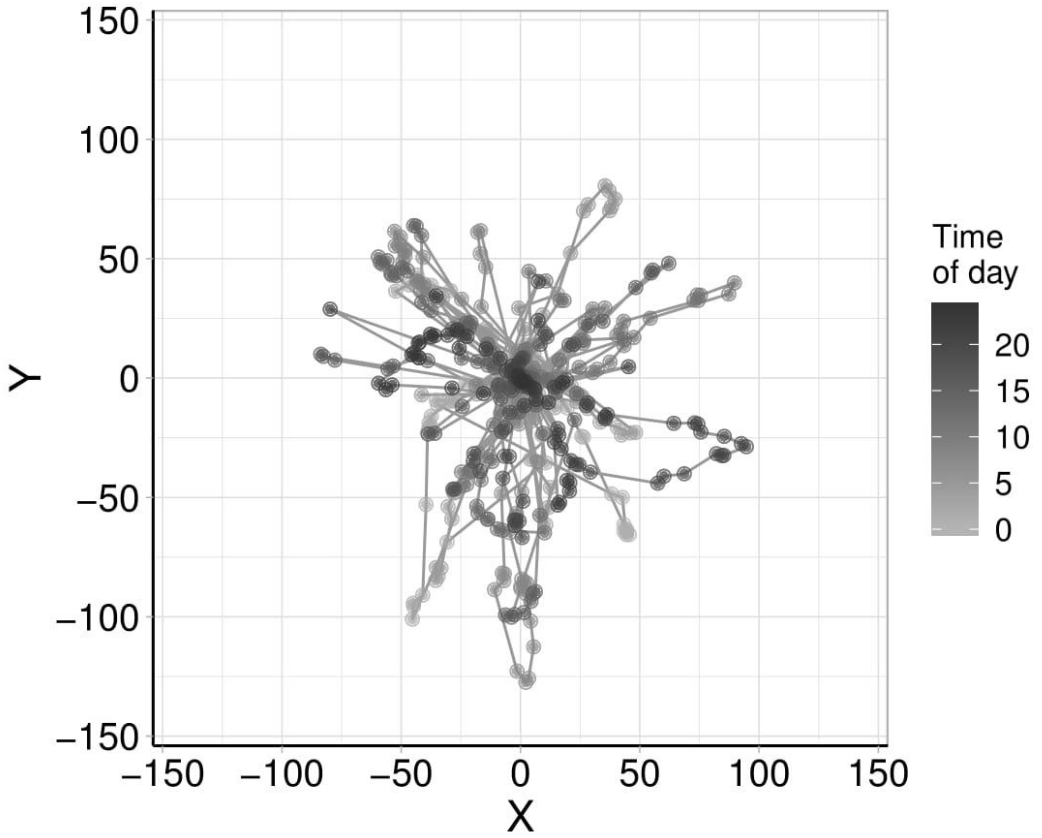
$$\min(\mathrm{d}(y_{obs} - y_{sim})) \longrightarrow \min(\mathrm{d}(s_{obs} - s_{sim}))$$



Distance metric:

$$\min(\mathrm{d}(s_{obs} - s_{sim})) \longrightarrow L(\boldsymbol{\vartheta}) \propto P(y_{obs}|\boldsymbol{\vartheta})$$





ABC – *Approximate* Bayesian Computation

$$P(\boldsymbol{\vartheta}|y_{obs}) = P(y_{obs}|\boldsymbol{\vartheta})P(\boldsymbol{\vartheta})\ \mathrm{c}$$

Bayesian

ABC – *Approximate* Bayesian Computation

$$P(\boldsymbol{\vartheta}|y_{obs}) = P(y_{obs}|\boldsymbol{\vartheta})P(\boldsymbol{\vartheta})\ \mathrm{c}$$

→ Bayesian

1. Summary Statistics s_{obs}

ABC – *Approximate* Bayesian Computation

$$P(\boldsymbol{\vartheta}|y_{obs}) = P(y_{obs}|\boldsymbol{\vartheta})P(\boldsymbol{\vartheta})\ \mathrm{c}$$

→ Bayesian

$$P(s_{obs}|\boldsymbol{\vartheta})$$

ABC – *Approximate* Bayesian Computation

$$P(\boldsymbol{\vartheta}|y_{obs}) = P(y_{obs}|\boldsymbol{\vartheta})P(\boldsymbol{\vartheta})\ \mathrm{c}$$

→ Bayesian

1. Summary Statistics s_{obs}

2. Rejection Sampling

ABC – *Approximate* Bayesian Computation

$$P(\boldsymbol{\vartheta}|y_{obs}) = P(y_{obs}|\boldsymbol{\vartheta})P(\boldsymbol{\vartheta})\ \mathrm{c}$$

Bayesian

1. Summary Statistics s_{obs}

$$d(s_{obs}, s_{sim}) < \varepsilon$$

ABC – *Approximate* Bayesian Computation

$$P(\boldsymbol{\vartheta}|y_{obs}) = P(y_{obs}|\boldsymbol{\vartheta})P(\boldsymbol{\vartheta})\ \mathrm{c}$$

