eflowsim: A simulation framework for e-flows power analysis

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Odum School of Ecology
University of Georgia

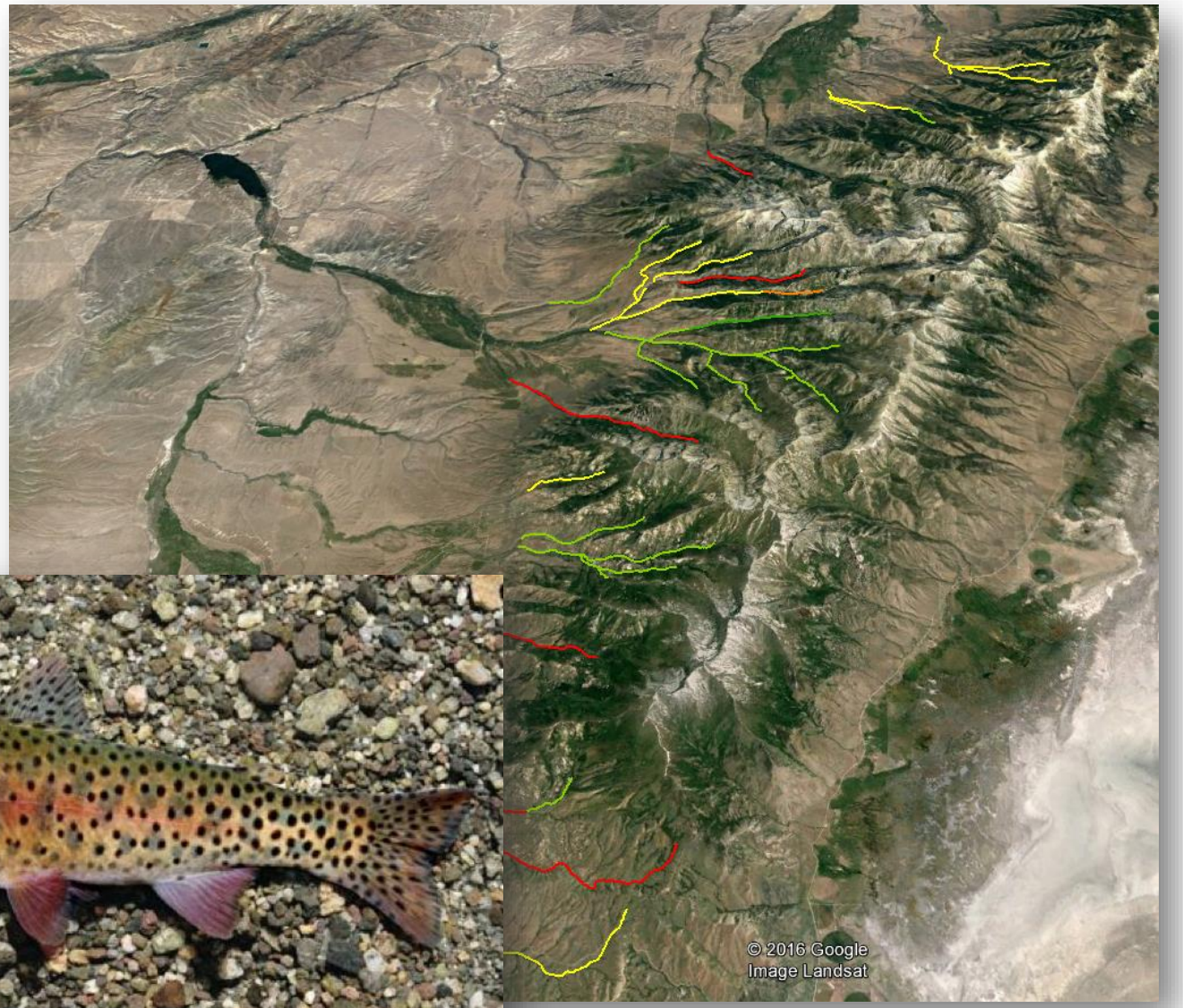
The Salmonid Population Viability Project

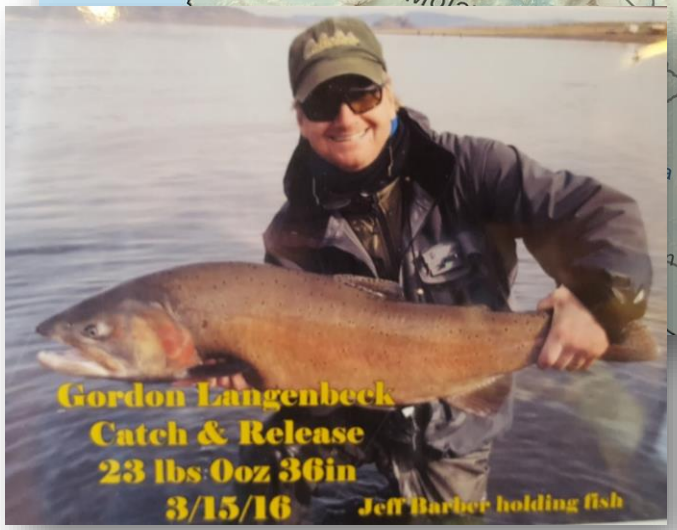
Lahontan Cutthroat Trout

Seth Wenger, Doug Leasure, Helen Neville, Dan Dauwalter, Kurt Fessenmyer, Robin Bjork, Jason Dunham, Nate Chelgren, Mary Peacock, Erin Landguth

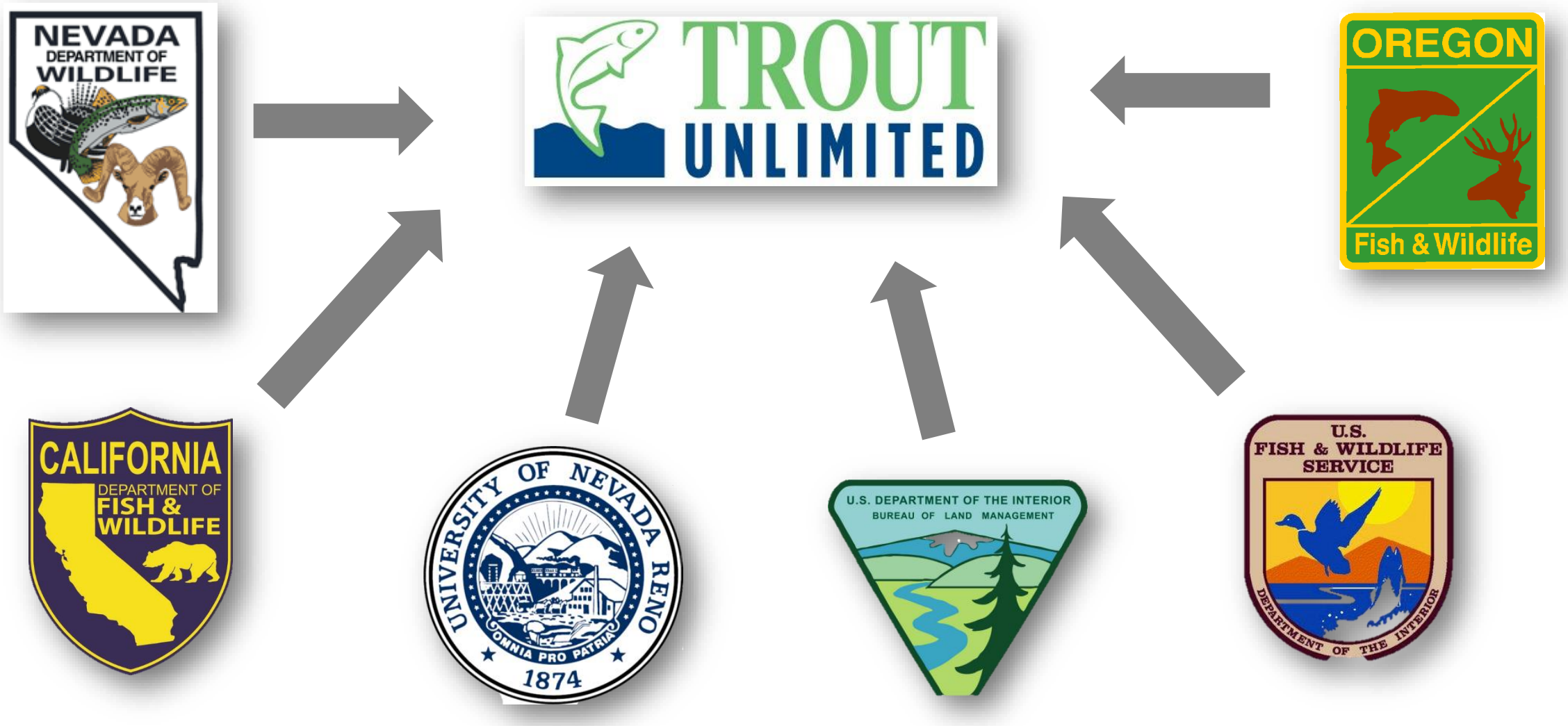
Lahontan Cutthroat Trout

(*Oncorhynchus clarkii henshawi*)

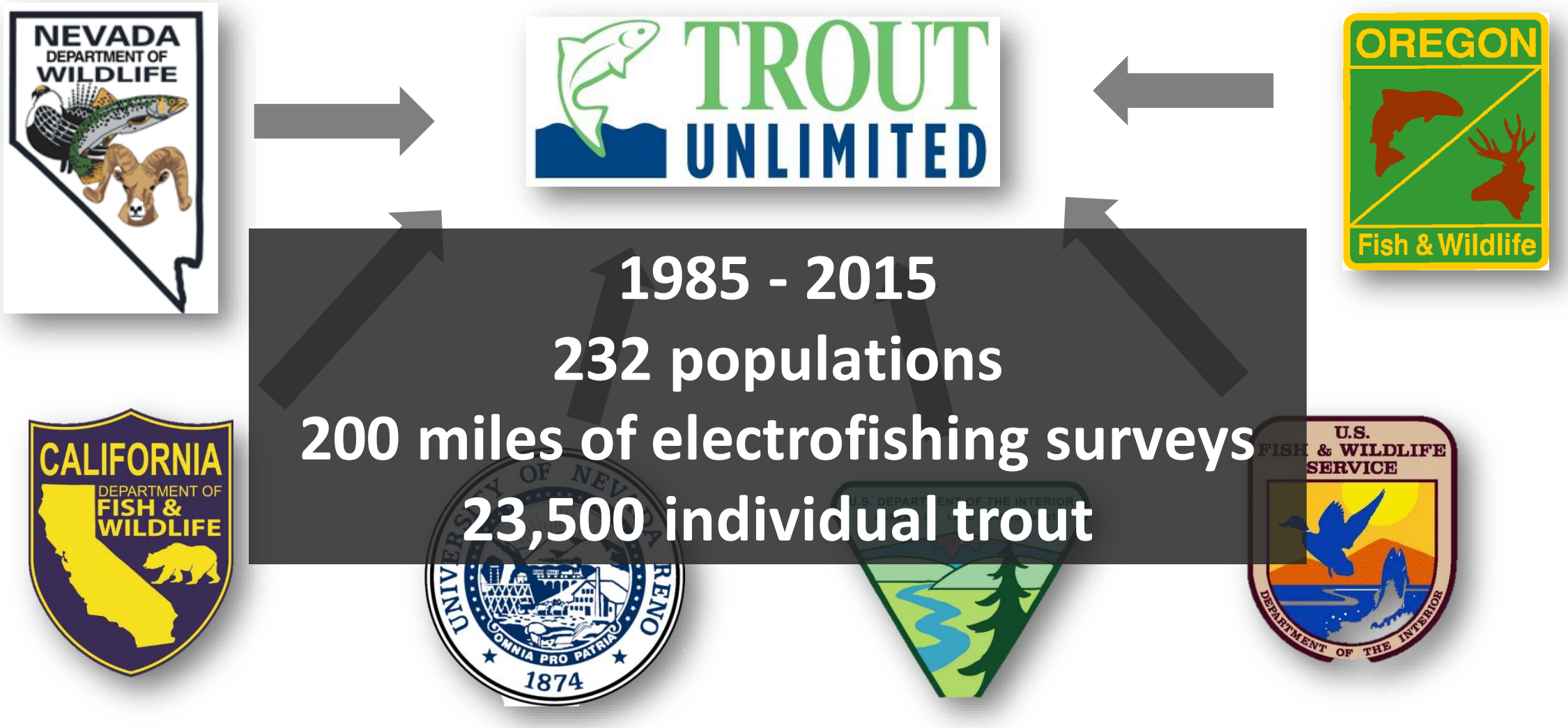




Lahontan Cutthroat Trout: Database



Lahontan Cutthroat Trout: Database



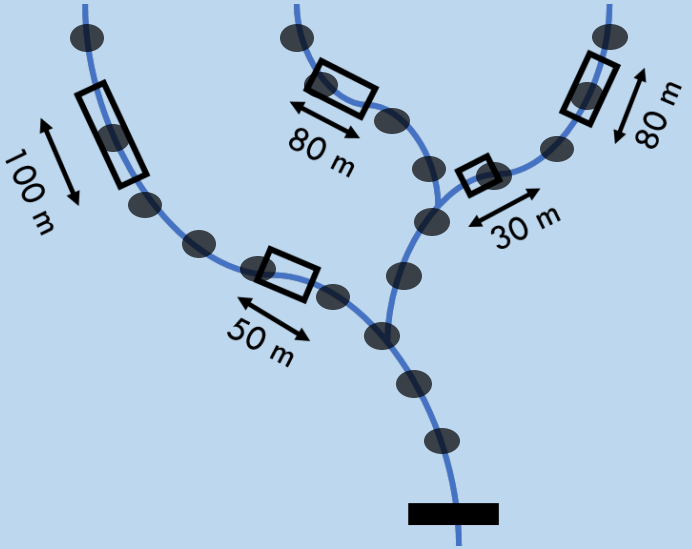
Spatio-Temporal Population Viability Analysis

