

# Simulation Results: Epoch linear preferential sampling (8 epochs - 6 months/epoch)

*Louis du Plessis*

*Last modified: 05 Aug 2019*

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## 1 Convergence

### 1.1 Constant-size

100/100 simulations converged with ESS of all parameters  $> 200$ .

### 1.2 Bottleneck

100/100 simulations converged with ESS of all parameters  $> 200$ .

### 1.3 Boom-bust

100/100 simulations converged with ESS of all parameters  $> 200$ .

### 1.4 Cyclical boom-bust

100/100 simulations converged with ESS of all parameters  $> 200$ .

### 1.5 Logistic growth and decline

100/100 simulations converged with ESS of all parameters  $> 200$ .

## 2 Summary statistics

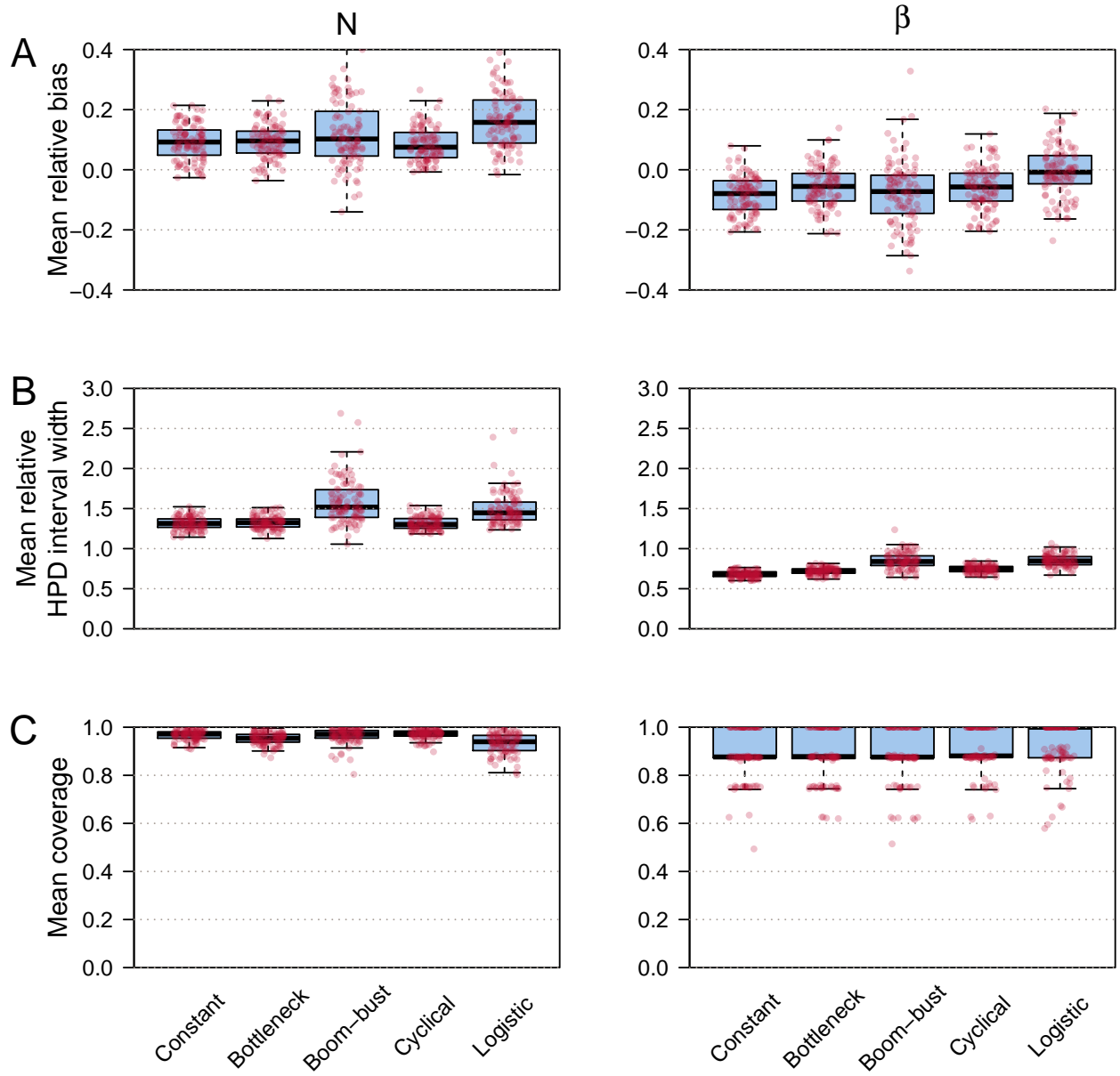


Figure 1: Boxplots and stripcharts displaying measures of the statistical performance of the BESP, evaluated on trees simulated under five different demographic models (constant, bottleneck, boom-bust, cyclical boom-bust, logistic growth and decline). We simulated 100 replicate trees for each scenario. Three measures of estimator performance are shown (A) mean relative bias, (B) mean relative HPD interval size, and (C) mean coverage. The left and right columns illustrate estimation performance for effective population size ( $N$ ) and sampling intensity ( $\beta$ ), respectively.