→ Bayesian

1. Summary Statistics s_{obs}

→ Approximation

2. Rejection Sampling

Known

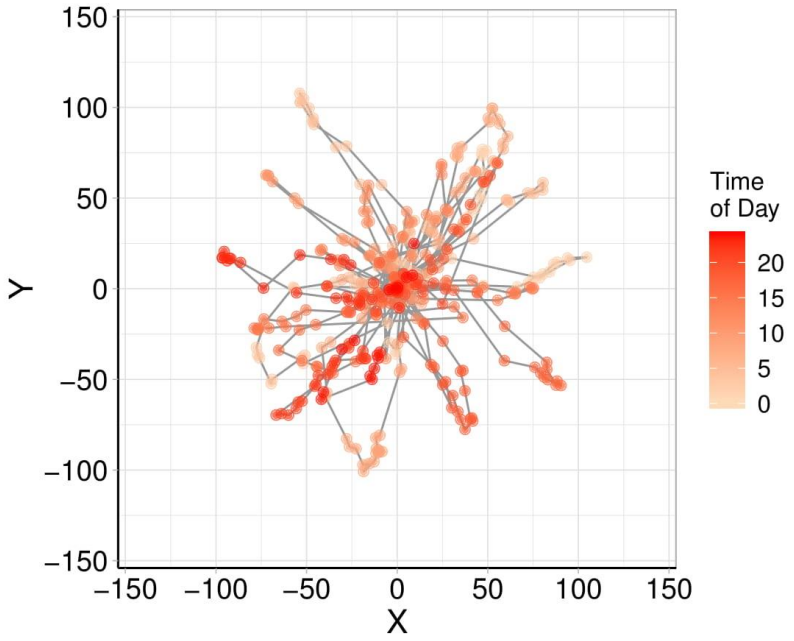
Concept

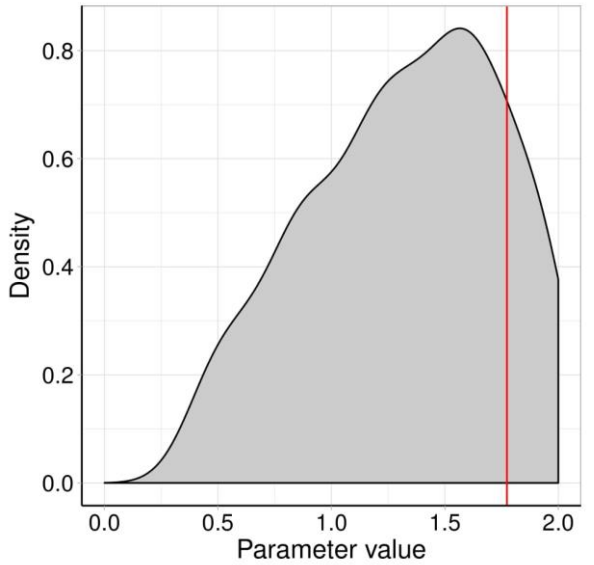
Unknown

„Observations“

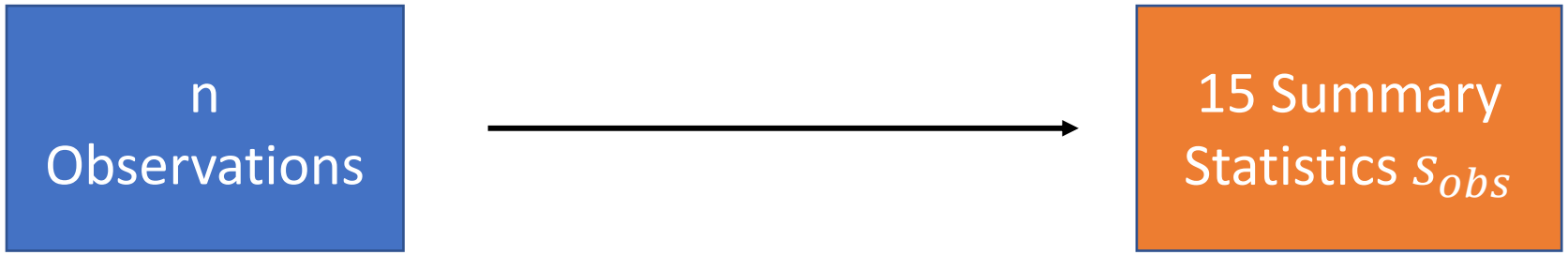
Movement model

Laziness
Basket size
Food radius
Concentration





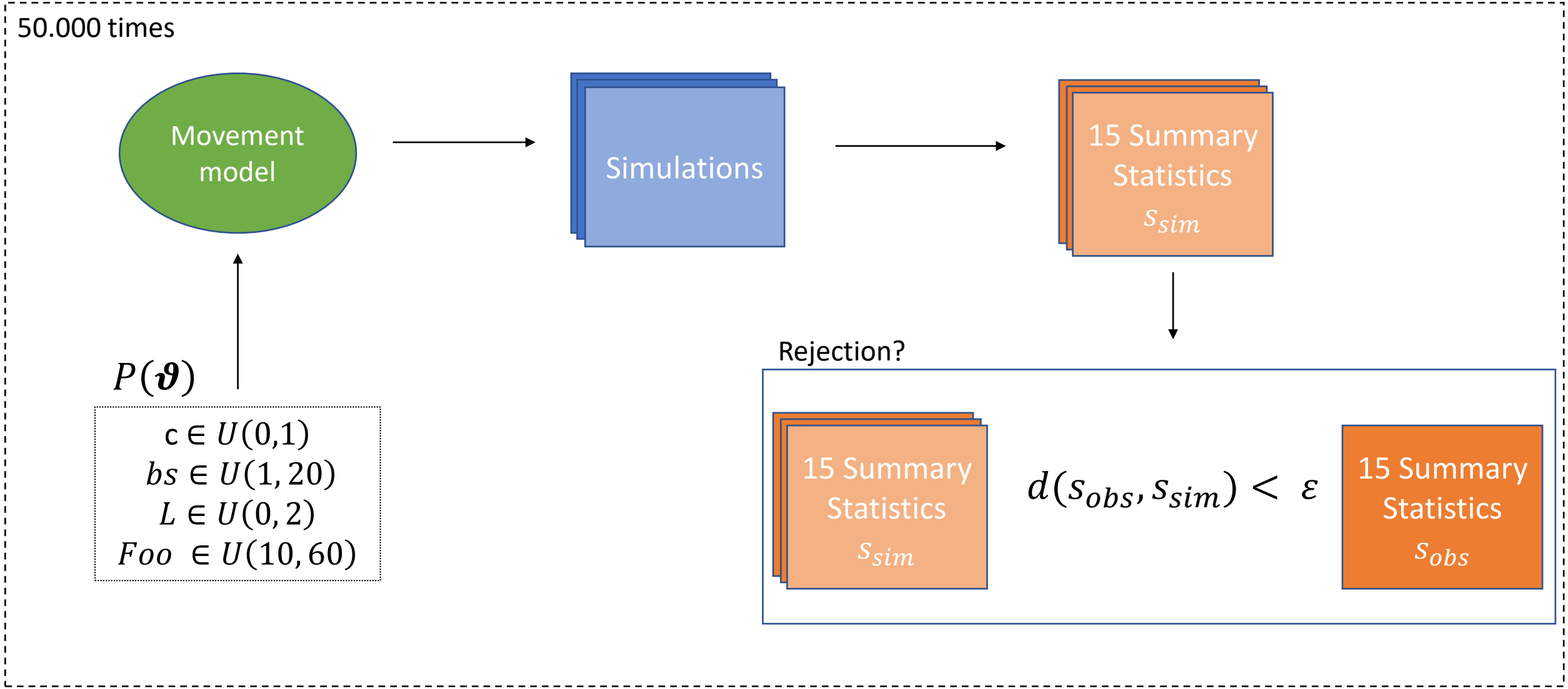
1. Approximation: from observations to path characteristics



