Table 1a. Description of parameters used in the model. See Materials and Methods for relevant equations and detailed descriptions.

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameter** | | **Name** | **Description** |
| *Overall* |  | |  |
|  | Counts | | Observed counts for depletion pass *d* in each year *t* at each site s |
|  | Density | | Mean density at time *t* and site *s* |
|  | Offset | | Offset: relative length of stream sampled to standardize abundance to fish per 100 m |
|  | Fixed effects | | Vector of fixed-effect coefficients effects on log-abundance |
| *Detection* | | |  |
|  | Capture probability | | Capture probability per fish for each pass in year at site s |
|  | Mean capture probability | | Mean probability of capturing and individual given that it is present at site *s* and time *t* |
|  | Capture variation | | Variation in capture probability among sites and years |
|  | Capture variance | | Variance of |
| *Spatial* | | |  |
|  | Spatial variation | | Spatial contribution (component?, variation?) to abundance following an Ornstein-Uhlenbeck process |
|  | Spatial variance | | Spatially-explicit variance between each parent and child node following an OU process |
|  | Spatial decay | | Exponential spatial decay rate in the correlation between parent and child nodes |
|  | Spatial OU variance | | Variation in the spatial OU process |
|  | Spatial correlation | | Spatial correlation between each parent and child node, resulting from an OU process |
| *Temporal* | | |  |
|  | Temporal variation | | Temporal variation in abundance resulting from AR1 autoregressive process across all locations |
|  | Temporal correlation matrix | | Correlation matrix for a first-order autocorrelation process |
|  | Temporal correlation | | Temporal correlation in the annual AR1 process between successive years |
|  | Temporal variance | | Variance in the temporal term |
| *Spatio-temporal* | | | |
|  | Spatio-temporal variation | | Spatio-temporal variation in abundance resulting from OU process |
|  | Spatio-temporal covariance | | Spatio-temporal covariance matrix |
|  | Spatio-temporal variance | | Spatio-temporal variance between each parent and child node |
|  | Temporal ST correlation | | Temporal autocorrelation (AR1) in the spatio-temporal pattern |
|  | Spatio-temporal correlation | | Spatio-temporal correlation between each parent and child node, resulting from an OU process |
|  | Spatio-temporal decay | | Exponential decay rate describing the spatio-temporal OU process |
|  | Spatio-temporal OU variance | | Variance describing the spatio-temporal OU process |
| *Independent* | | |  |
|  | Overdispersion | | Random log-normal variation beyond Poisson expectation (also termed overdispersion or nugget) |
|  |  | | sigmaIID |

Table 1b

Table 2. Covariate Summary for W. Susquehanna by Stream Reach

|  |  |  |  |
| --- | --- | --- | --- |
| Variable | Mean | Min | Max |
| Percent forest cover (%) | 79.15 | 0 | 100 |
| Percent surficial coarseness (AB?) | 6.62 | 0 | 100 |
| Previous summer mean temperature (C) | 17.74 | 15.21 | 21.66 |
| Previous fall mean temperature (C) | 3.49 | -0.09 | 7.3 |
| Winter mean temperature (C) | -1.77 | -7.99 | 2.87 |
| Spring mean temperature (C) | 14.63 | 10.31 | 17.31 |
| Previous summer mean precipitation (mm) | 3.78 | 1.59 | 8.92 |
| Previous fall mean precipitation (mm) | 2.99 | 1.29 | 5.01 |
| Winter mean precipitation (mm) | 2.58 | 1.1 | 4.73 |
| Spring mean precipitation (mm) | 2.91 | 1.42 | 6.9 |

Table 3. Description of models compared with AIC for adult and YOY Brook Trout populations in the West Susquehanna watershed.

|  |  |  |
| --- | --- | --- |
| Num | Model | Model components |
| 1 | Basic |  |
| 2 | Spatial (S) |  |
| 3 | Temporal (T) |  |
| 4 | S + T |  |
| 5 | Spatio-temporal (ST) |  |
| 6 | S + ST |  |
| 7 | T + ST |  |
| 8 | S + T + ST |  |

Table 4. Comparison of adult Brook Trout models using AIC.