### 3 Example results

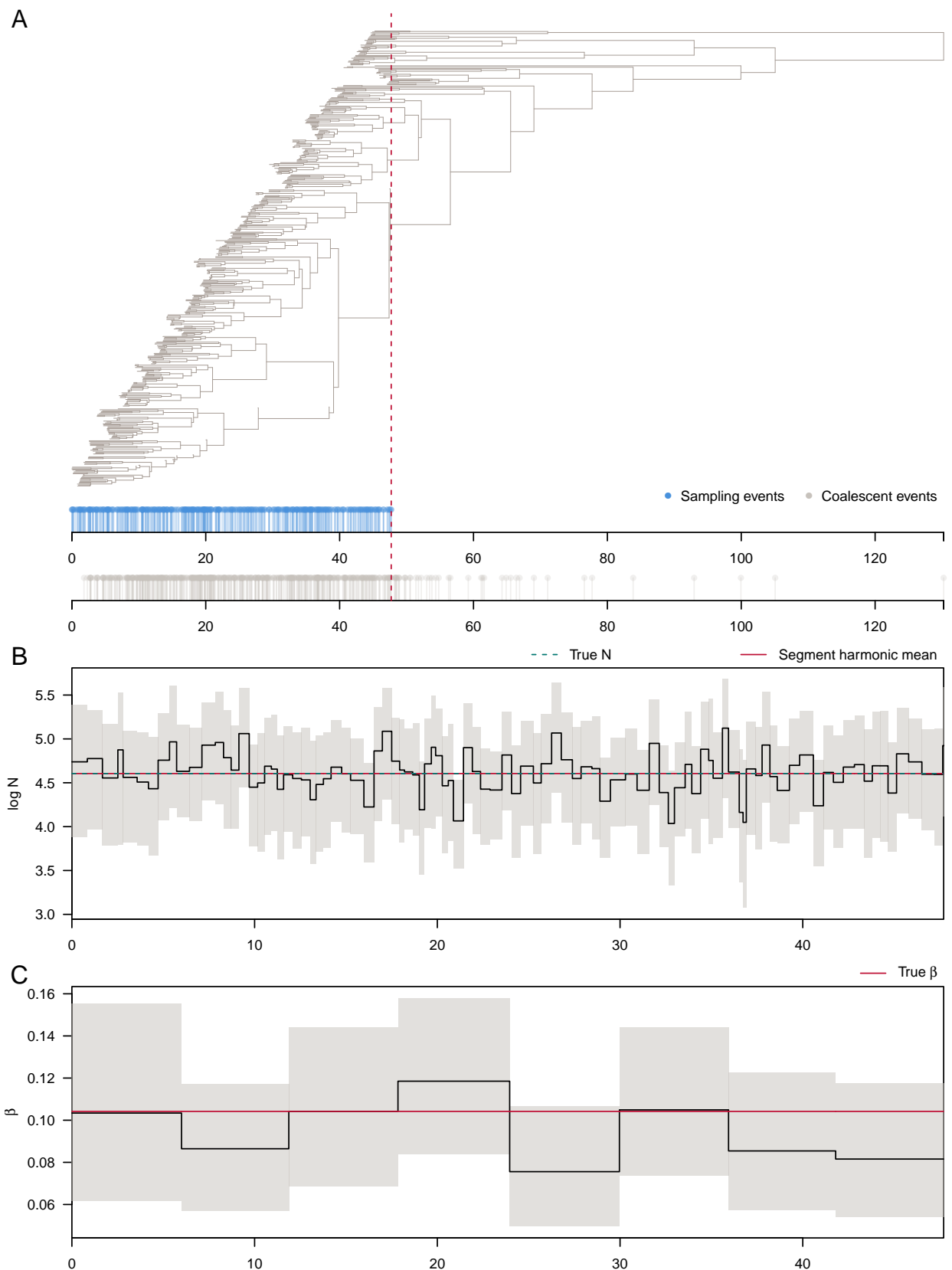


Figure 2: **Constant** (best ranked simulation): (A) Simulated tree with sampling (blue) and coalescent (grey) events. (B) Median (solid black line) and HPD intervals (shaded areas) for the  $N$ -estimates between the most recent and most ancient samples. The dashed green line shows the true  $N$ -trajectory used to simulate the tree and the red line the harmonic mean of the true  $N$  during each segment. (C) Median (solid black line) and HPD intervals (shaded areas) for the sampling intensity (beta) estimates for each epoch. The red line shows the true beta used to simulate the tree.