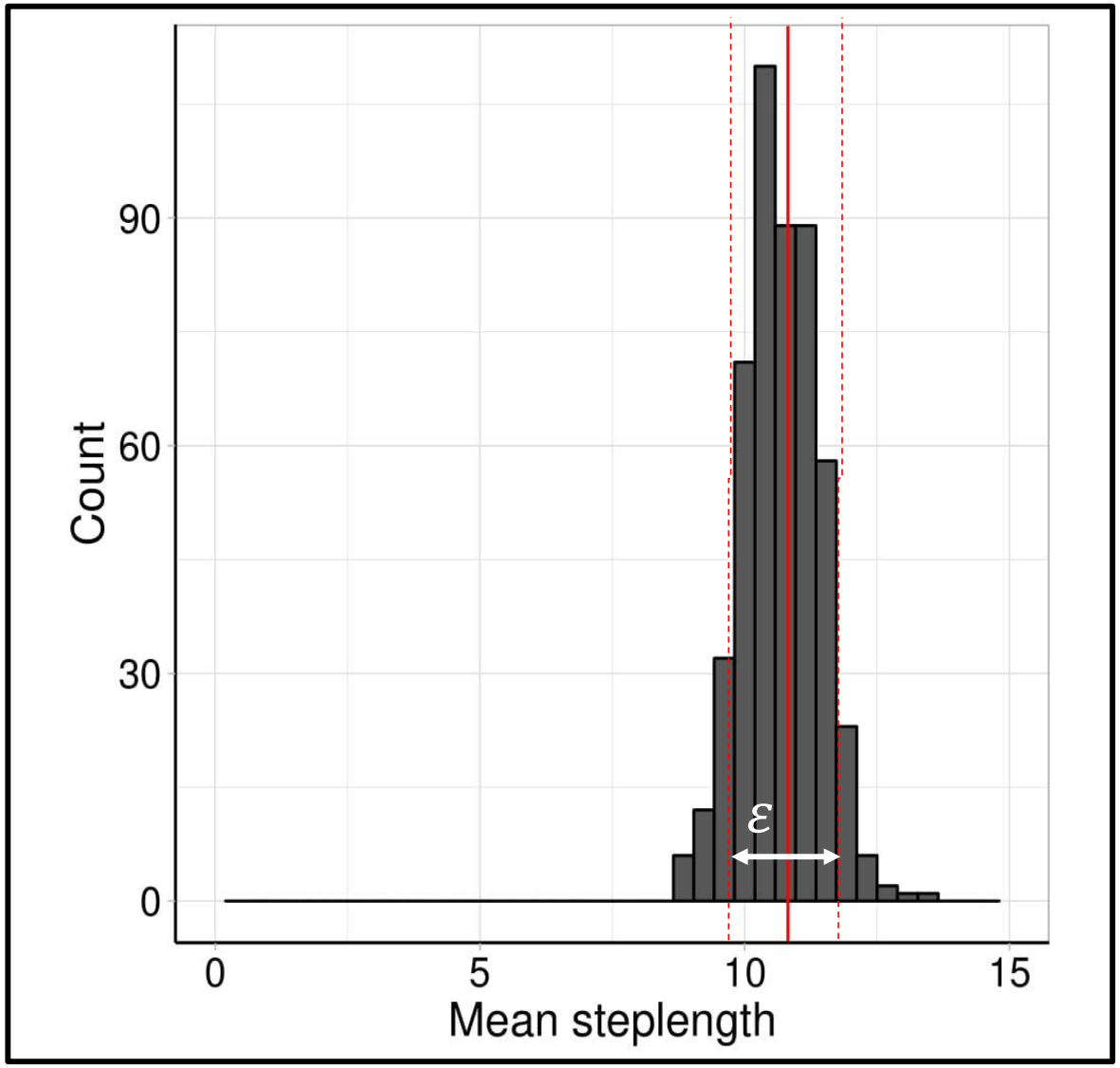
ID	day	time	x	y
…				
90	1	3.54	53.811	3.353
91	1	3.58	55.605	0.198
92	1	3.63	56.668	-0.646
93	1	3.67	58.46	-2.96
…				

Meansteplength	4.888
Sdsteplength	8.433
Meanturning	0.578
Meandayreturns	11.00
Mediandisttocamp	11.606
…	

2. Approximation: rejection sampling



2. Approximation: rejection sampling



Acceptance Rule

15 Summary Statistics s_{sim}

$d(s_{obs}, s_{sim}) < \varepsilon$

15 Summary Statistics s_{obs}

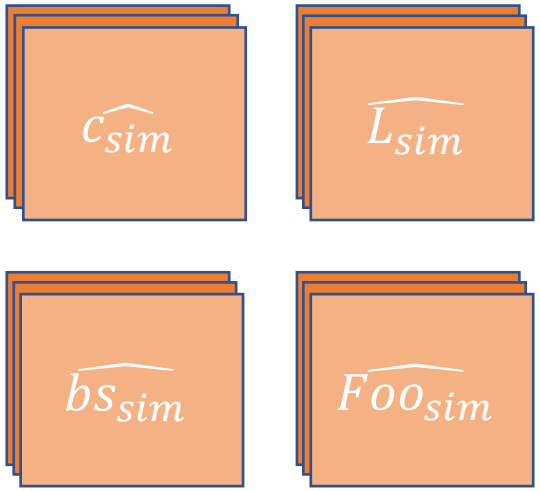
1. Approximation revisited: sufficient summary statistics

$$rf_1(c \sim s_1 + s_2 + \ldots + s_{15}, data = s_{sim}) \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \quad \hat{c} = predict(rf_1, newdata = s_{obs})$$

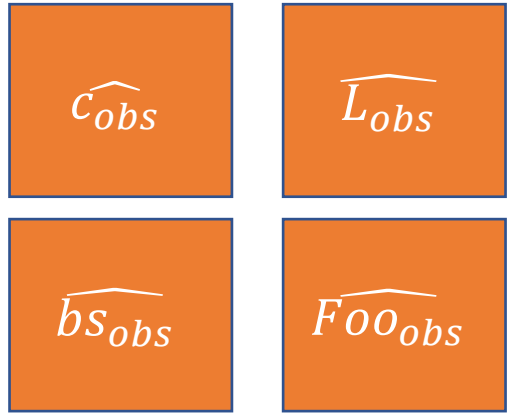
$$rf_2(bs \sim s_1 + s_2 + \ldots + s_{15} + \hat{c}, data = s_{sim}) \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \quad \widehat{bs} = predict(rf_1, newdata = s_{obs})$$

$$rf_3(L \sim s_1 + s_2 + \ldots + s_{15} + \hat{c} + \widehat{bs}, data = s_{sim}) \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \quad \widehat{L} = predict(rf_1, newdata = s_{obs})$$

$$rf_4(Foo \sim s_1 + s_2 + \ldots + s_{15} + \hat{c} + \widehat{bs} + \hat{L}, data = s_{sim}) \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \quad \widehat{Foo} = predict(rf_1, newdata = s_{obs})$$