|  |  |  |  |
| --- | --- | --- | --- |
| M\_num | Model | AIC | delta\_AIC |
| 4 | Spatiotemporal | 9408 | 0.0 |
| 5 | Temporal + ST | 9408 | 0.3 |
| 7 | Spatial + Temporal | 9583 | 174.9 |
| 3 | Spatial | 9588 | 180.2 |
| 2 | Temporal | 9783 | 375.3 |
| 1 | Obs | 9794 | 386.5 |

Table 5. Comparison of YOY Brook Trout models using AIC.

|  |  |  |  |
| --- | --- | --- | --- |
| M\_num | Model | AIC | delta\_AIC |
| 5 | Temporal + ST | 9592 | 0 |
| 6 | S+T+ST | 9596 | 4 |
| 4 | Spatiotemporal | 9663 | 71 |
| 8 | Spatial + ST | 9666 | 74 |
| 7 | Spatial + Temporal | 9739 | 147 |
| 3 | Spatial | 9801 | 209 |
| 2 | Temporal | 9925 | 333 |
| 1 | Obs | 10048 | 456 |

Table 6. Summary of parameter estimates from the model including temporal and spatiotemporal components for adult Brook Trout in the West Susquehanna watershed.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Parameter | Estimate | Std..Error | z.value | Pr...z.2.. |
| mean\_N | 36.686 | 4.051 | 9.1 | 1e-19 |
| mu (alpha/intercept) | 0.086 | 0.011 | 7.5 | 5e-14 |
| sigmaIID | 0.360 | 0.036 | 10.0 | 2e-23 |
| rhot | 0.592 | 0.255 | 2.3 | 2e-02 |
| sigmat | 0.158 | 0.059 | 2.7 | 7e-03 |
| log\_theta\_vec | -1.845 | 0.199 | -9.3 | 2e-20 |
| theta\_st | 0.158 | 0.032 | 5.0 | 5e-07 |
| SDinput\_st | 0.588 | 0.059 | 10.0 | 1e-23 |
| rho\_st | 0.974 | 0.008 | 128.2 | 0e+00 |
| forest | 0.822 | 0.116 | 7.1 | 1e-12 |
| surfcoarse | 0.013 | 0.064 | 0.2 | 8e-01 |
| temp\_mean\_summer\_1 | -0.263 | 0.052 | -5.1 | 4e-07 |
| temp\_mean\_fall\_1 | 0.092 | 0.032 | 2.9 | 4e-03 |
| temp\_mean\_winter | -0.009 | 0.031 | -0.3 | 8e-01 |
| temp\_mean\_spring | -0.159 | 0.051 | -3.1 | 2e-03 |
| prcp\_mean\_summer\_1 | -0.018 | 0.014 | -1.3 | 2e-01 |
| prcp\_mean\_fall\_1 | 0.049 | 0.016 | 3.1 | 2e-03 |
| prcp\_mean\_winter | 0.043 | 0.020 | 2.1 | 4e-02 |
| prcp\_mean\_spring | 0.045 | 0.022 | 2.1 | 4e-02 |

Table 7. Summary of parameter estimates from the model including temporal and spatiotemporal components for YOY Brook Trout in the West Susquehanna watershed.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Parameter | Estimate | Std..Error | z.value | Pr...z.2.. |
| mean\_N | 44.398 | 7.786 | 5.7 | 1e-08 |
| mu | 0.033 | 0.010 | 3.3 | 9e-04 |
| sigmaIID | 0.527 | 0.042 | 12.7 | 6e-37 |
| rhot | -0.053 | 0.208 | -0.3 | 8e-01 |
| sigmat | 0.763 | 0.132 | 5.8 | 7e-09 |
| log\_theta\_vec | -2.052 | 0.188 | -10.9 | 9e-28 |
| theta\_st | 0.129 | 0.024 | 5.3 | 1e-07 |
| SDinput\_st | 0.653 | 0.065 | 10.0 | 1e-23 |
| rho\_st | 0.981 | 0.006 | 168.8 | 0e+00 |
| forest | 1.120 | 0.155 | 7.2 | 5e-13 |
| surfcoarse | 0.042 | 0.083 | 0.5 | 6e-01 |
| temp\_mean\_fall\_1 | 0.022 | 0.113 | 0.2 | 8e-01 |
| temp\_mean\_winter | 0.054 | 0.106 | 0.5 | 6e-01 |
| temp\_mean\_spring | -0.679 | 0.161 | -4.2 | 2e-05 |
| prcp\_mean\_fall\_1 | 0.005 | 0.041 | 0.1 | 9e-01 |
| prcp\_mean\_winter | -0.011 | 0.046 | -0.2 | 8e-01 |
| prcp\_mean\_spring | -0.060 | 0.058 | -1.0 | 3e-01 |