Observation Model

Site abundance = observed + unobserved animals

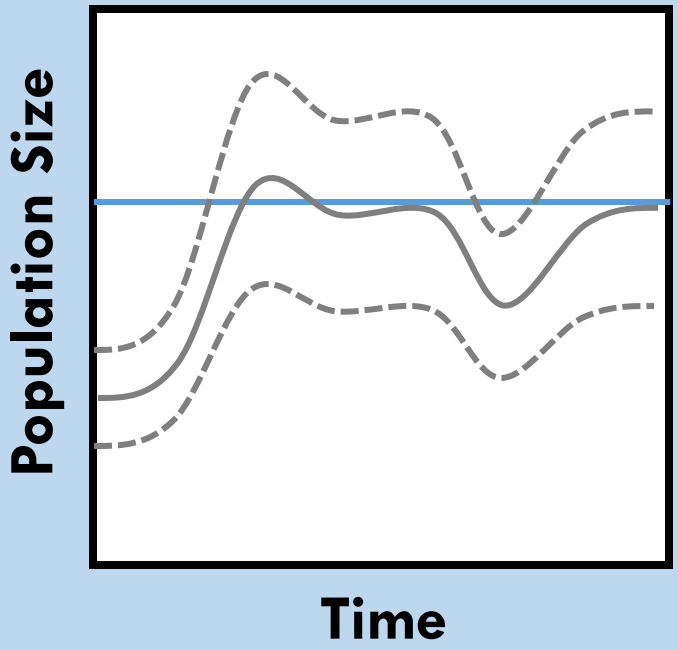
Sampling Model

Total population = sampled + unsampled habitat



Process Model

Population change = births - deaths



Spatio-Temporal Population Viability Analysis

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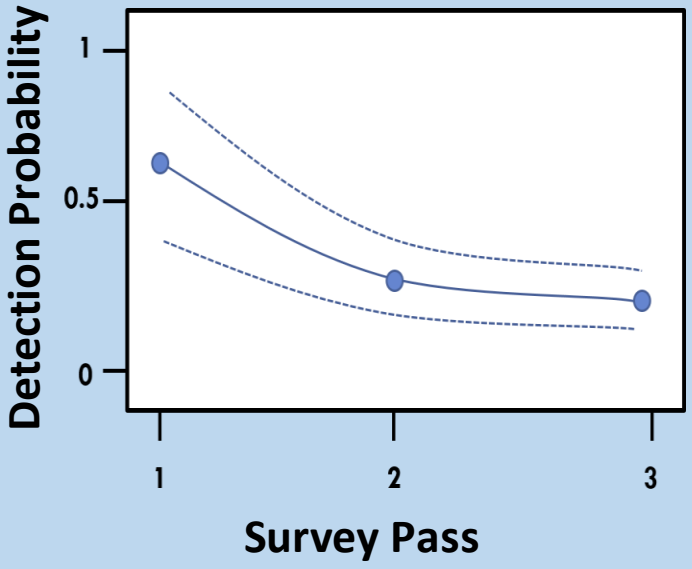

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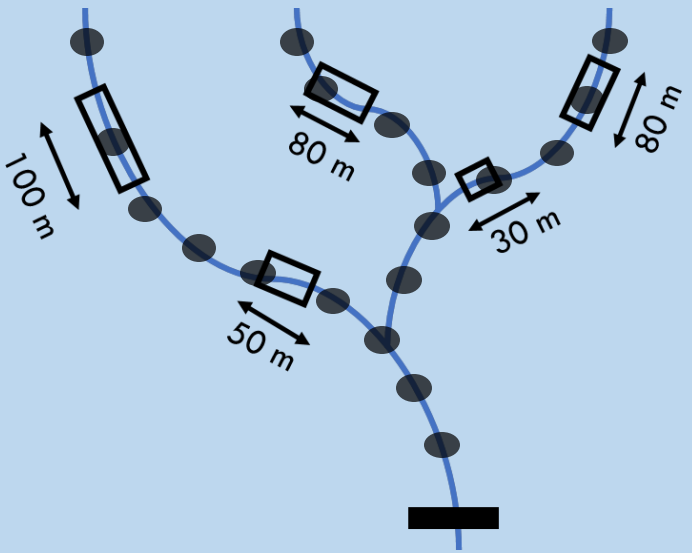

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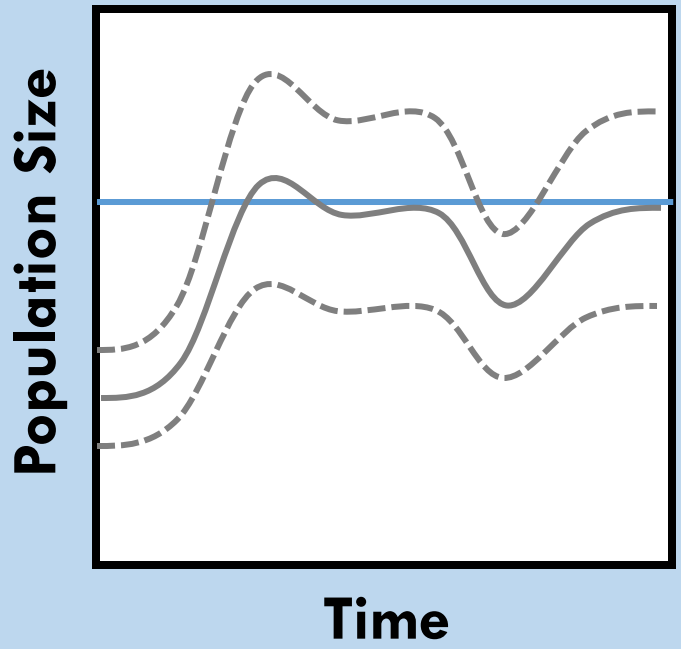

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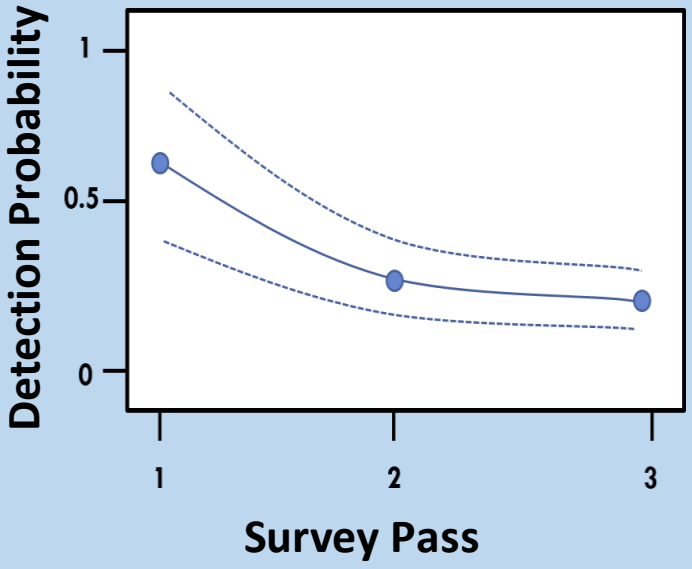

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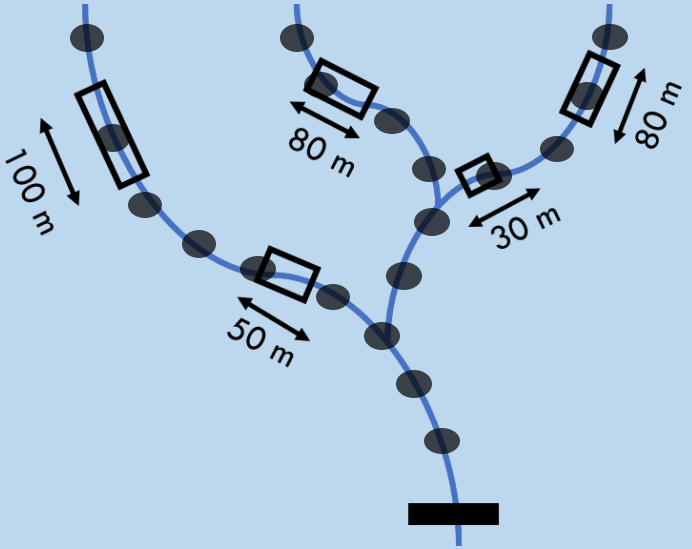

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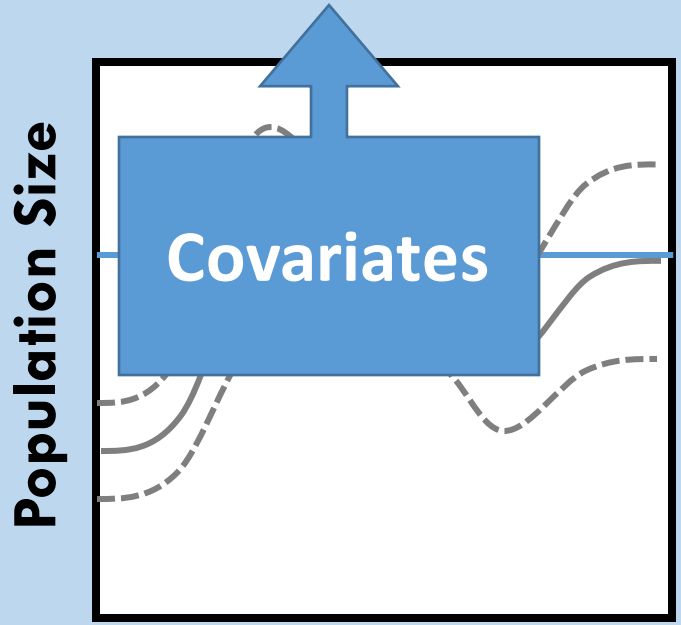

Spatio-Temp **eflowsim** iability Analysis

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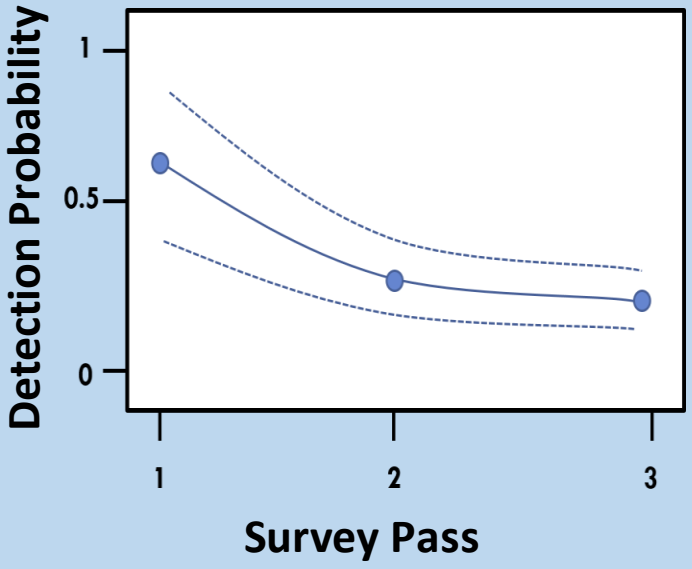

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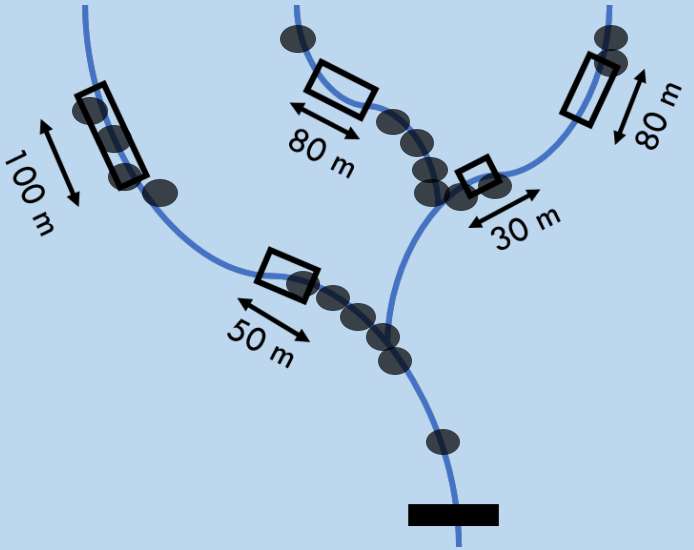