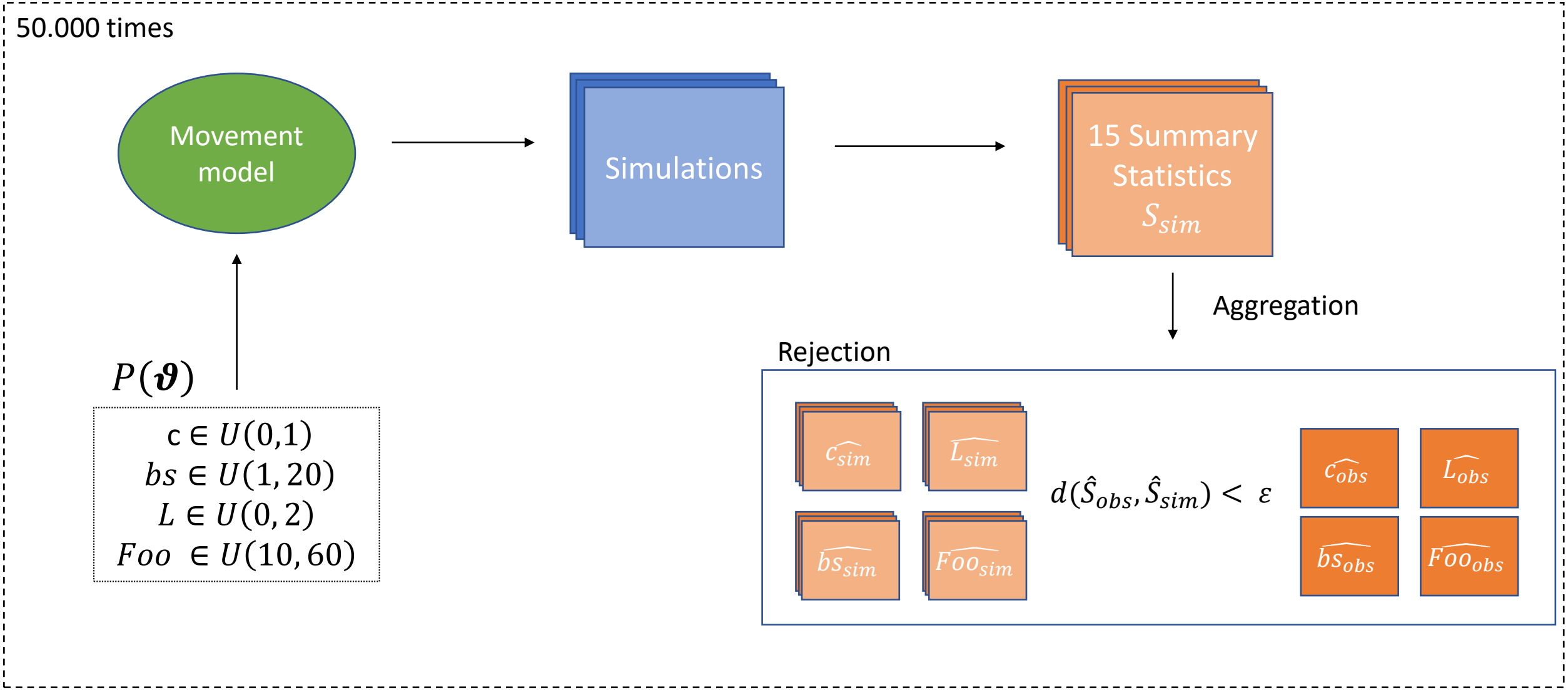


$$= \hat{s}_{sim}$$



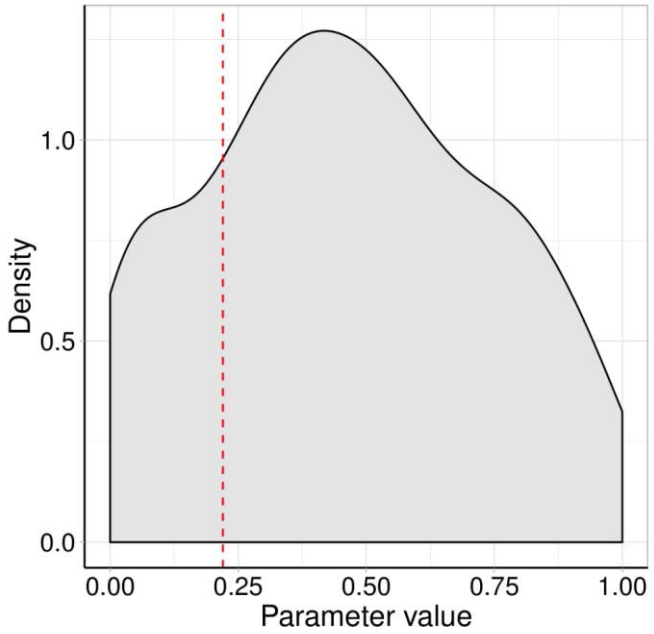
$$= \hat{s}_{obs}$$

2. Approximation: rejection sampling

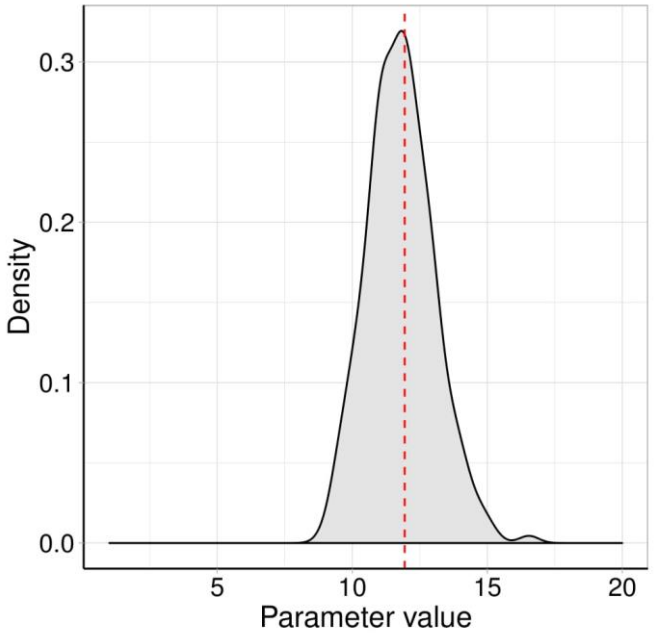


ABC posterior distributions

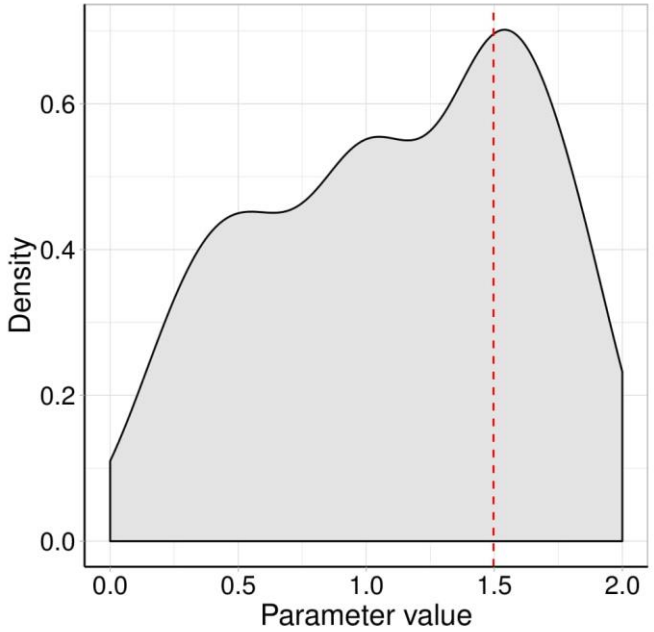
Concentration