**Figures**

Figure 1. Diagram of network structure with parent-child relationships

Figure 2. Parameter estimates across different values of theta from the spatial simulation study varying theta and sigma. Parameter estimates, abundance estimates, and abundance accuracy (RMSE) were compared for the spatial model and a non-spatial model. Variation in the boxplots represents the combined uncertainty from 200 simulations and variation in simulated levels of sigma.

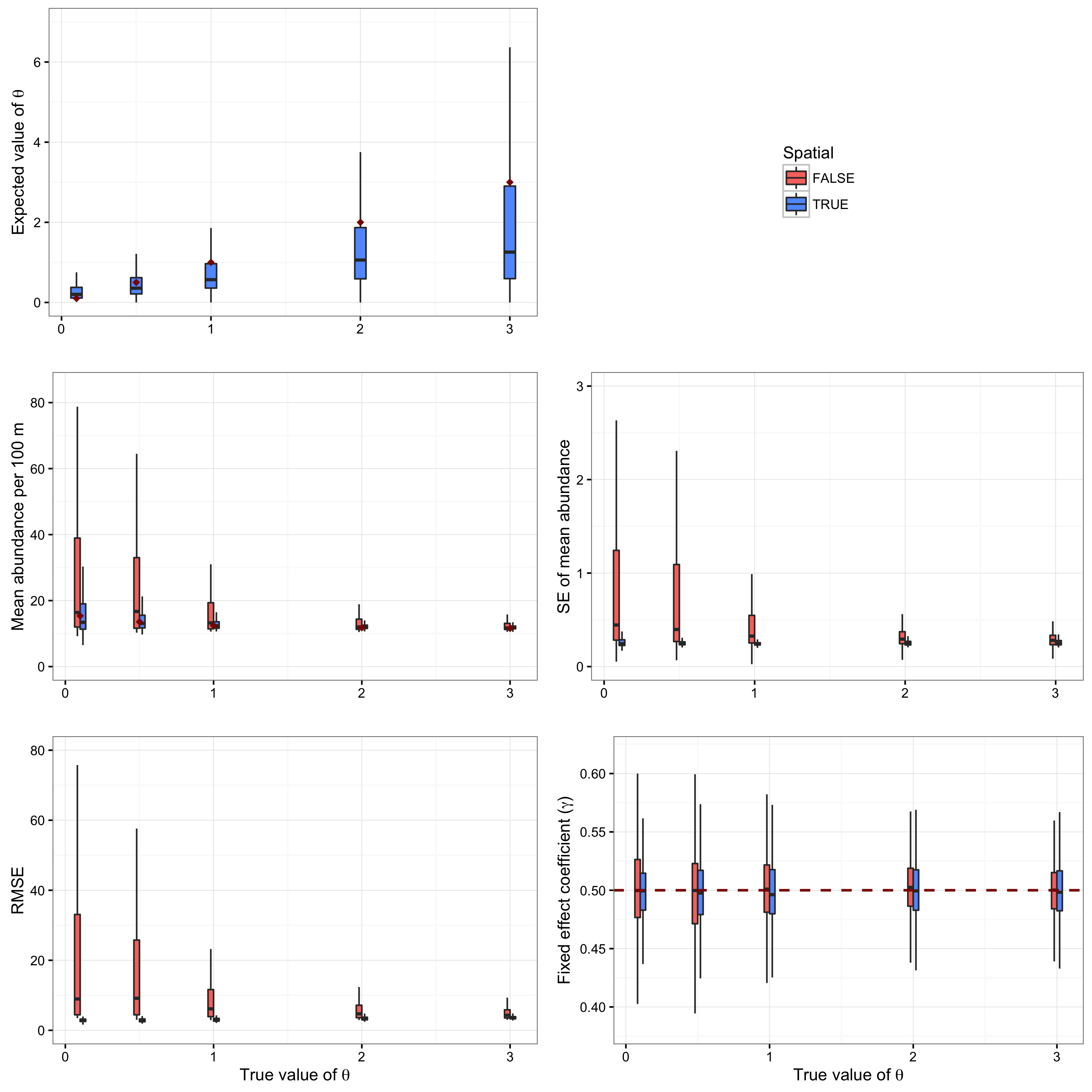


Figure 3. Parameter estimates across different values of sigma from the spatial simulation study varying theta and sigma. Parameter estimates, abundance estimates, and abundance accuracy (RMSE) were compared for the spatial model and a non-spatial model. Variation in the boxplots represents the combined uncertainty from 200 simulations and variation in simulated levels of theta.