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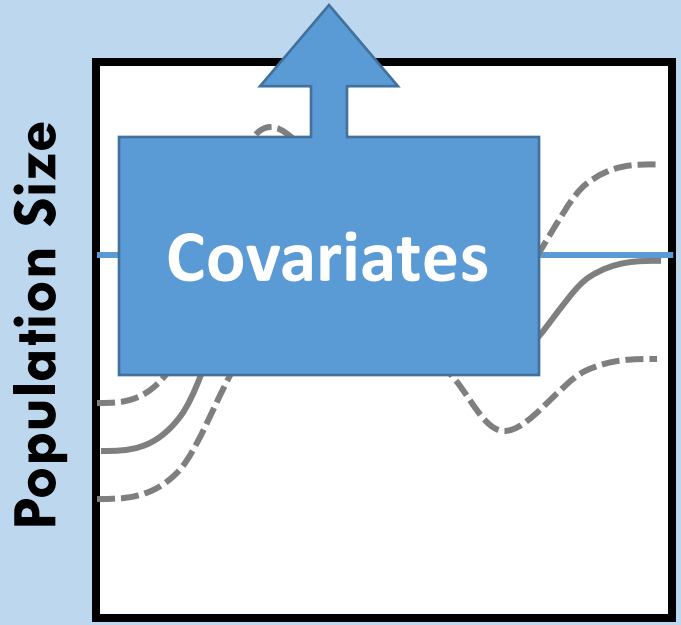
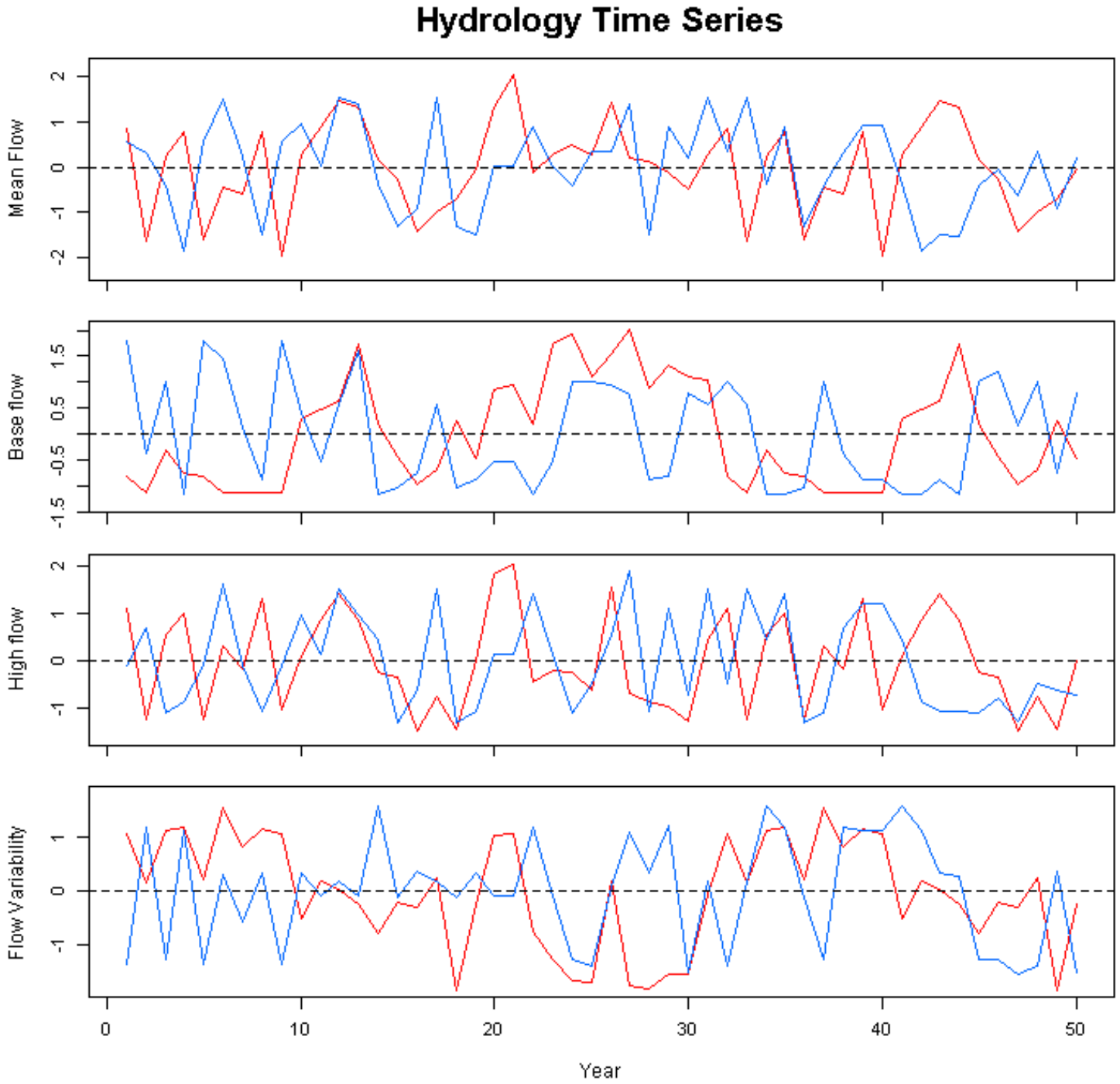
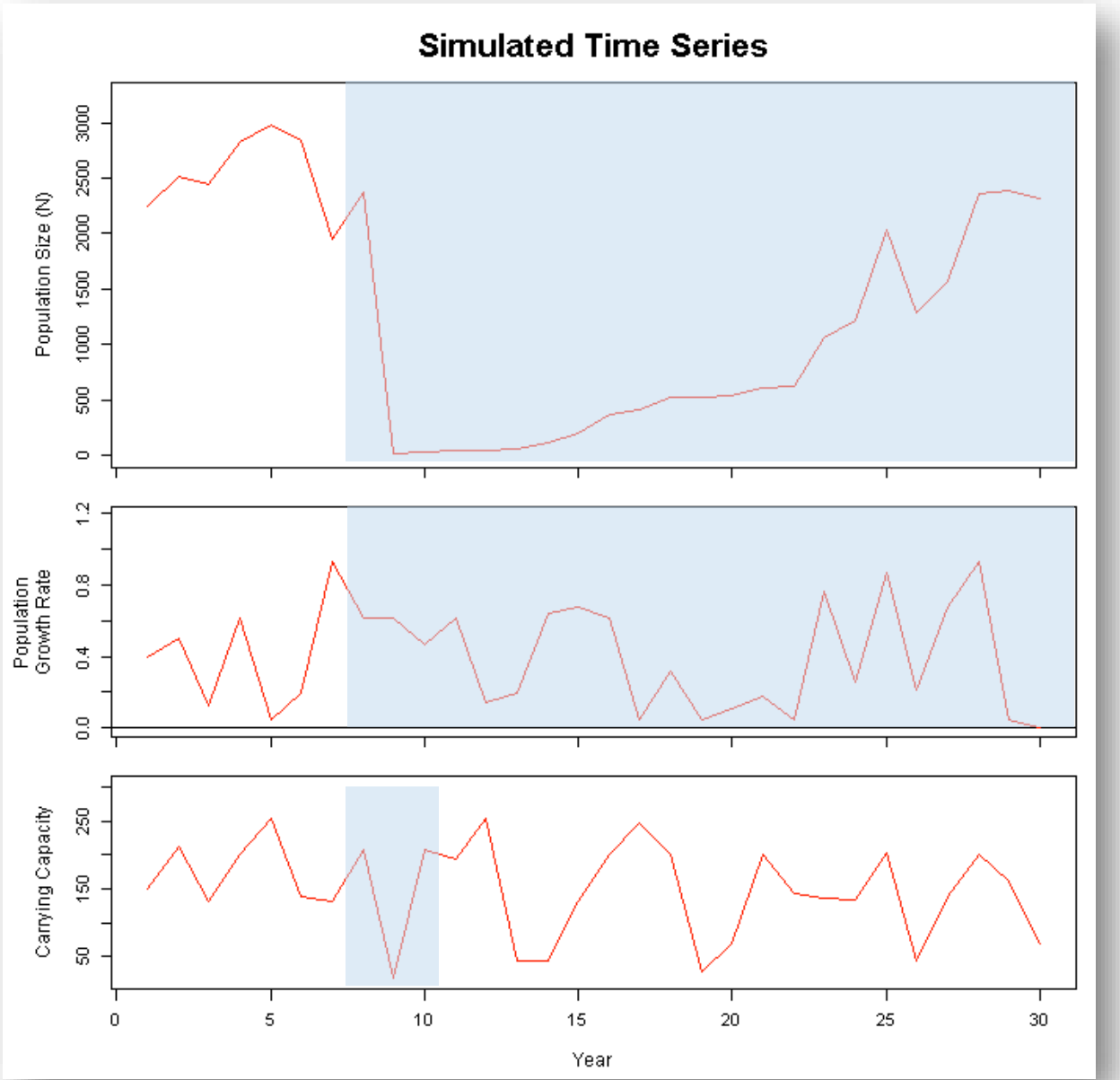


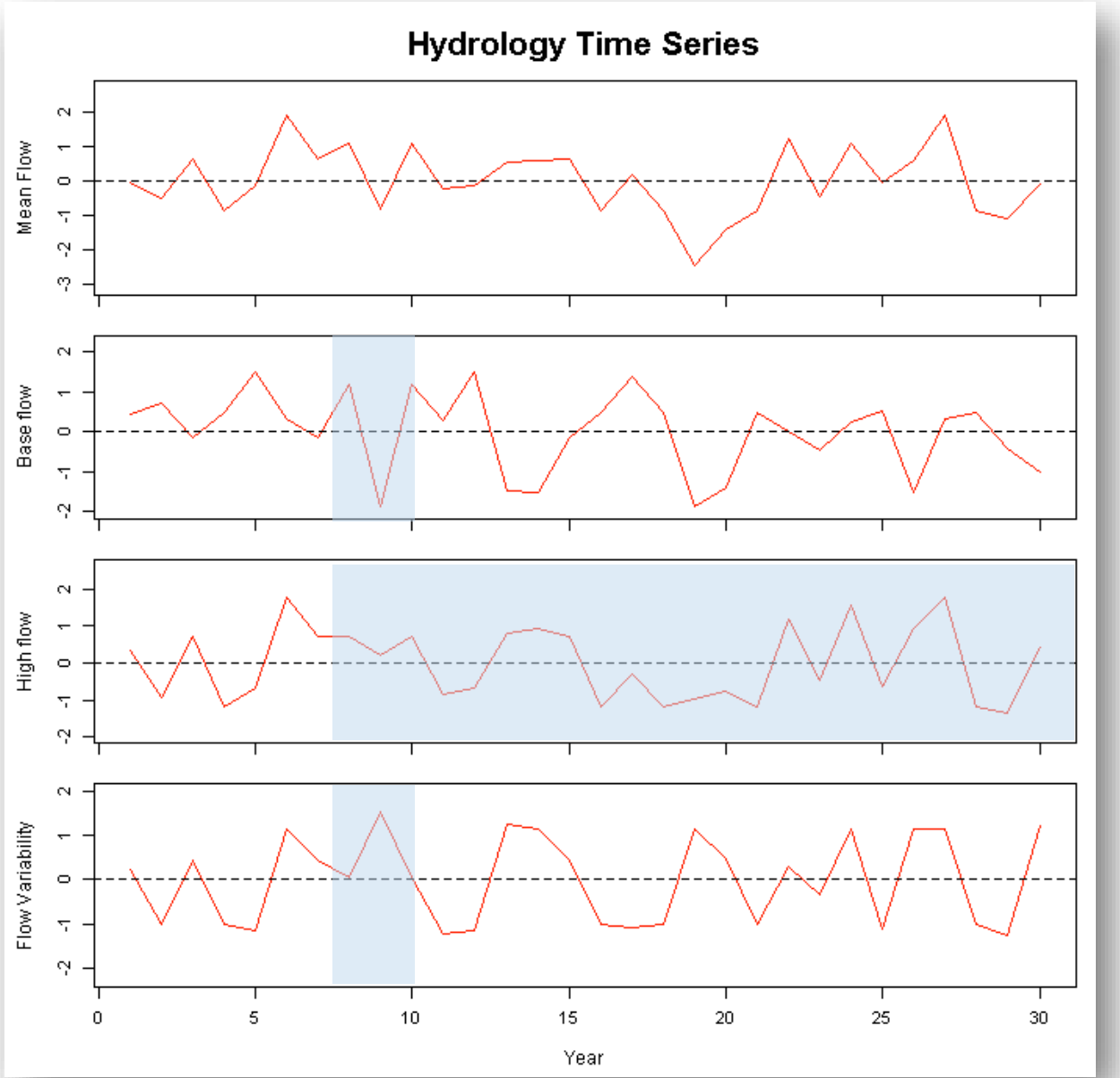
Gage ID: Maggie Creek, NV

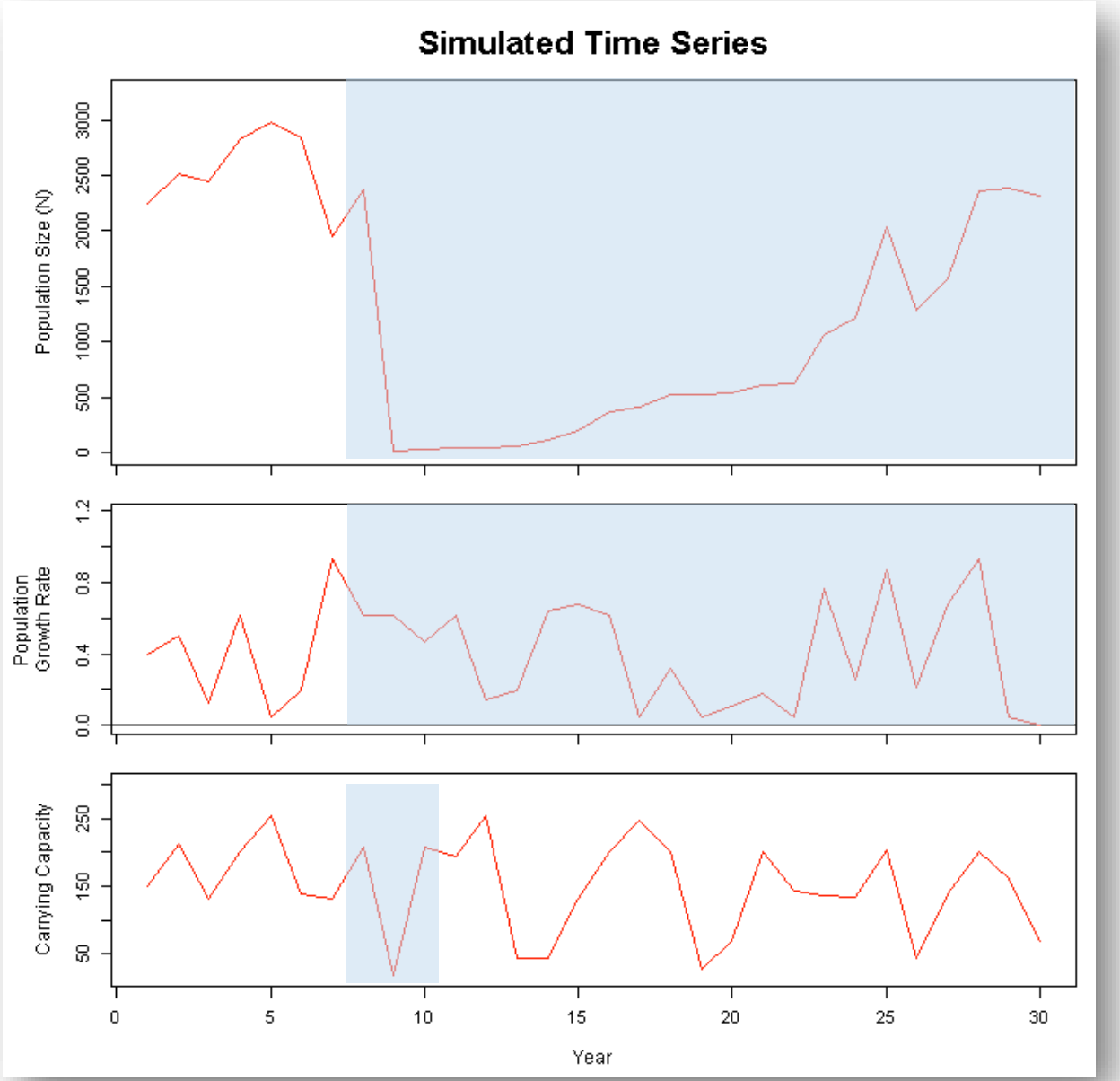
Annual Flow Statistics

1. Mean discharge
2. Base flow
3. Flood magnitude
4. Flow variability




Simulated Time Series
Population Size (N)
0
500
1000
1500
2000
2500
3000
Population Growth Rate
0.0
0.4
0.8
1.2
Carrying Capacity
50
150
250
0
5
10
15
20
25
30
Year