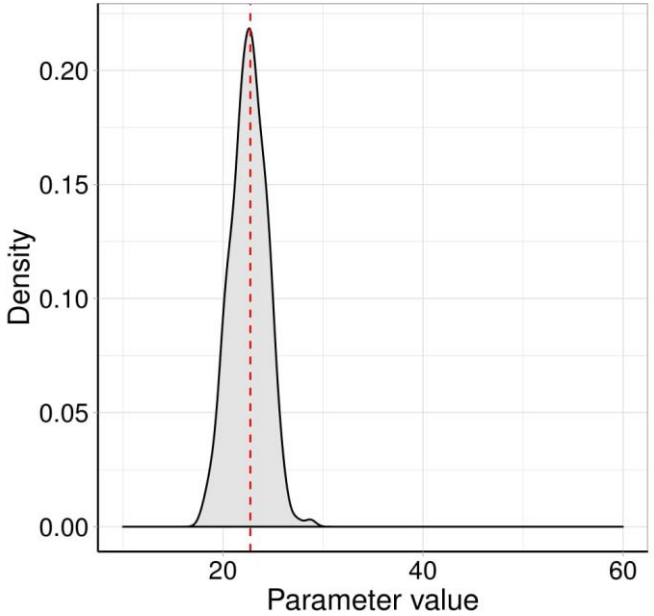
Basket size



Laziness



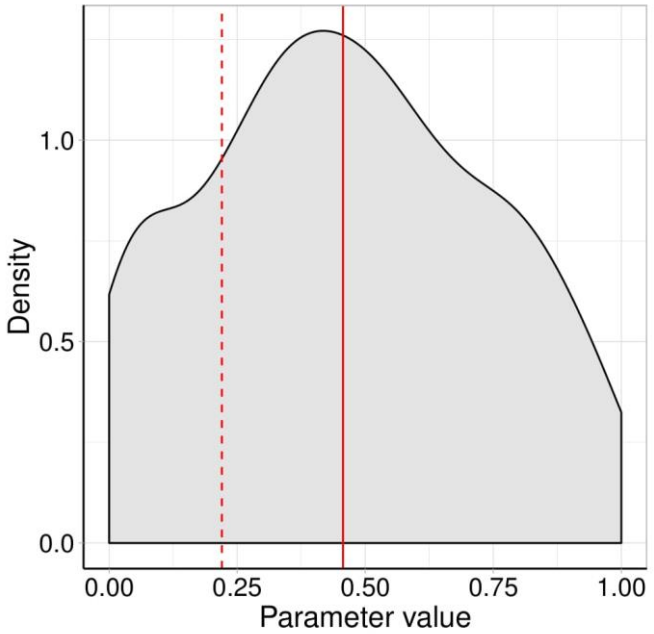
Food radius



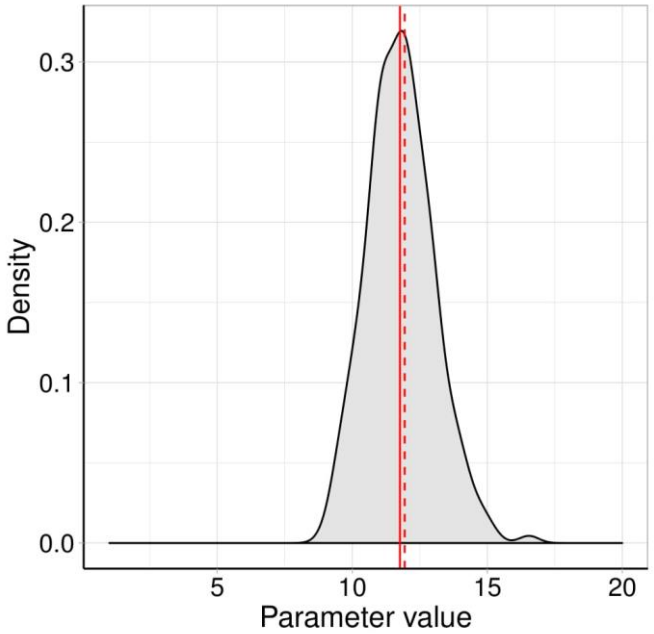
True Parameter value

ABC posterior distributions

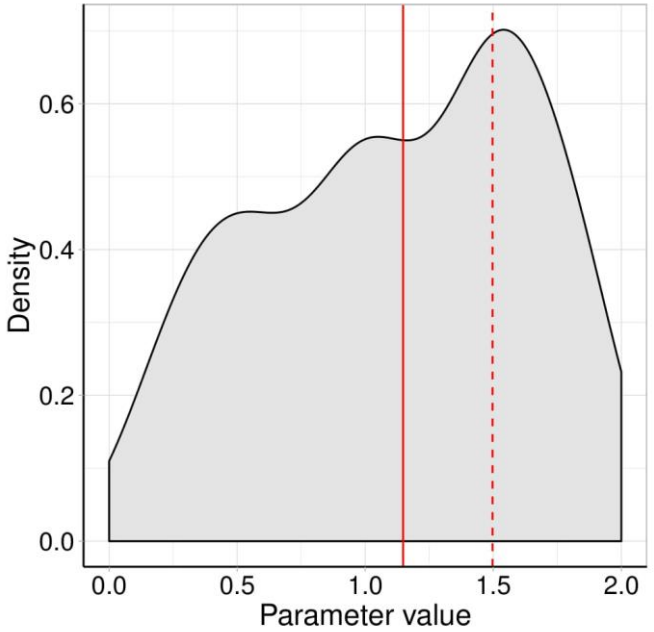
Concentration



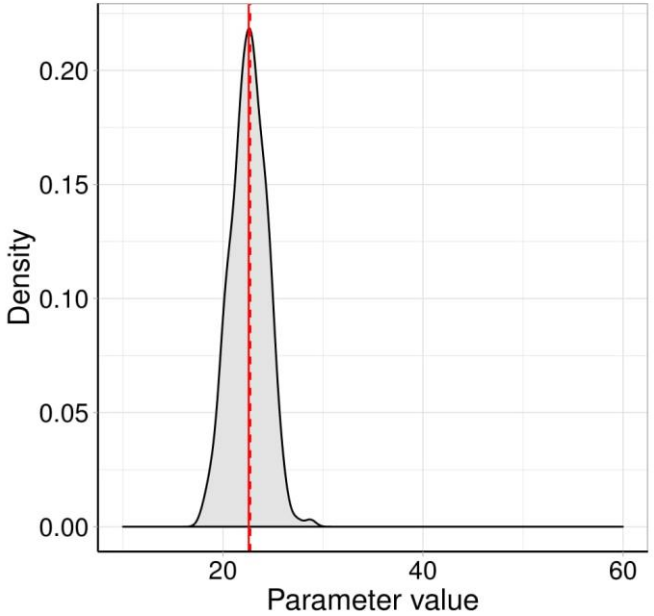