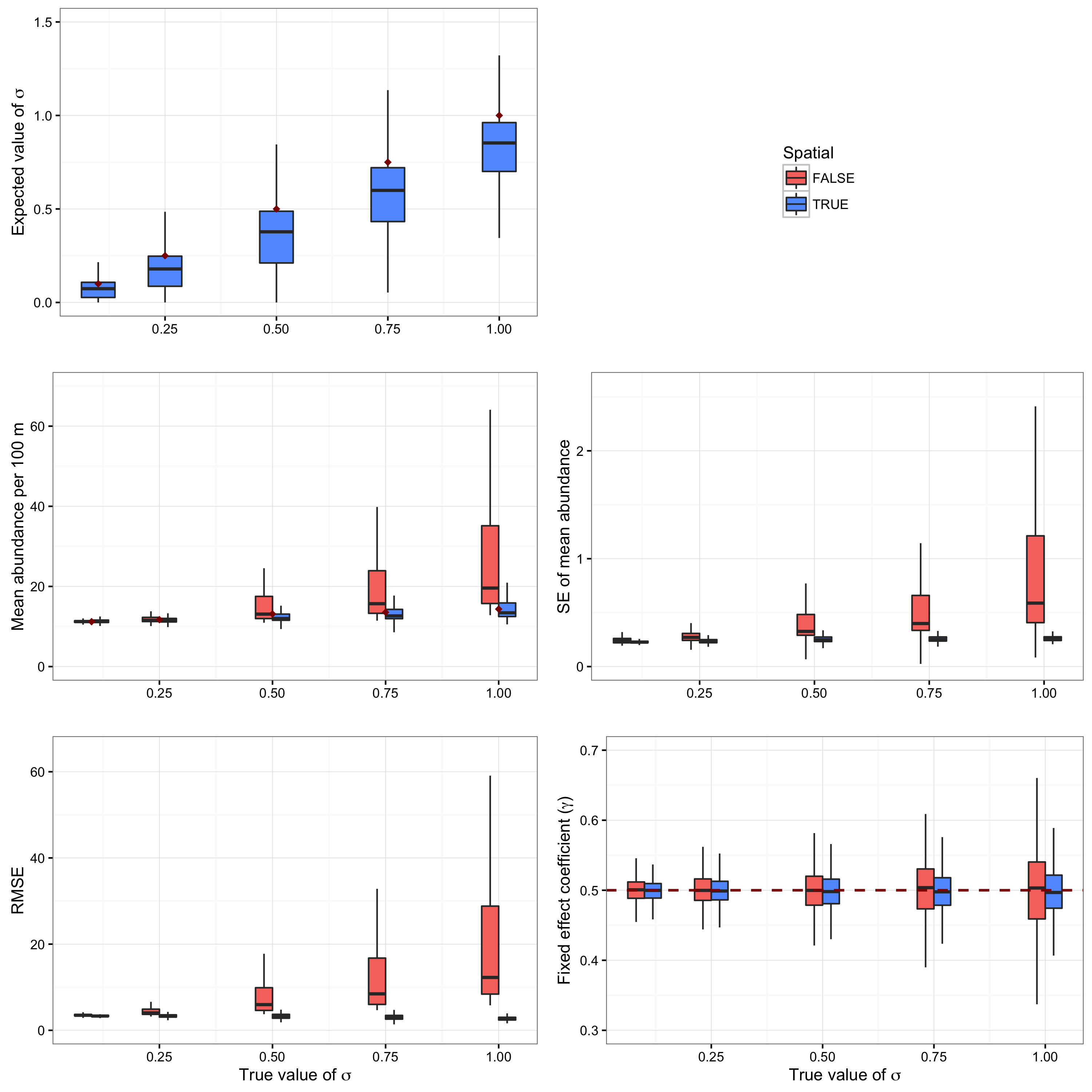


Figure 4. Results from the power analysis simulations showing the effect of varying the number years each site is surveyed. Variation described by each boxplot results from the 200 simulations and varying the number of sites (while holding the number of years constant).