Hydrology Time Series
Mean Flow
Base flow
High flow
Flow Variability
-3
-2
-1
0
1
2
0
5
10
15
20
25
30
Year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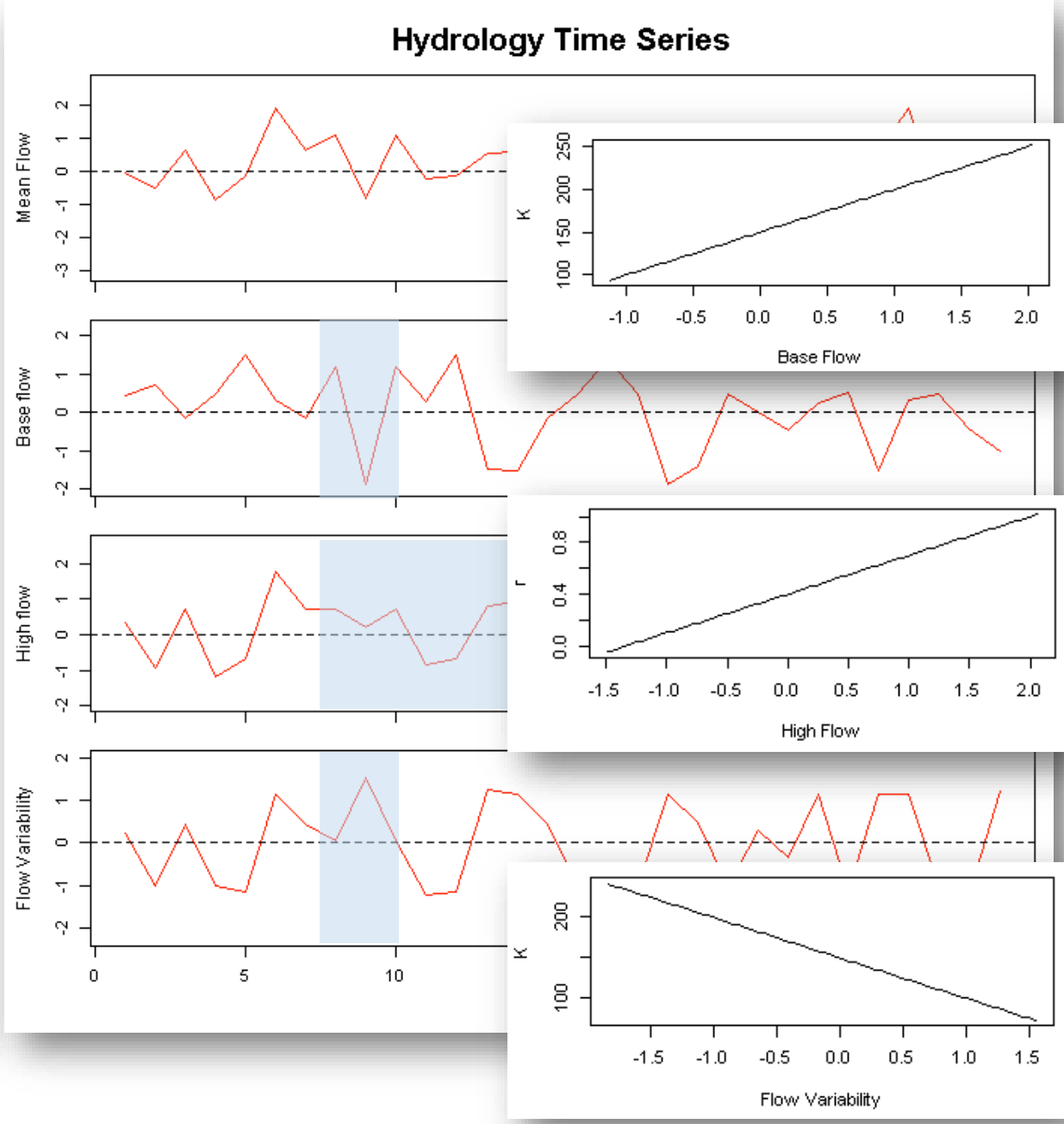
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-2
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0
1
2
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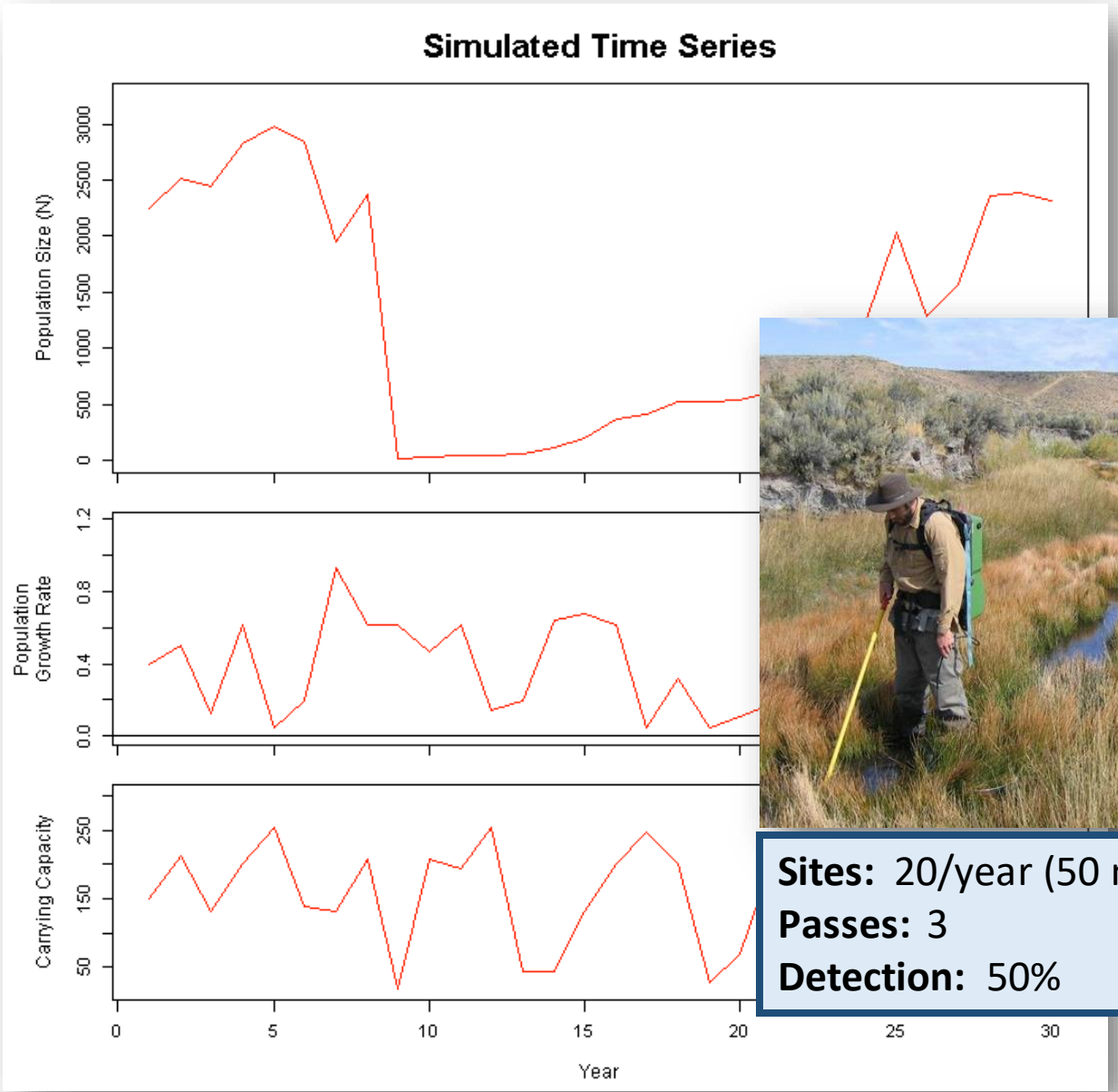
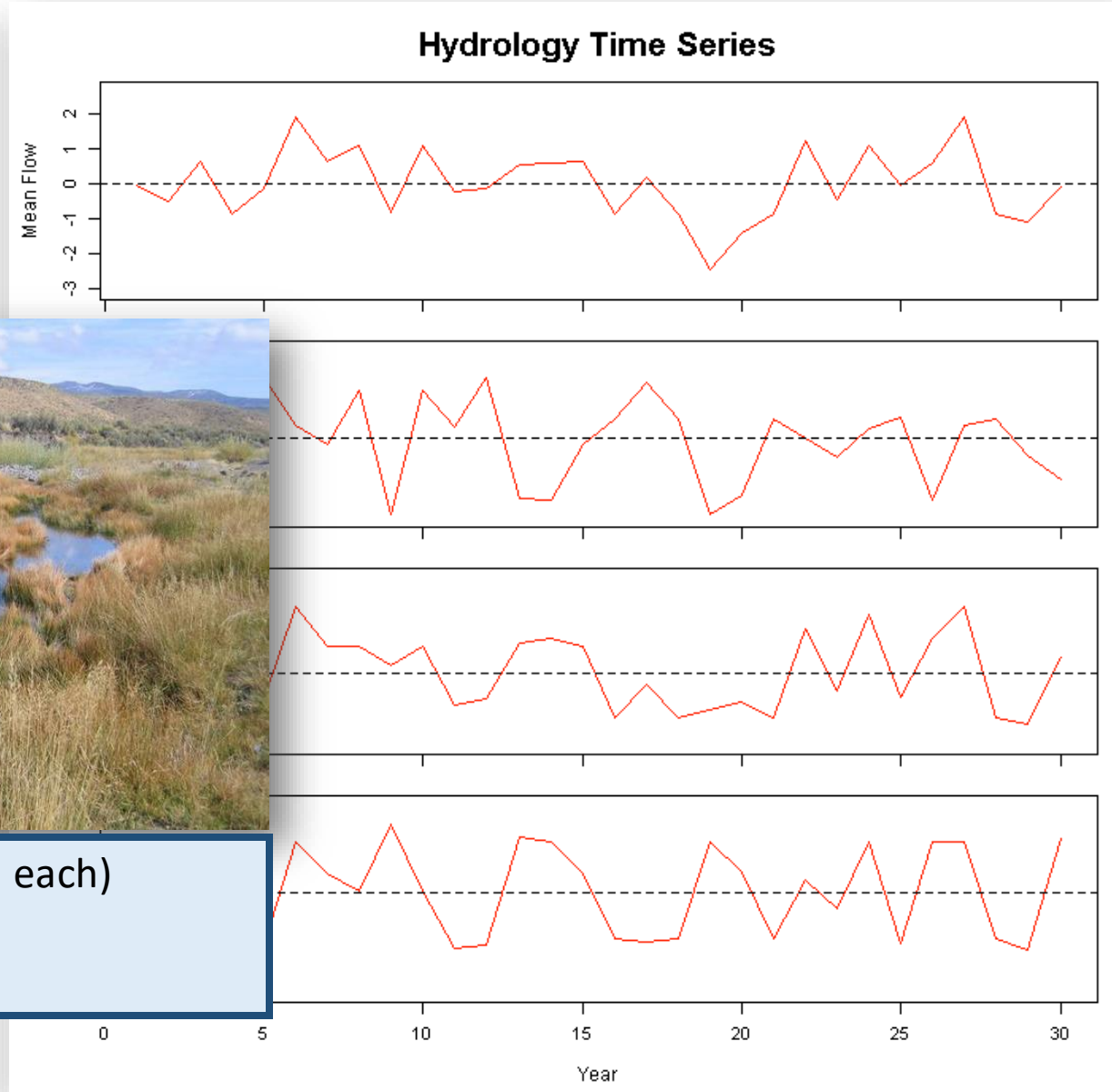
5
10
K
100
150
200
250
-1.0
-0.5
0.0
0.5
1.0
1.5
2.0
Base Flow
r
0.0
0.4
0.8
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
2.0
High Flow
K
100
200
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
Flow Variability