Basket size



Laziness



Food radius



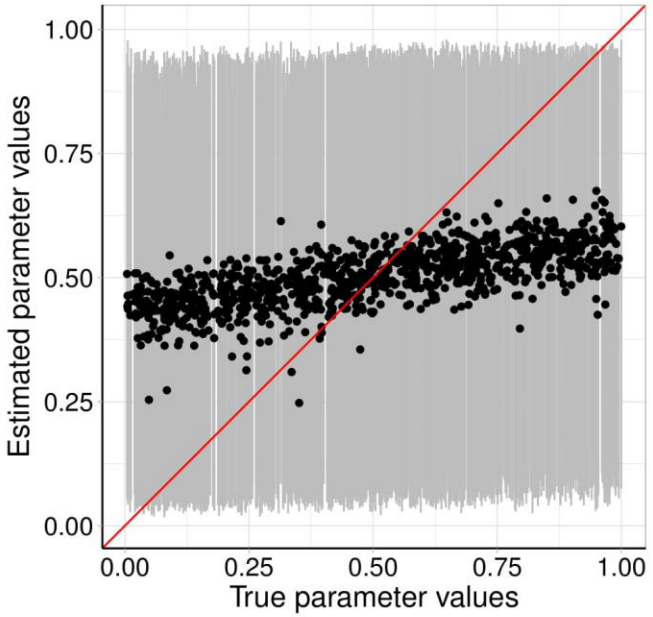
True Parameter values

Estimated Parameter values

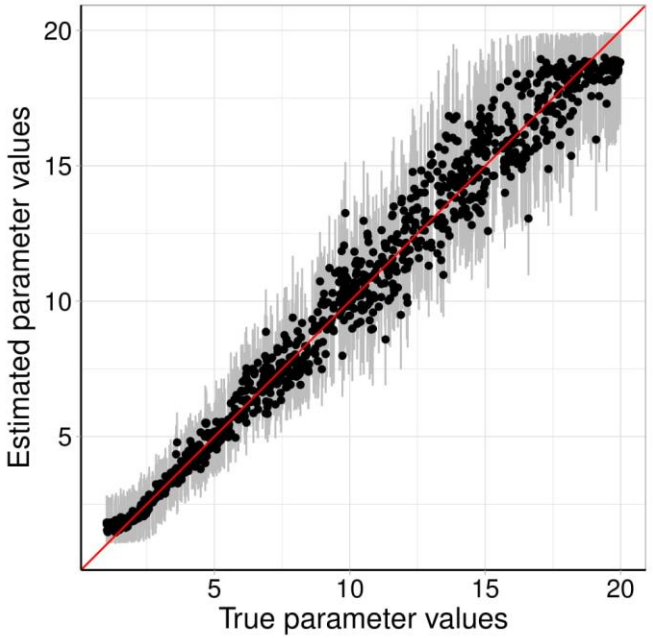
$\hat{c}$ $\hat{L}$

$\widehat{bs}$ $\widehat{Foo}$

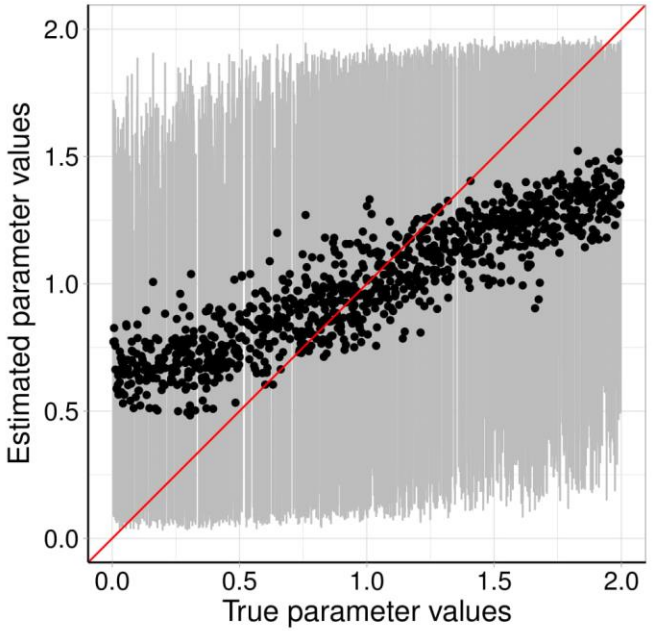
Concentration