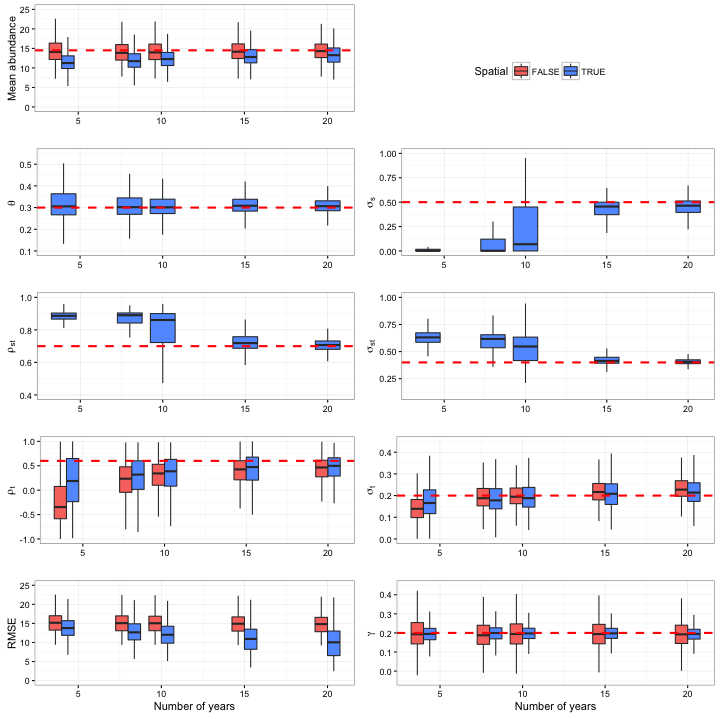


Figure 5. Results from the power analysis simulations showing the effect of varying the number sites surveyed. Variation described by each boxplot results from the 200 simulations and varying the number of years each site was surveyed (while holding the number of sites constant).

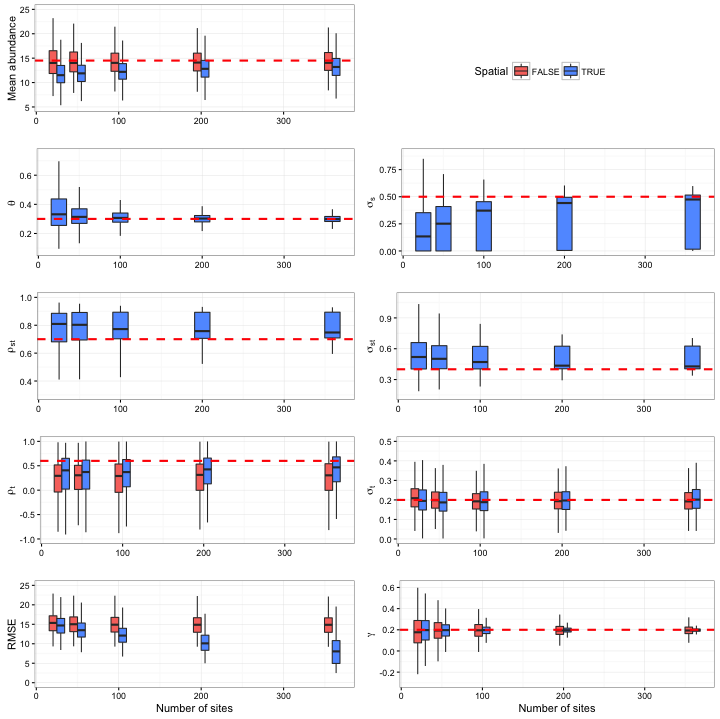


Figure 6 (low res). Example of a spatiotemporal simulation of the abundance along a stream network over time. The top row shows the true (simulated) abundances and the middle row depicts the mean expected abundance based on the matching spatiotemporal model. The bottom row shows the mean expected abundance for a model with temporal autocorrelation but no spatial and spatiotemporal correlations. The simulation used values of theta, sigma, theta\_st, sigma\_st, AR1, sampled at N\_sites = 50 in N\_years = 8.