Sites: 20/year (50 m each)
Passes: 3
Detection: 50%



Simulation Options

Response:
Abundance estimator

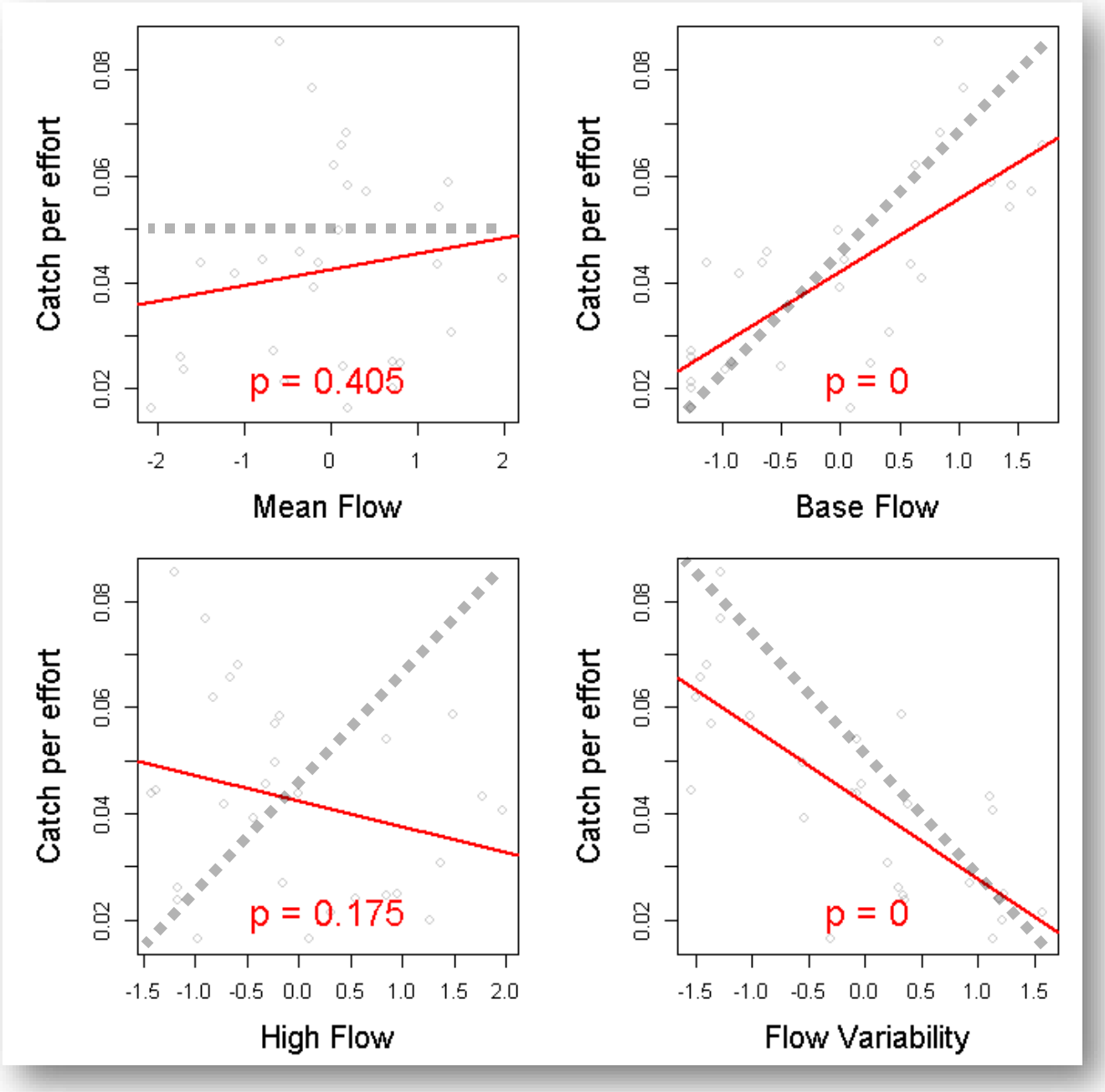
Simulations: 50
Years: 30

Showing results from only one of these simulations

Stochasticity

Demographic: 0.01
Sampling: 0.01
Detection: 0.01

Sites: 20/year (50 m each)
Passes: 3
Detection: 50%



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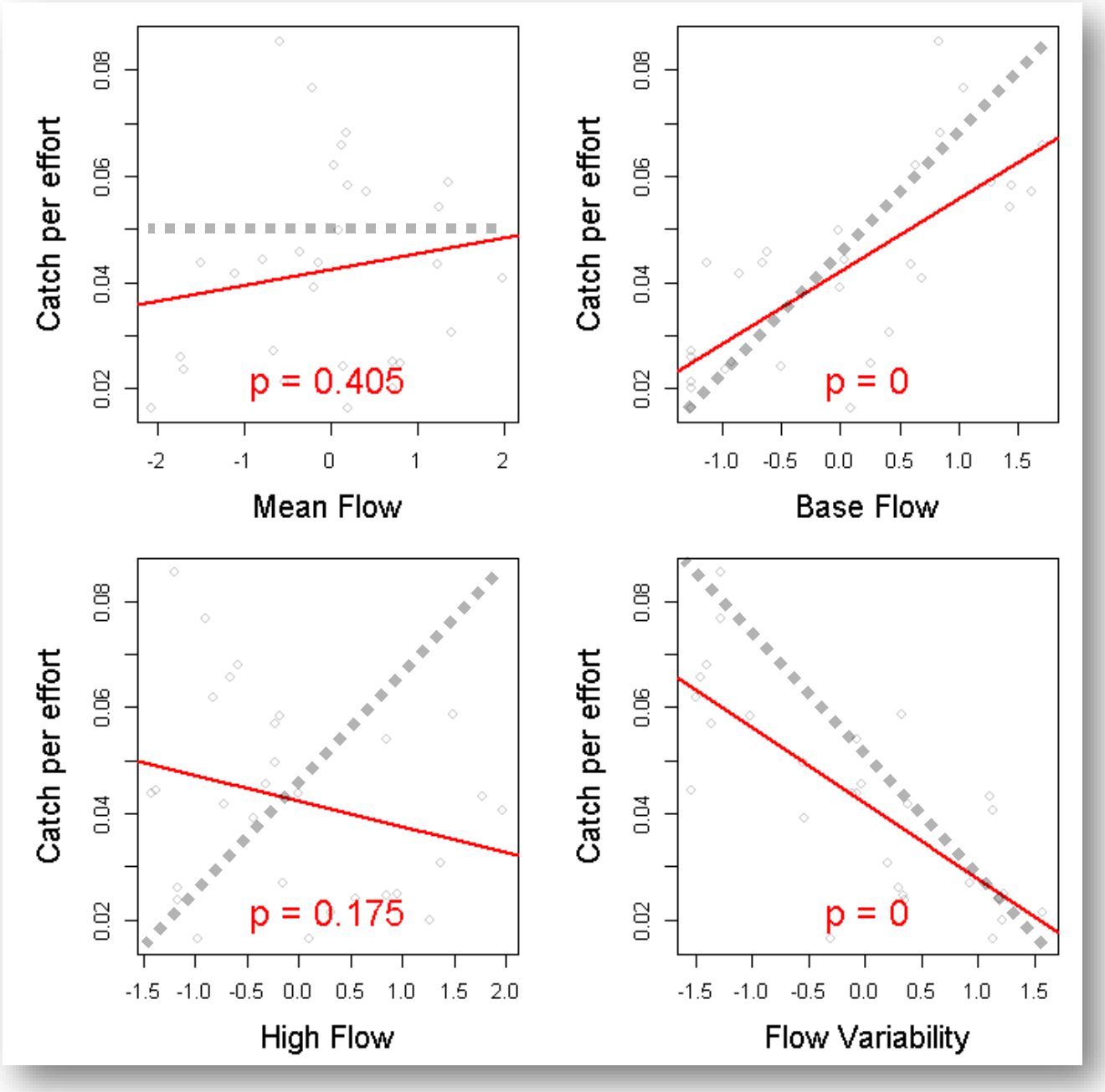

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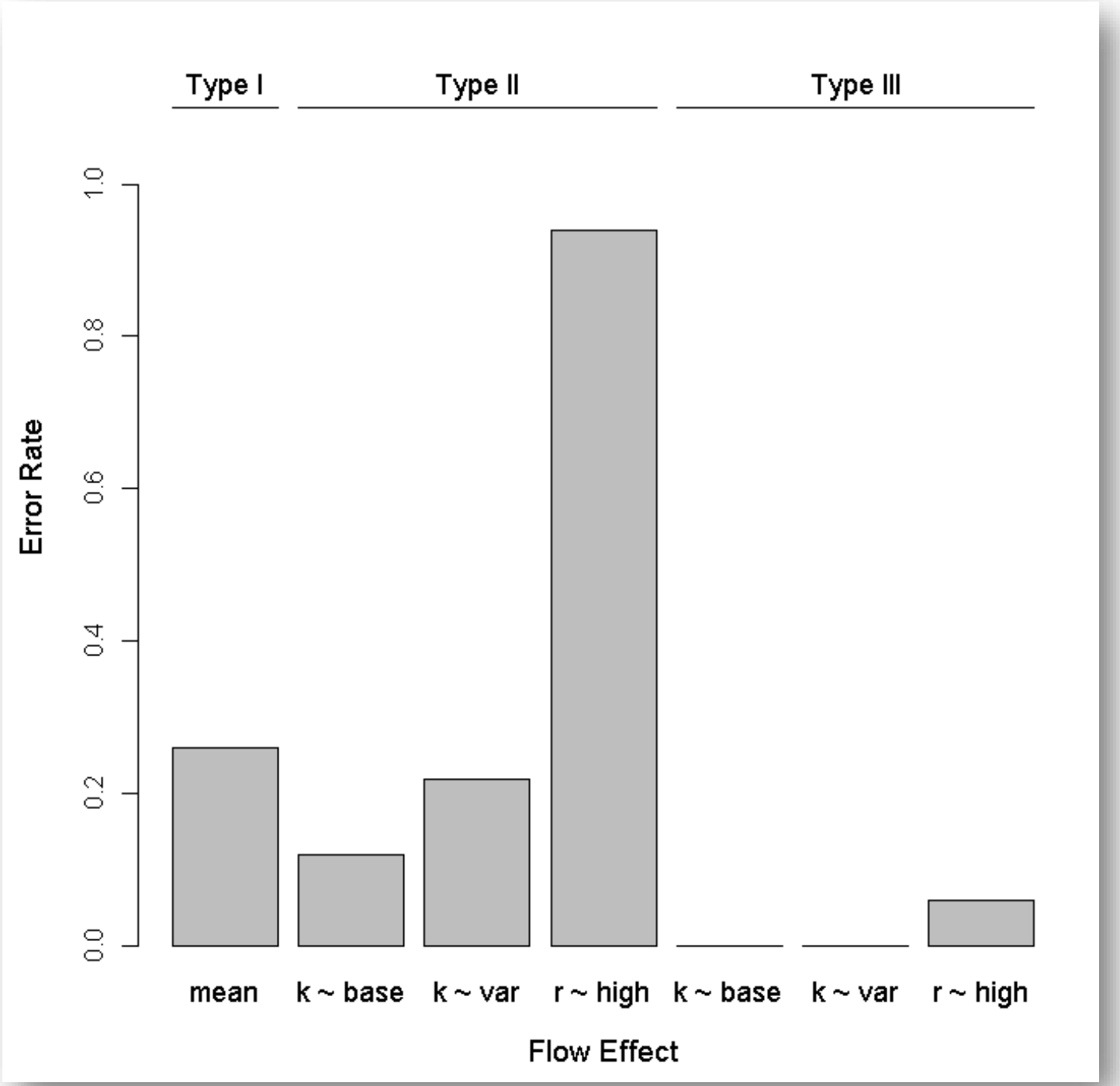

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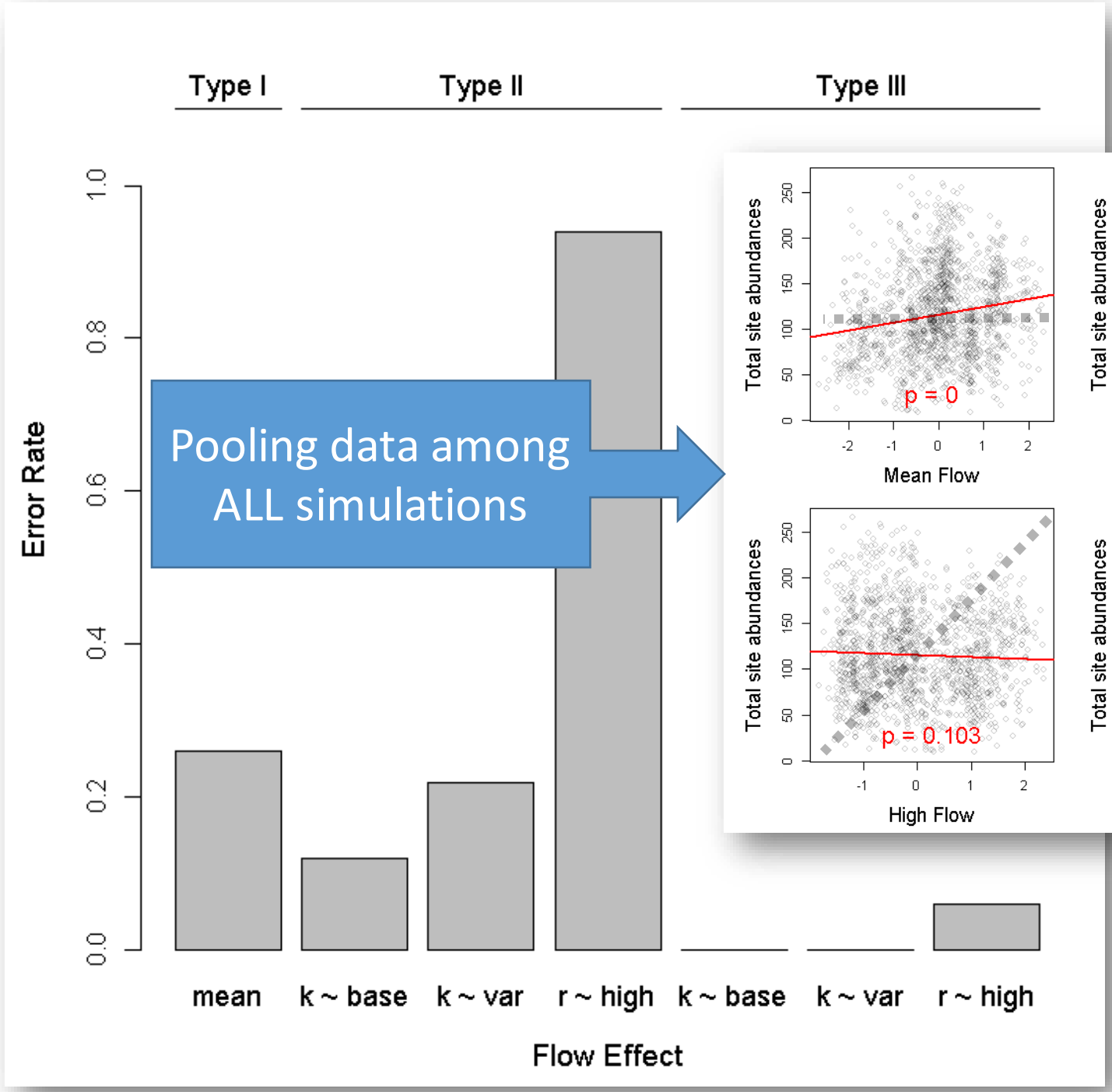