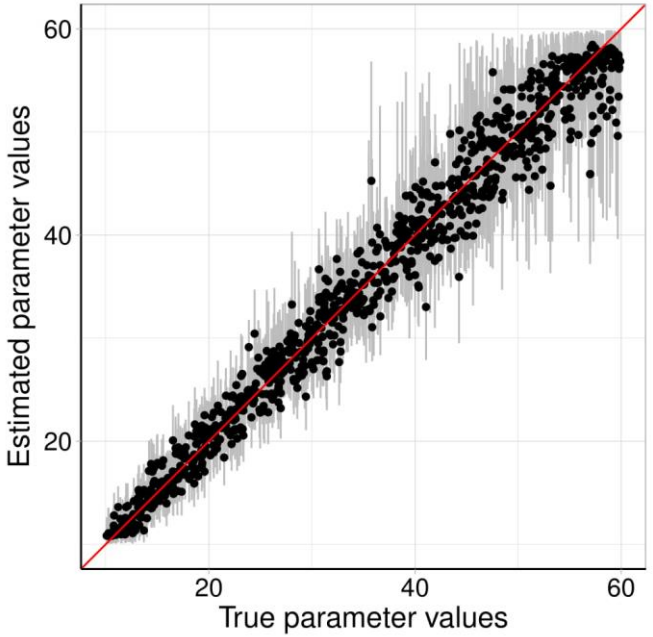
Basket size



Laziness

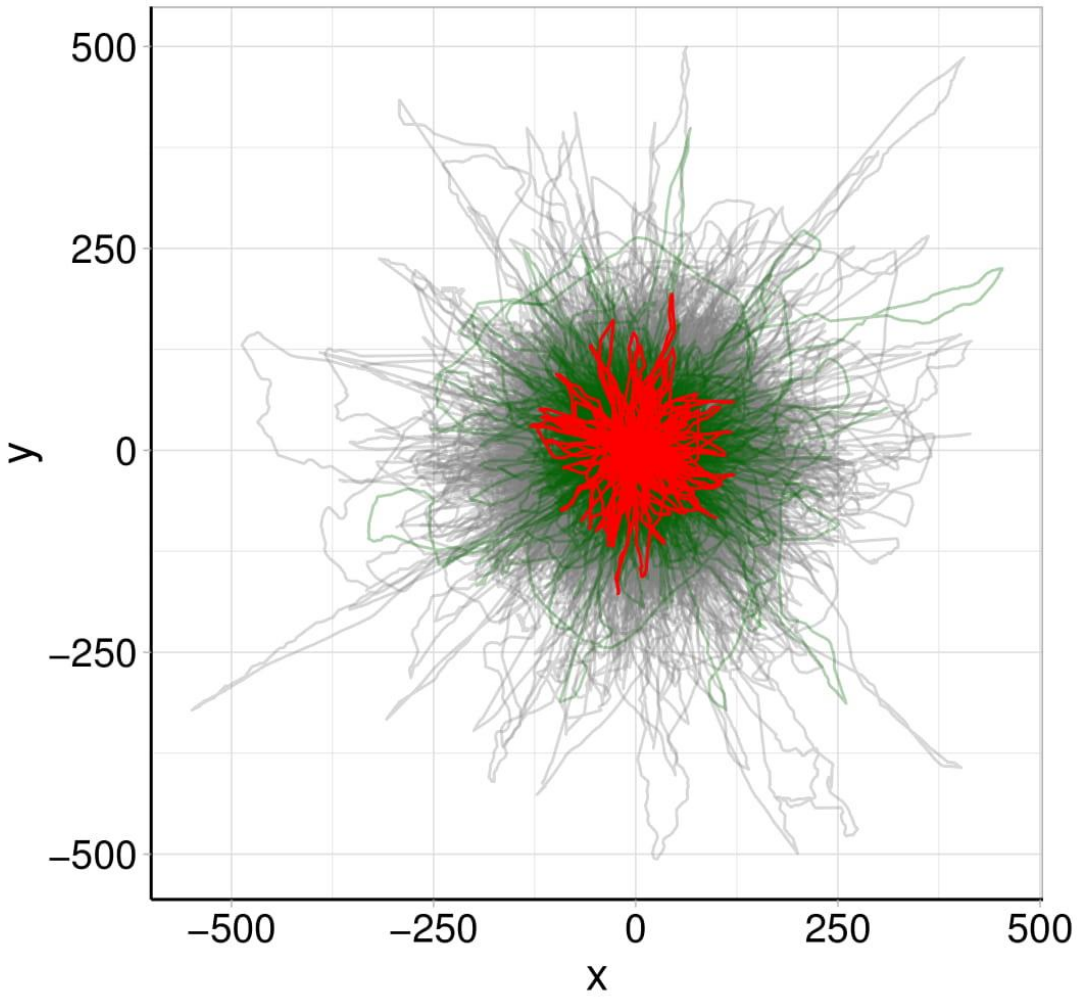


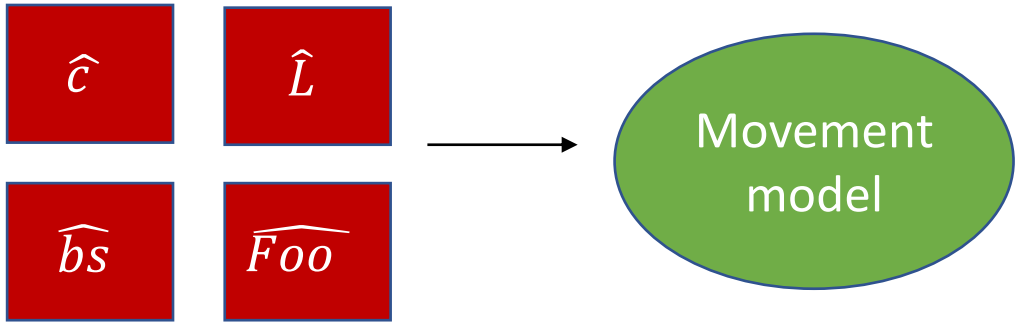
Food radius



Random forest regression

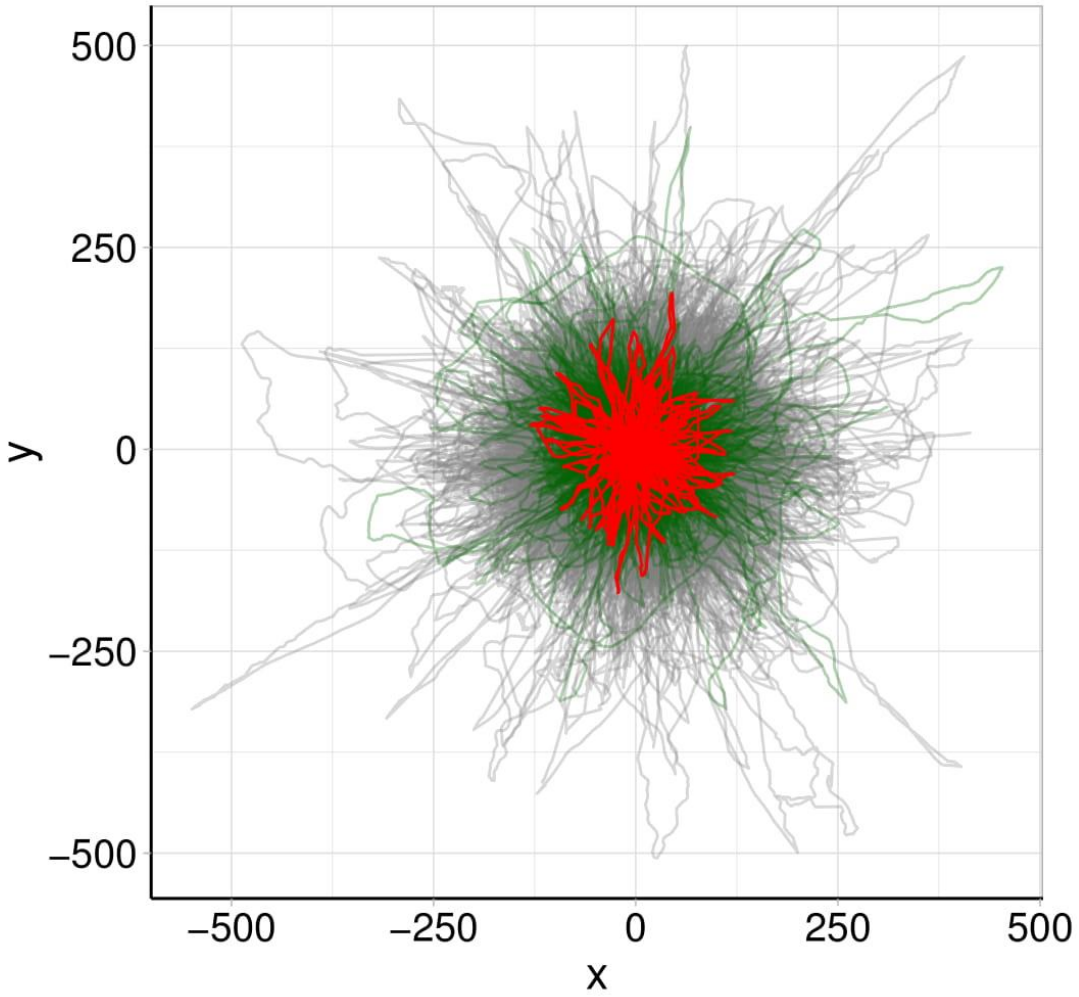
Predicting paths





Random
Accepted
Predicted

Predicting paths



Thank you!