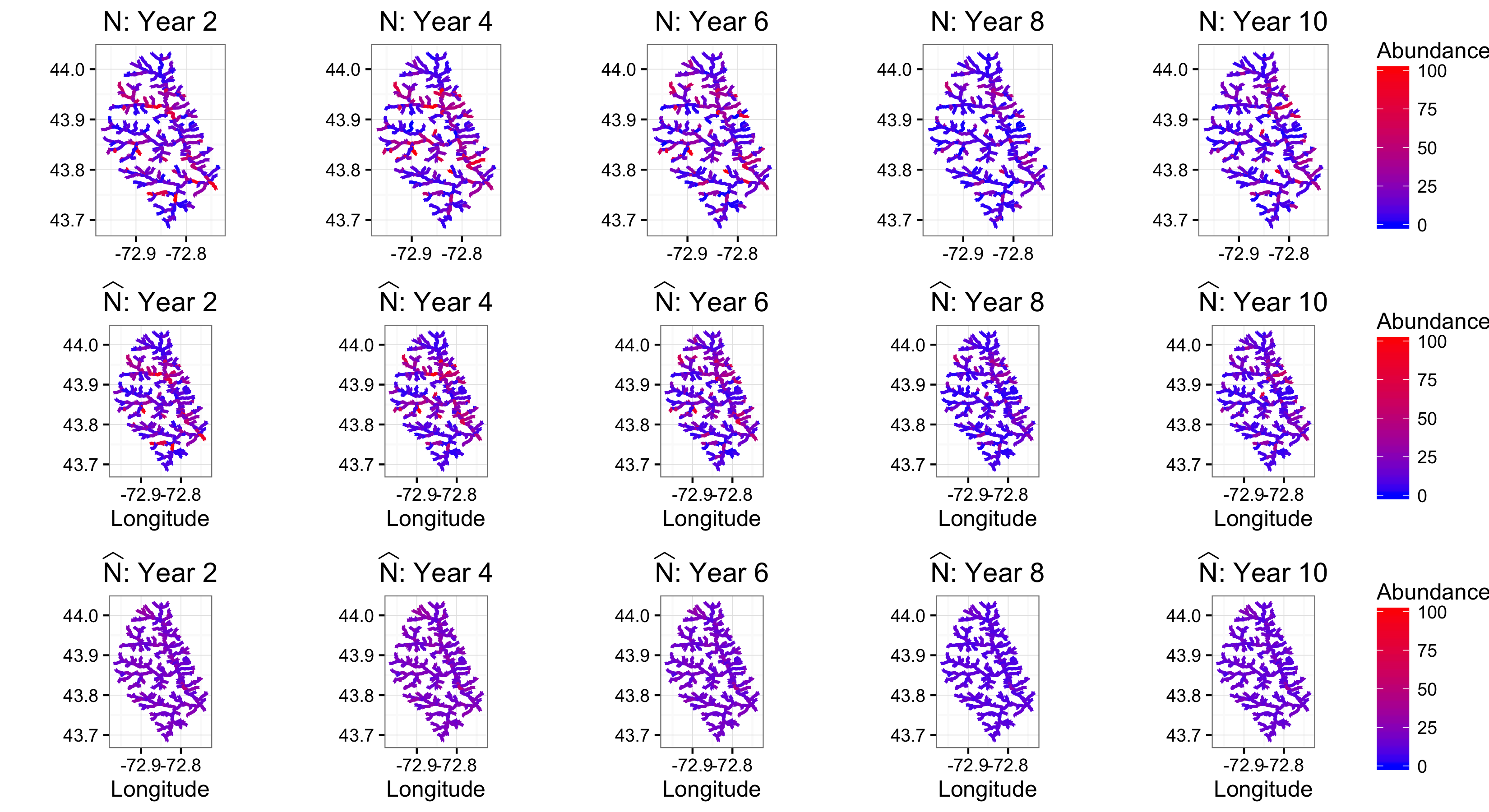


Figure 7. Decay curves with distance for adult and YOY Brook Trout in the West Susquehanna watershed for the model including temporal and spatiotemporal components. rho\_nu(s) is the expected correlation between parent and child nodes for a given distance.