Simulation Options

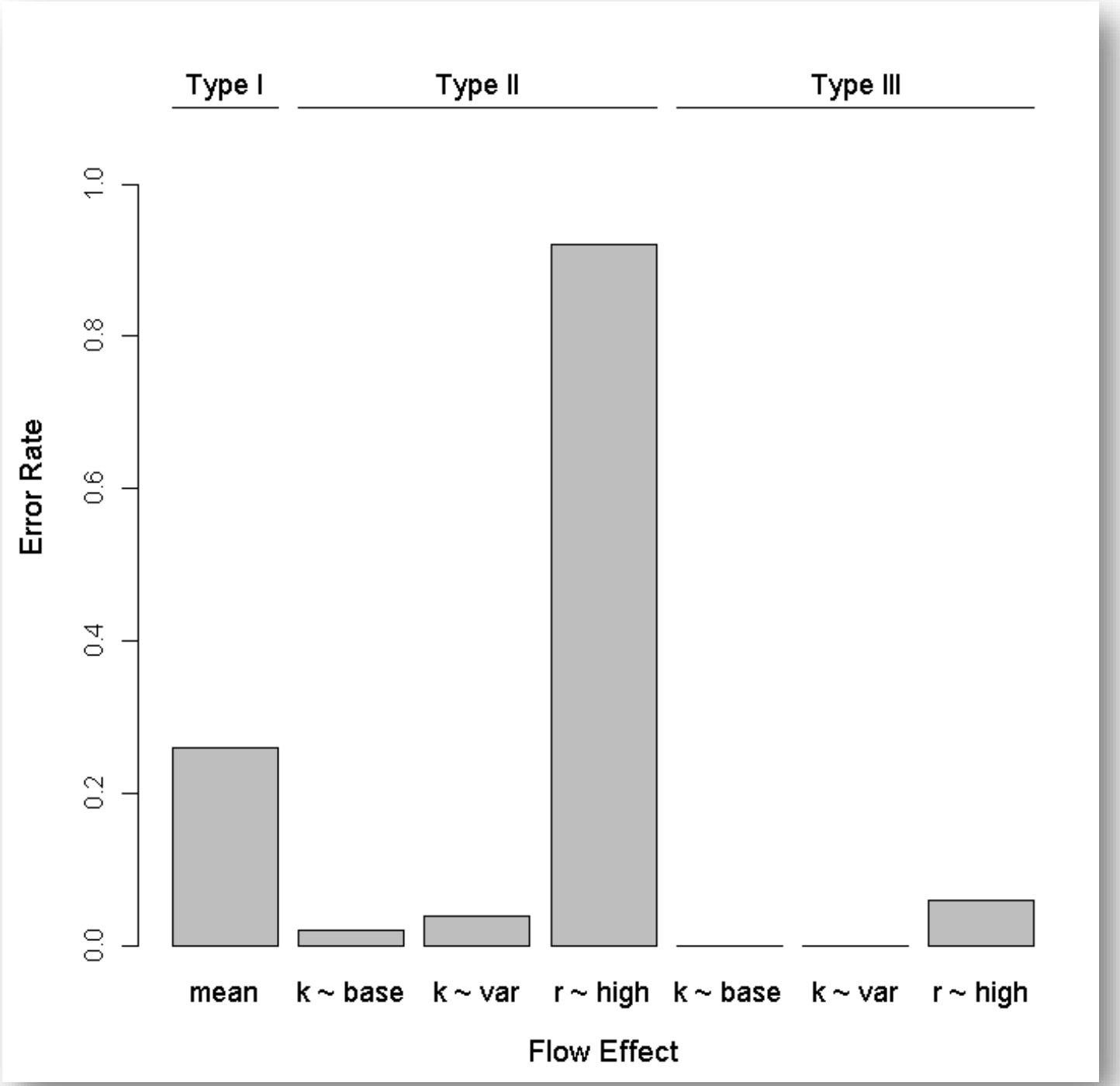
Response:
Change in abundance estimator

Simulations: 50
Years: 30

Stochasticity

Demographic: 0.01
Sampling: 0.01
Detection: 0.01

Sites: 20/year (50 m each)
Passes: 3
Detection: 50%



Simulation Options

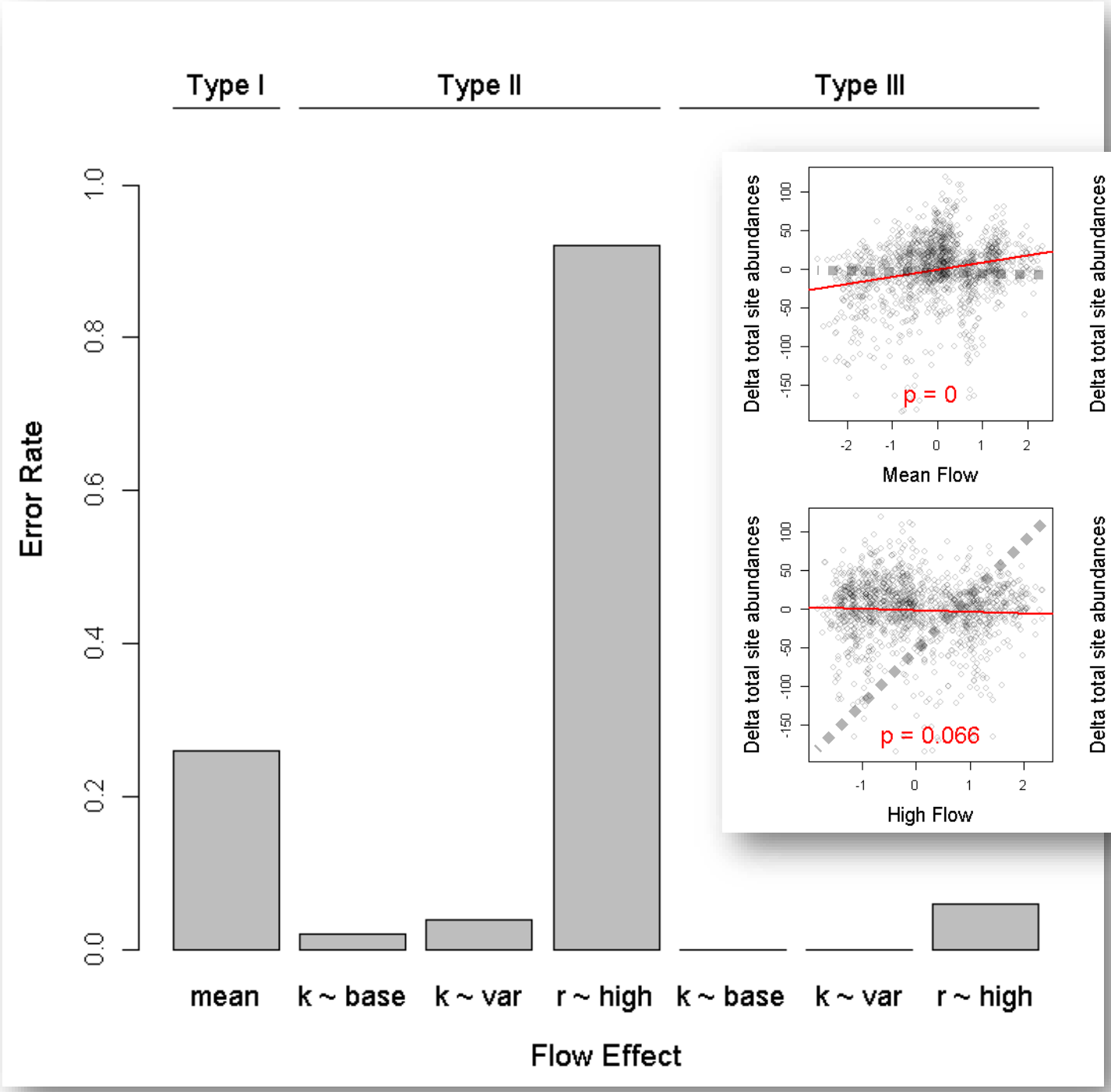
Response:
Change in abundance estimator

Simulations: 50
Years: 30

Stochasticity

Demographic: 0.01
Sampling: 0.01
Detection: 0.01

Sites: 20/year (50 m each)
Passes: 3
Detection: 50%



Simulation Options

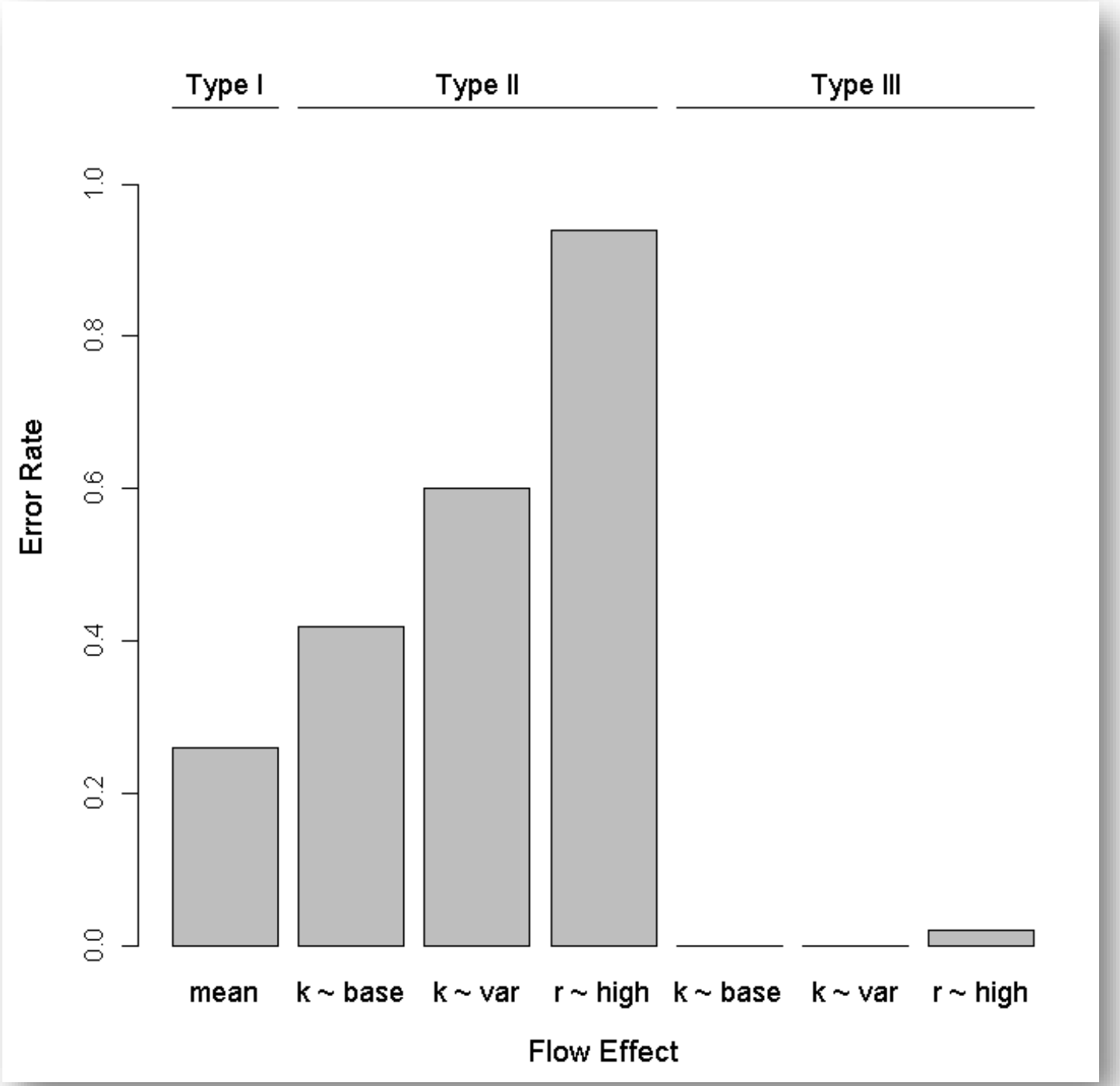
Response:
Change in abundance estimator

Simulations: 50
Years: 30

Stochasticity

Demographic: 0.01
Sampling: **1.00**
Detection: 0.01

Sites: 20/year (50 m each)
Passes: 3
Detection: 50%



Simulation Options

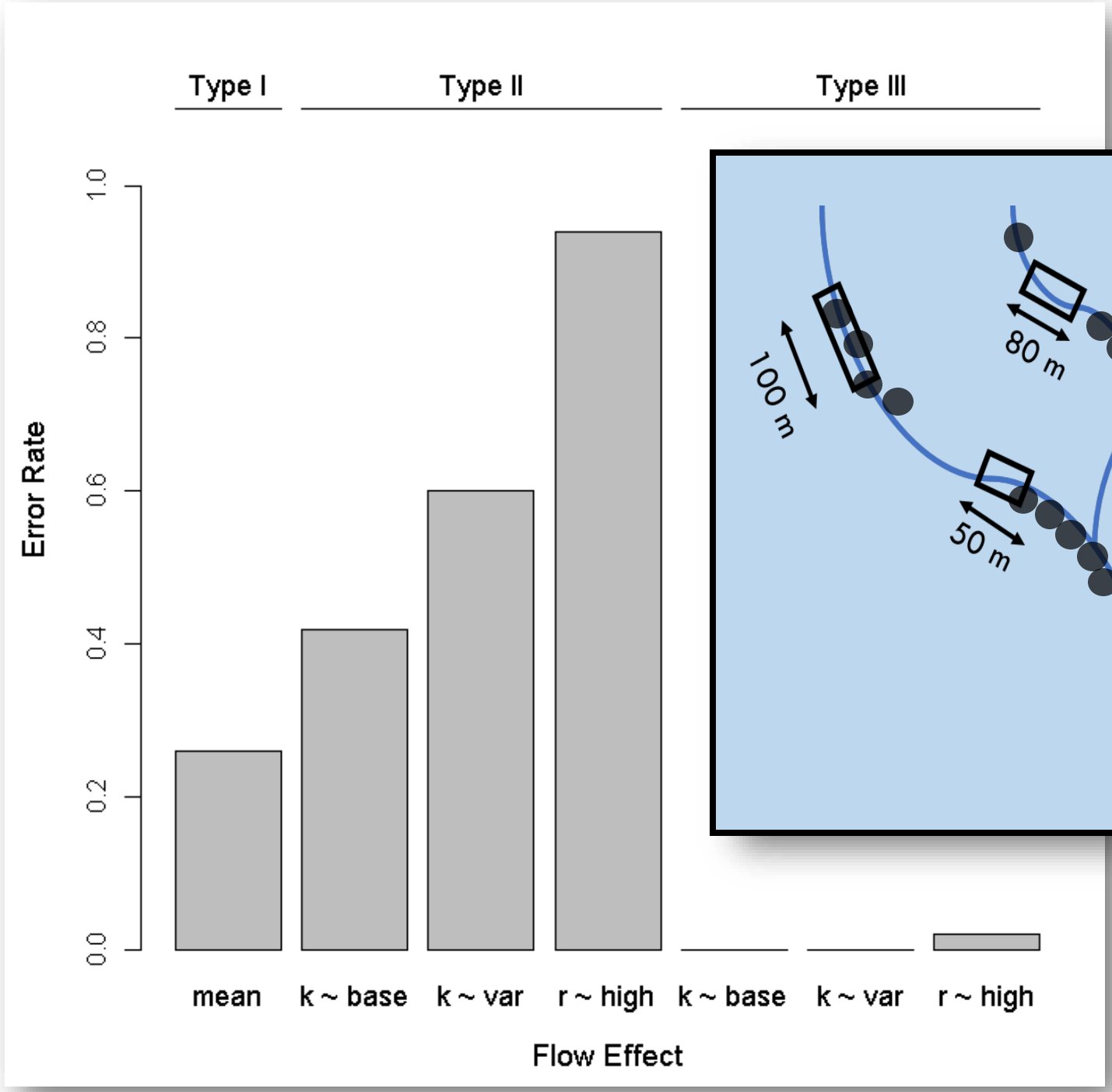
Response:
Change in abundance estimator

Simulations: 50
Years: 30

Stochasticity

Demographic: 0.01
Sampling: **1.00**
Detection: 0.01

Sites: 20/year (50 m each)
Passes: 3
Detection: 50%



Simulation Options

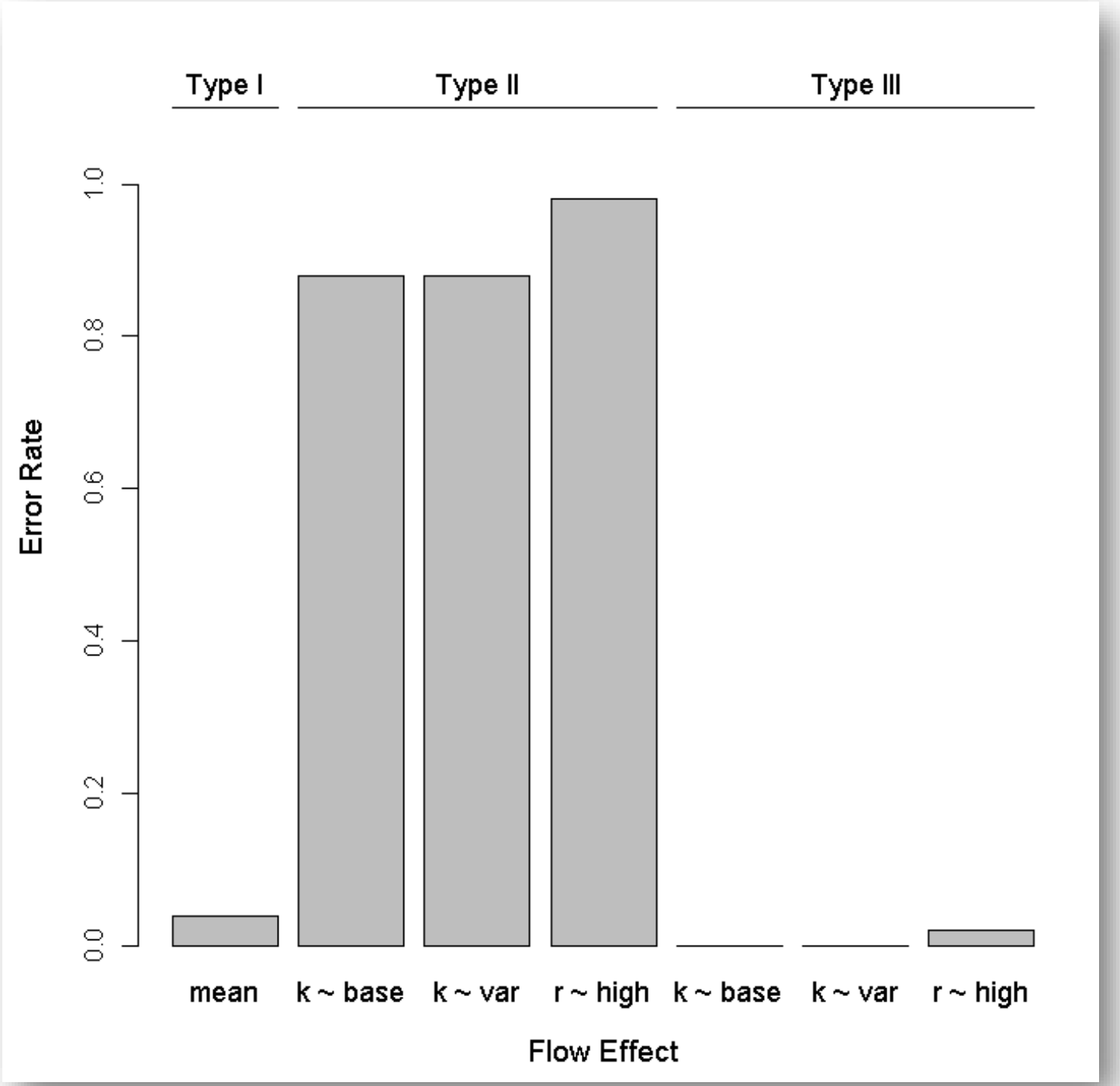
Response:
Change in abundance estimator

Simulations: 50
Years: 30

Stochasticity

Demographic: **0.70**
Sampling: **1.00**
Detection: 0.01

Sites: 20/year (50 m each)
Passes: 3
Detection: 50%