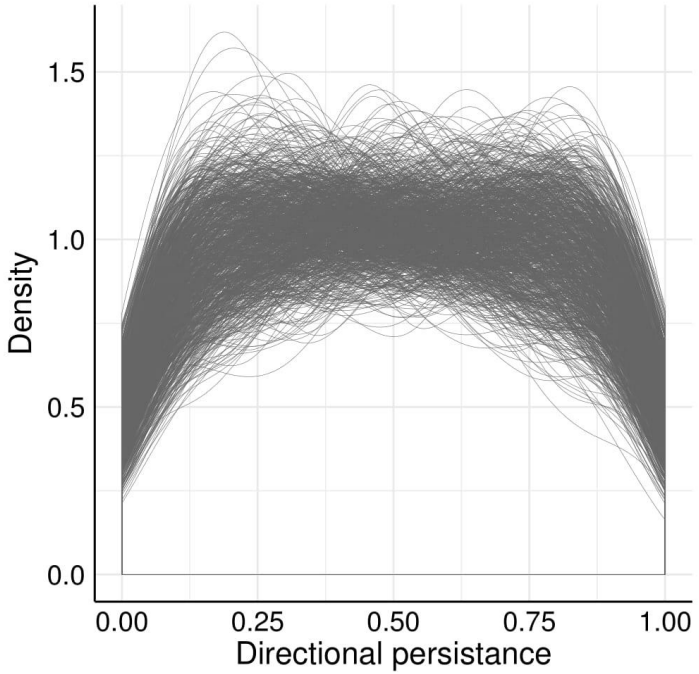
Random forest: summary statistics importance

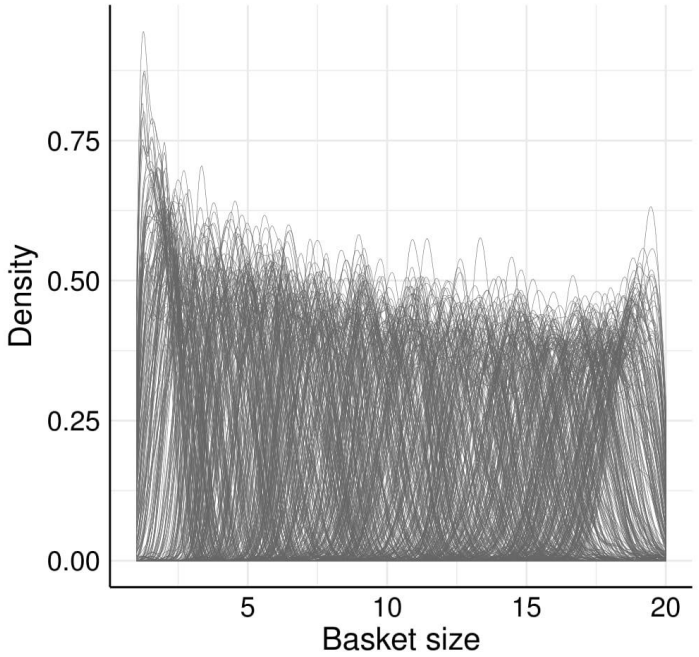
RF1: variable importance (impurity)

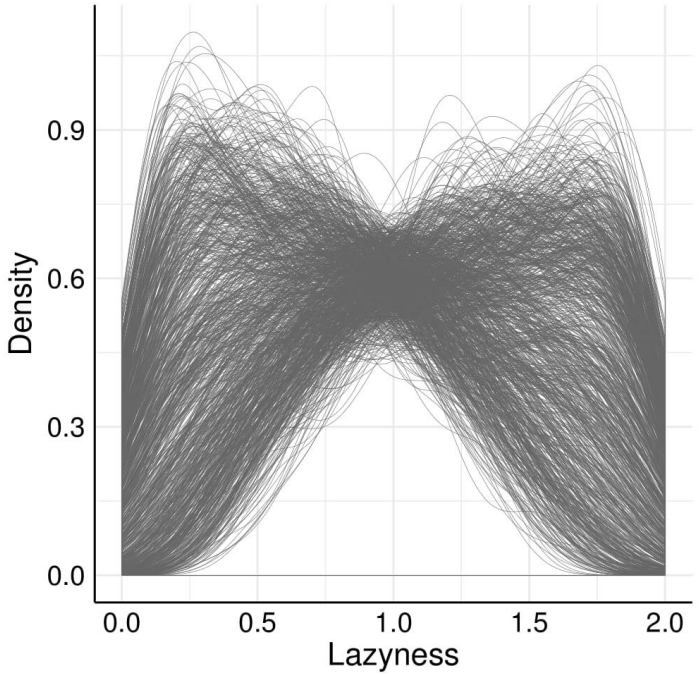
Meandisplacement3	42.57915
Displacementbydistance	63.40940
meandisplacement	68.09301
meandisttocamp	90.80862
sddisplacement3	92.88594
quantile50	93.97087
xquantile90	95.74502
sddisplacement	114.44592
maxdisttocamp	131.01203
mediandisttocamp	131.63789
sdturning3	341.68142
Meandayreturns	454.50767
sdturning	517.69378
meanturning3	688.93763
Meanturning	1144.57222

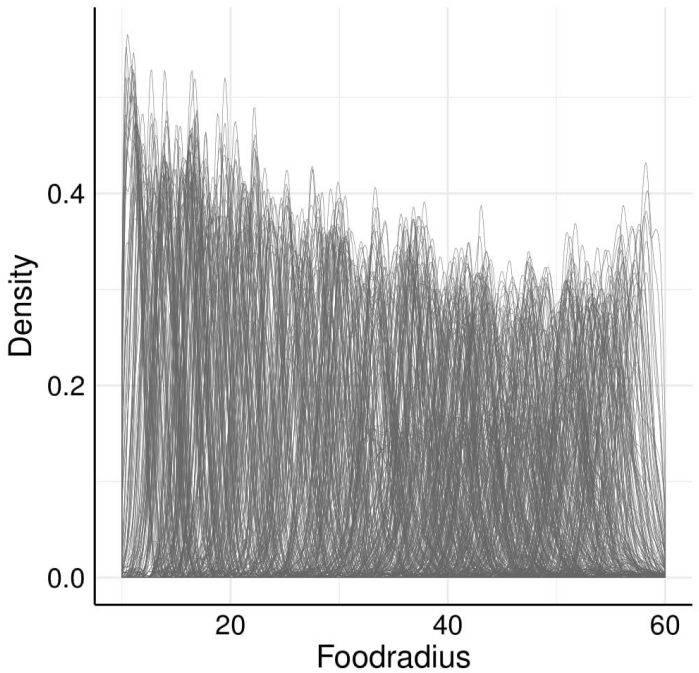
RF2: variable importance (impurity)

Sdturning	3982.244
maxdisttocamp	5657.688
meanturning	7387.011
sdturning3	10913.640
c	13574.786
sddisplacement3	17892.071
xquantile90	27949.146
meanturning3	40984.235
Meandisplacement3	42971.396
sddisplacement	62092.707
meandisttocamp	86890.544
meandisplacement	108211.122
xquantile50	138974.935
mediandisttocamp	215024.889
Displacementbydistance	311789.108
meandayreturns	378759.727









ABC posterior distributions for 1000 individuals