Simulation Options

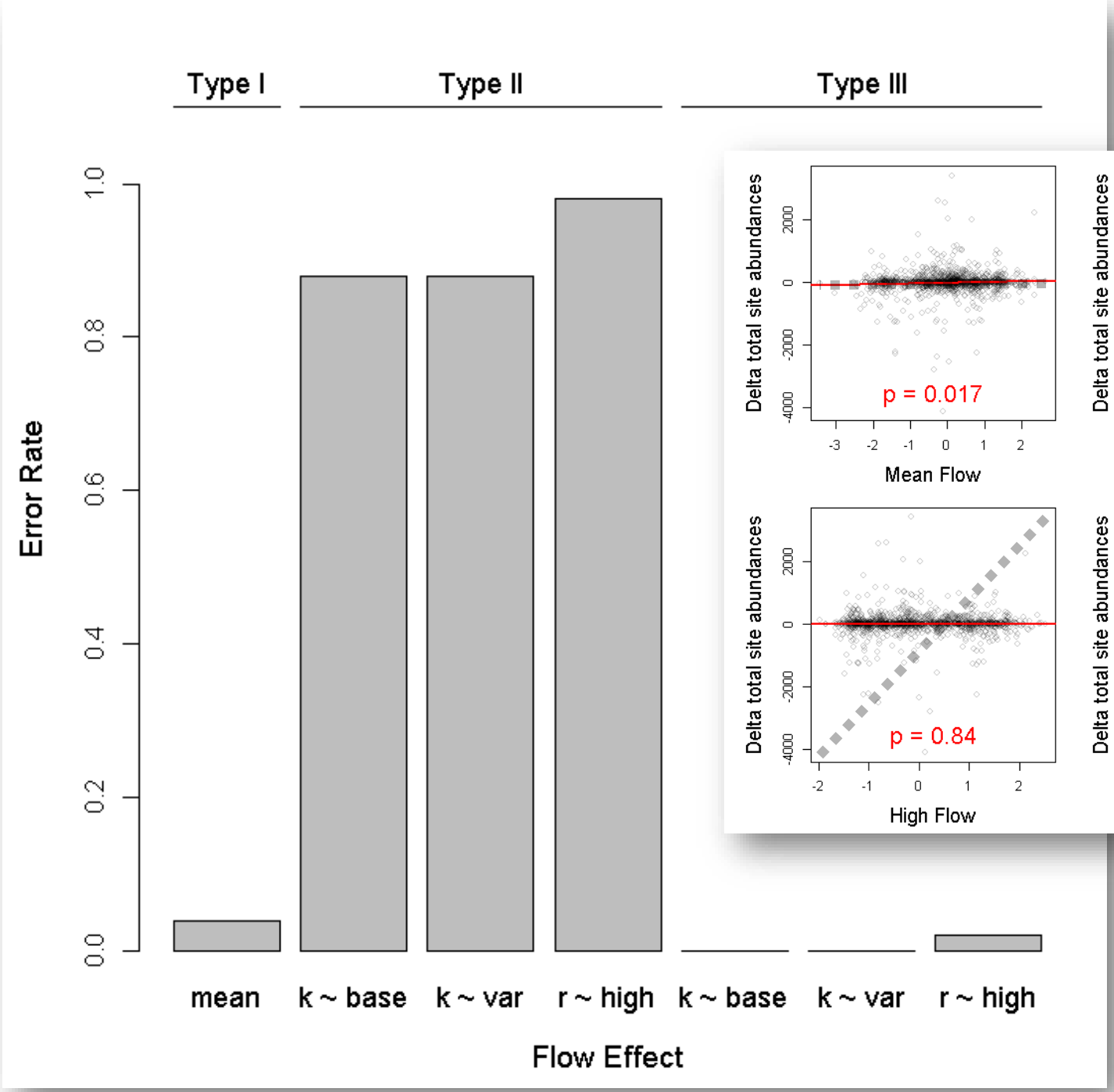
Response:
Change in abundance estimator

Simulations: 50
Years: 30

Stochasticity

Demographic: **0.70**
Sampling: **1.00**
Detection: 0.01

Sites: 20/year (50 m each)
Passes: 3
Detection: 50%



Simulation Options

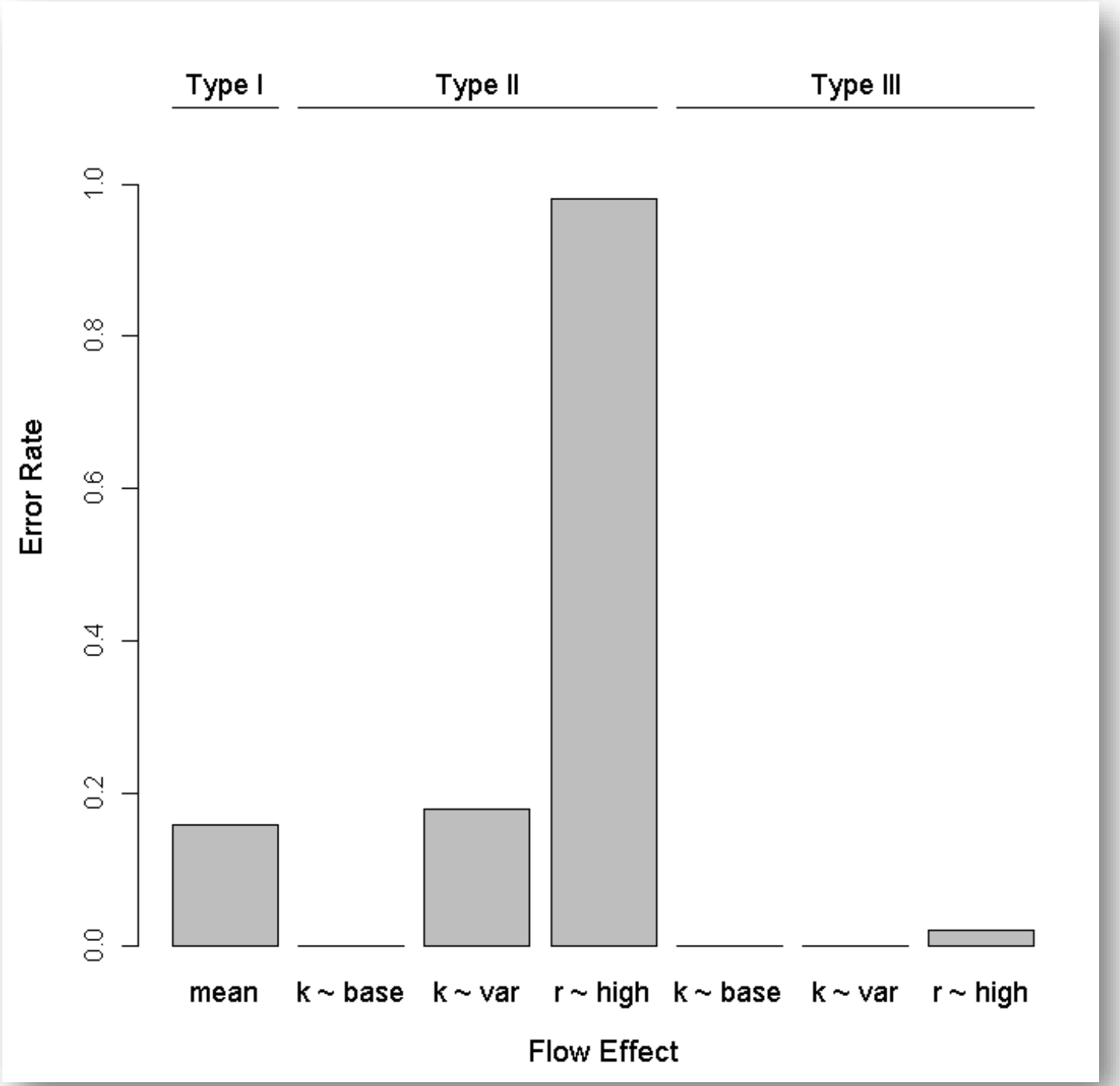
Response:
Change in abundance estimator

Simulations: 50
Years: 30

Stochasticity

Demographic: **0.10**
Sampling: **0.10**
Detection: **0.00**

Sites: 20/year (50 m each)
Passes: 3
Detection: 50%



Simulation Options

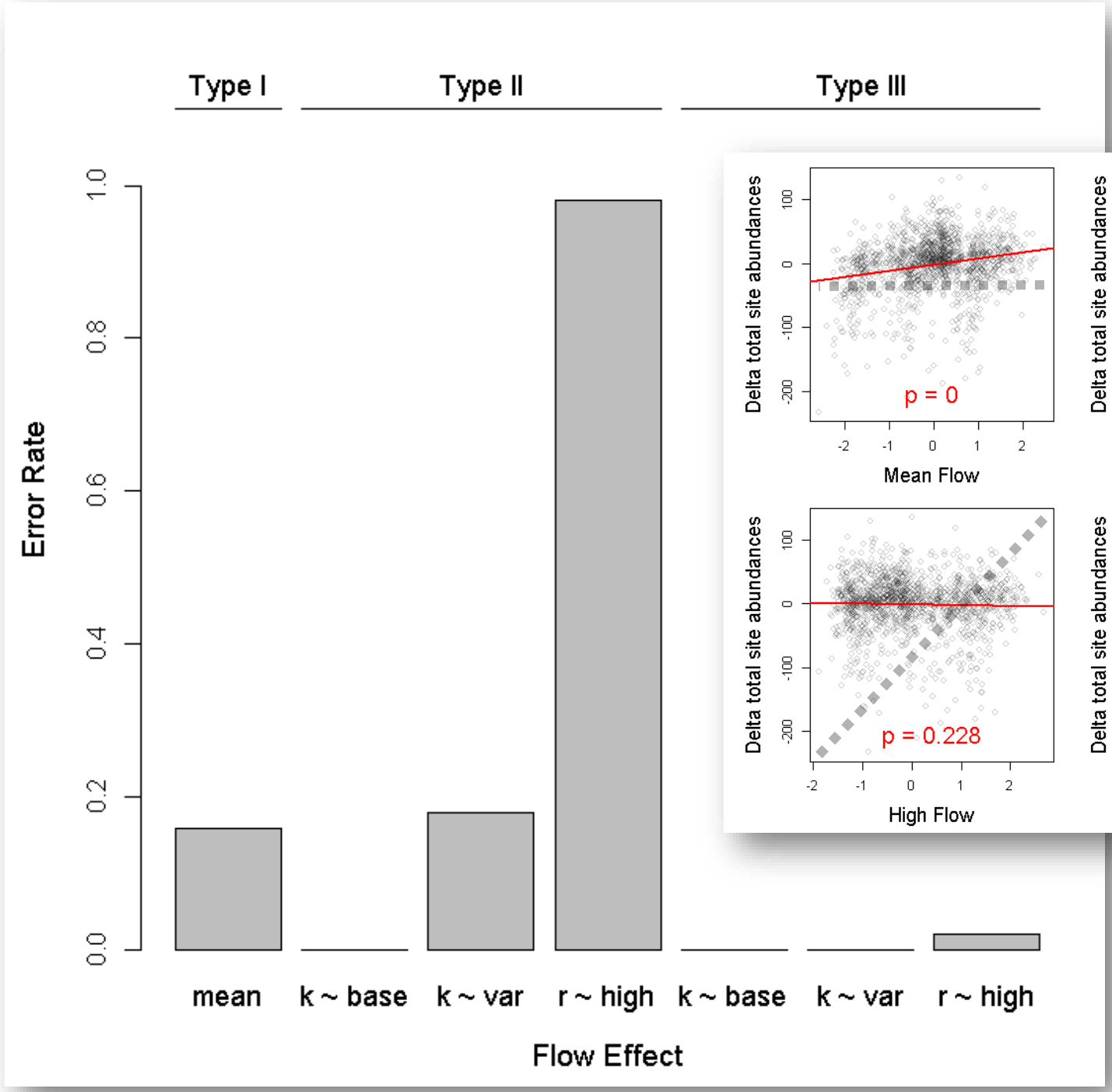
Response:
Change in abundance estimator

Simulations: 50
Years: 30

Stochasticity

Demographic: **0.10**
Sampling: **0.10**
Detection: **0.00**

Sites: 20/year (50 m each)
Passes: 3
Detection: 50%



Simulation Options

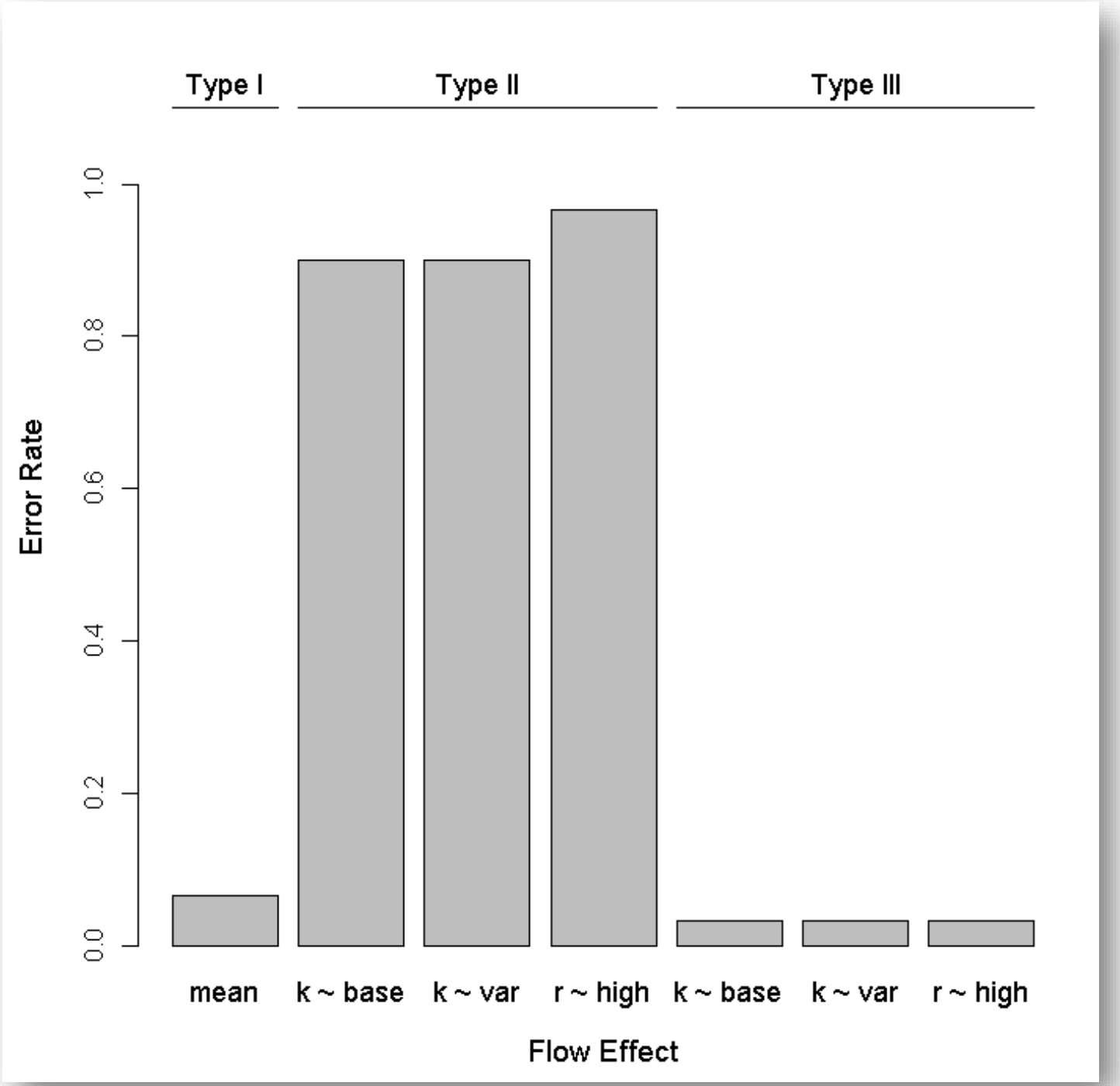
Response:
Change in abundance estimator

Simulations: 30
Years: 5

Stochasticity

Demographic: 0.10
Sampling: 0.10
Detection: 0.00

Sites: 20/year (50 m each)
Passes: 3
Detection: 50%



Simulation Options

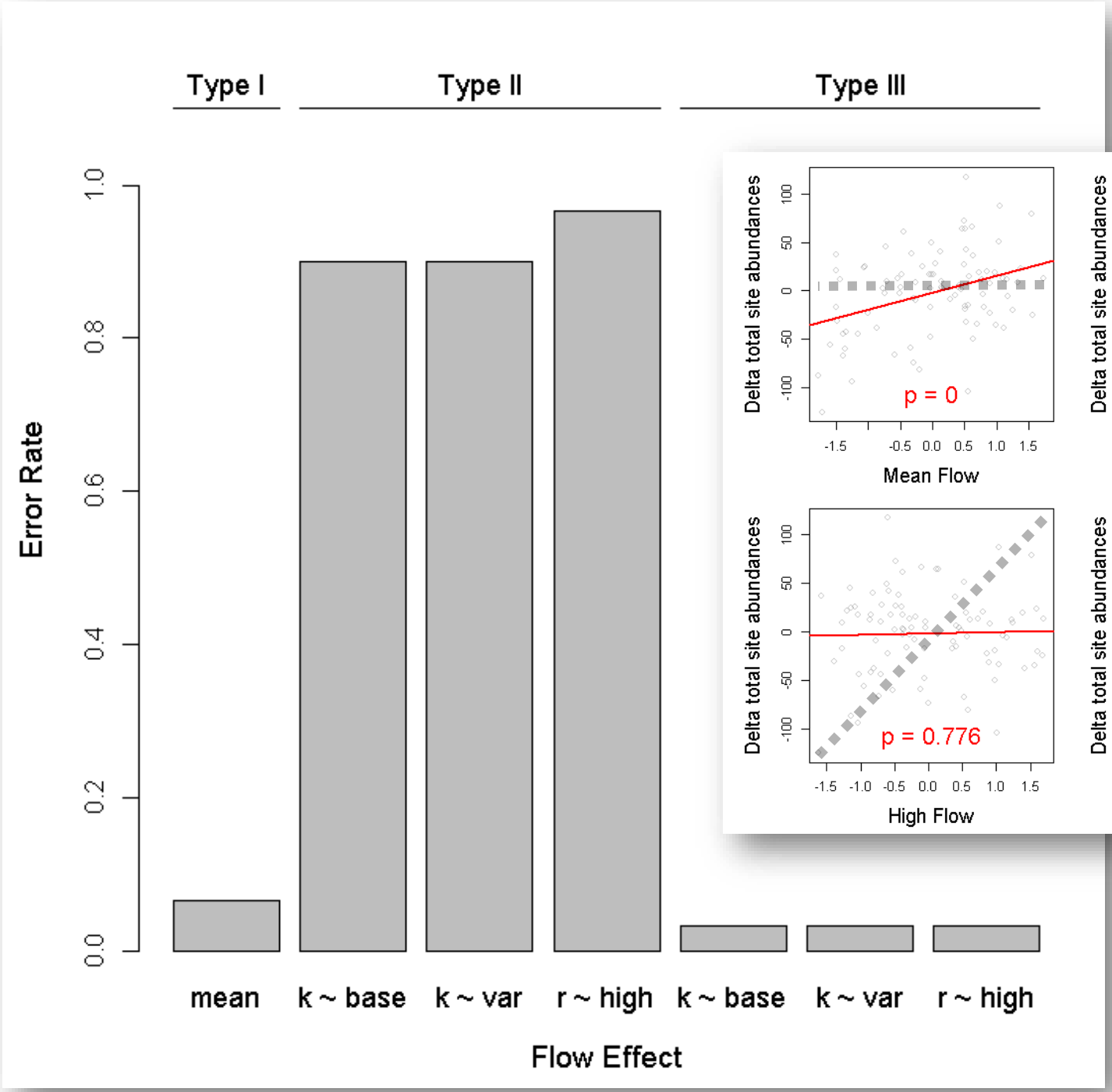
Response:
Change in abundance estimator

Simulations: 30
Years: 5

Stochasticity

Demographic: 0.10
Sampling: 0.10
Detection: 0.00

Sites: 20/year (50 m each)
Passes: 3
Detection: 50%



Simulation Options

Response:
Change in abundance estimator

Simulations: 5
Years: 30

Stochasticity

Demographic: 0.10
Sampling: 0.10
Detection: 0.00

Sites: 20/year (50 m each)
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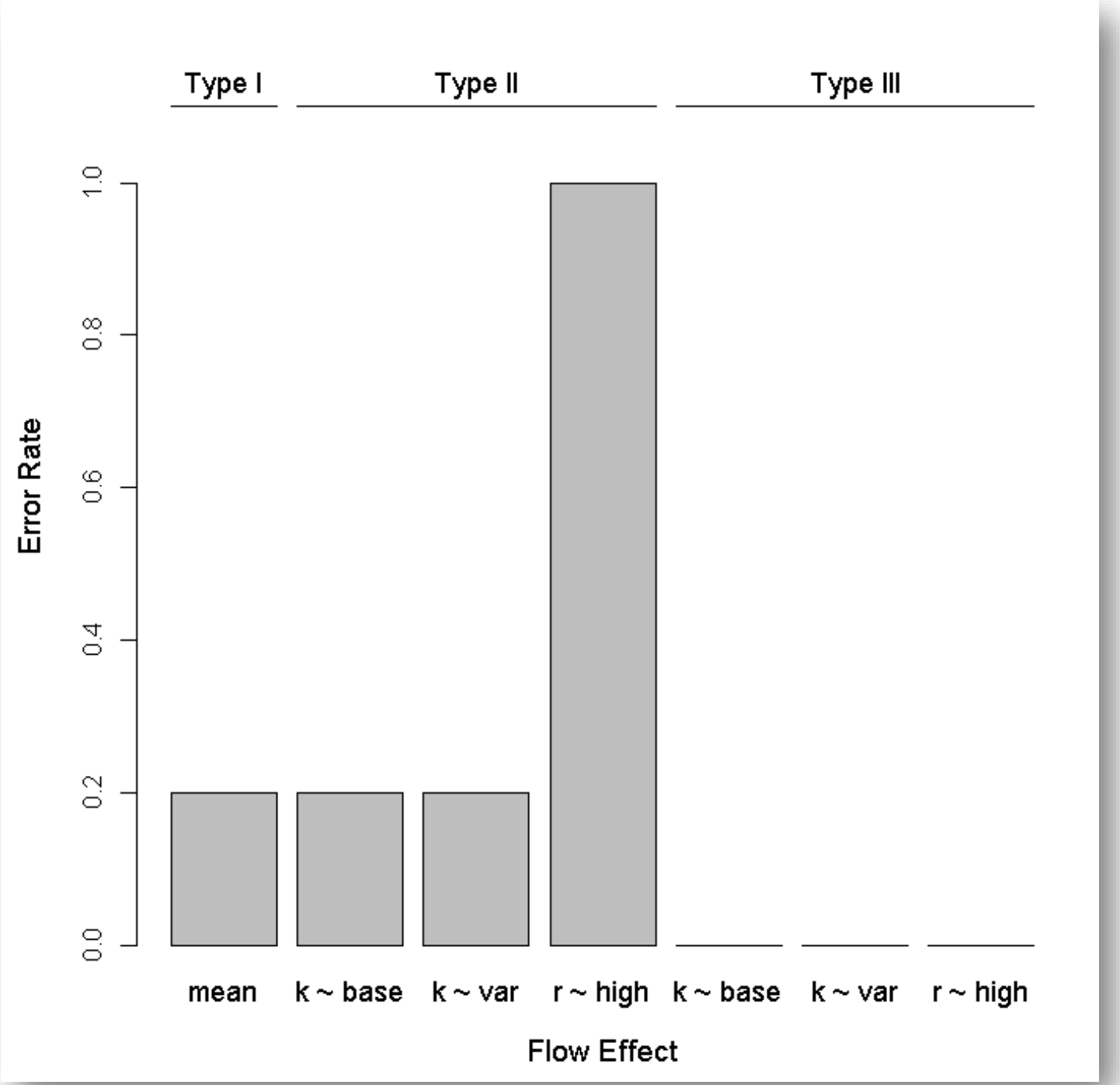

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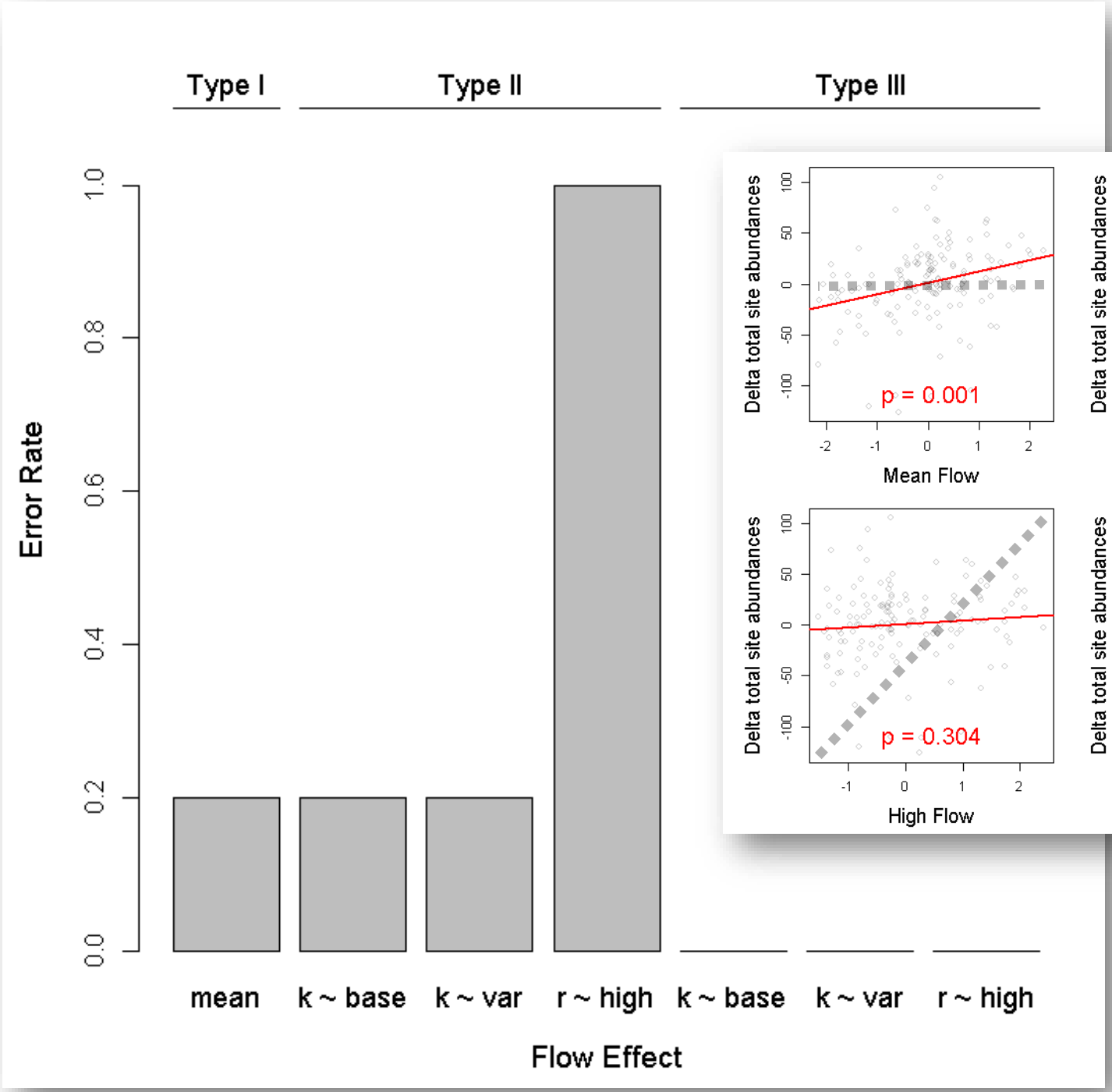
Passes: 3
Detection: 50%



Summary/Conclusions

1. **Hidden effects on growth rates**
2. **Signal-to-noise**
   - Demographic stochasticity + unexplained variance
   - Sampling error
   - Observation error
3. **States *vs.* rates**
4. **Many short-term studies *vs.* few long-term studies**

**** Simulation results may change in a different stream!**

What's next?

1. **The e-flows data challenge.**
    a. Data generated for several scenarios (fish/river/data collection characteristics).
    b. Simulation parameters kept secret.
    c. Participating labs analyze replicate datasets independently.
    d. Compare conclusions to known flow effects.

2. **eflowsim: A web app and/or R package.**
    a. Simulate your own fish populations in any stream
    b. Generate fish survey data using different sampling designs
    c. Assess error rates of your preferred analytical approach