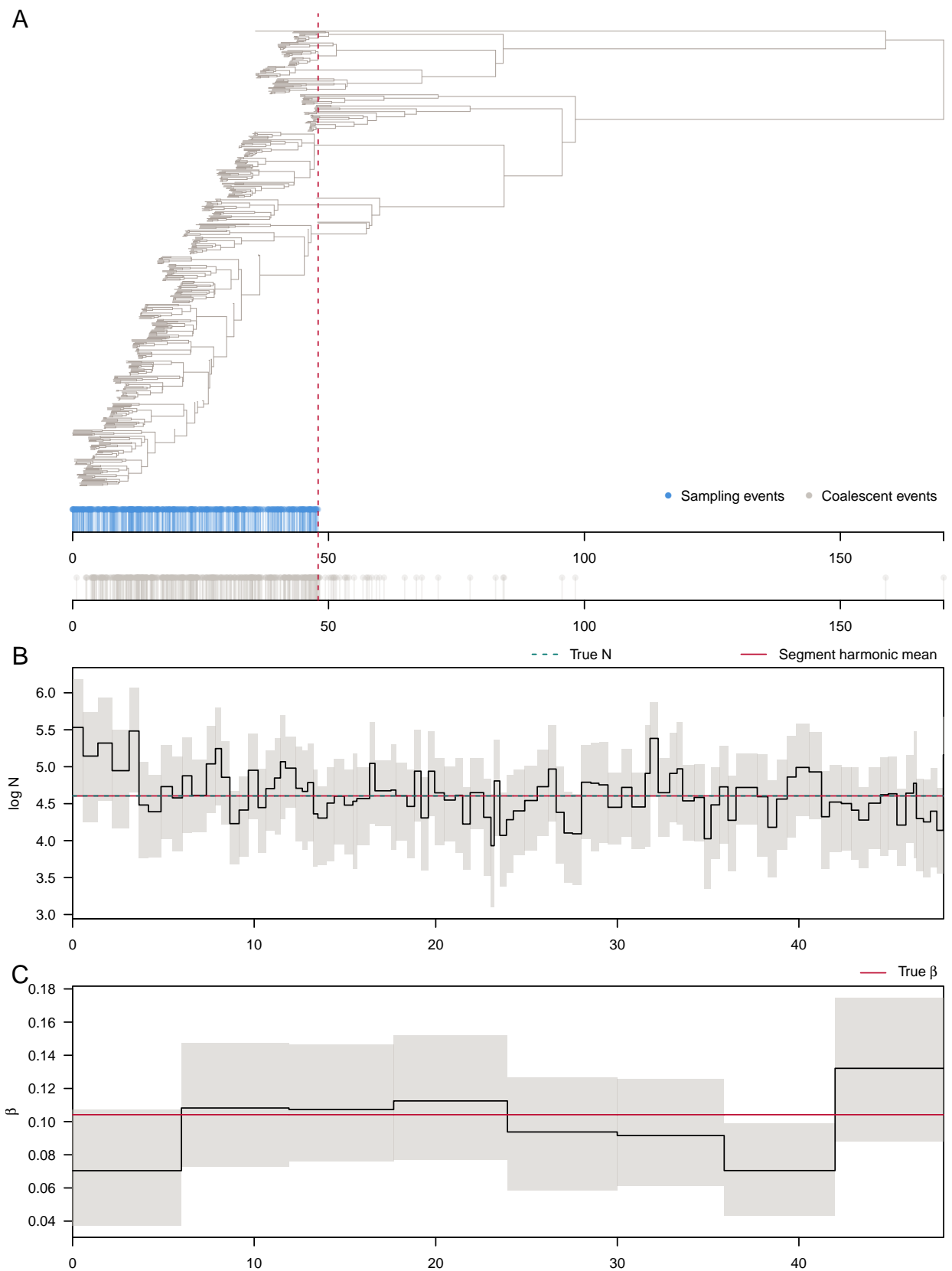


Figure 3: **Constant** (median ranked simulation): (A) Simulated tree with sampling (blue) and coalescent (grey) events. (B) Median (solid black line) and HPD intervals (shaded areas) for the  $N$ -estimates between the most recent and most ancient samples. The dashed green line shows the true  $N$ -trajectory used to simulate the tree and the red line the harmonic mean of the true  $N$  during each segment. (C) Median (solid black line) and HPD intervals (shaded areas) for the sampling intensity (beta) estimates for each epoch. The red line shows the true beta used to simulate the tree.

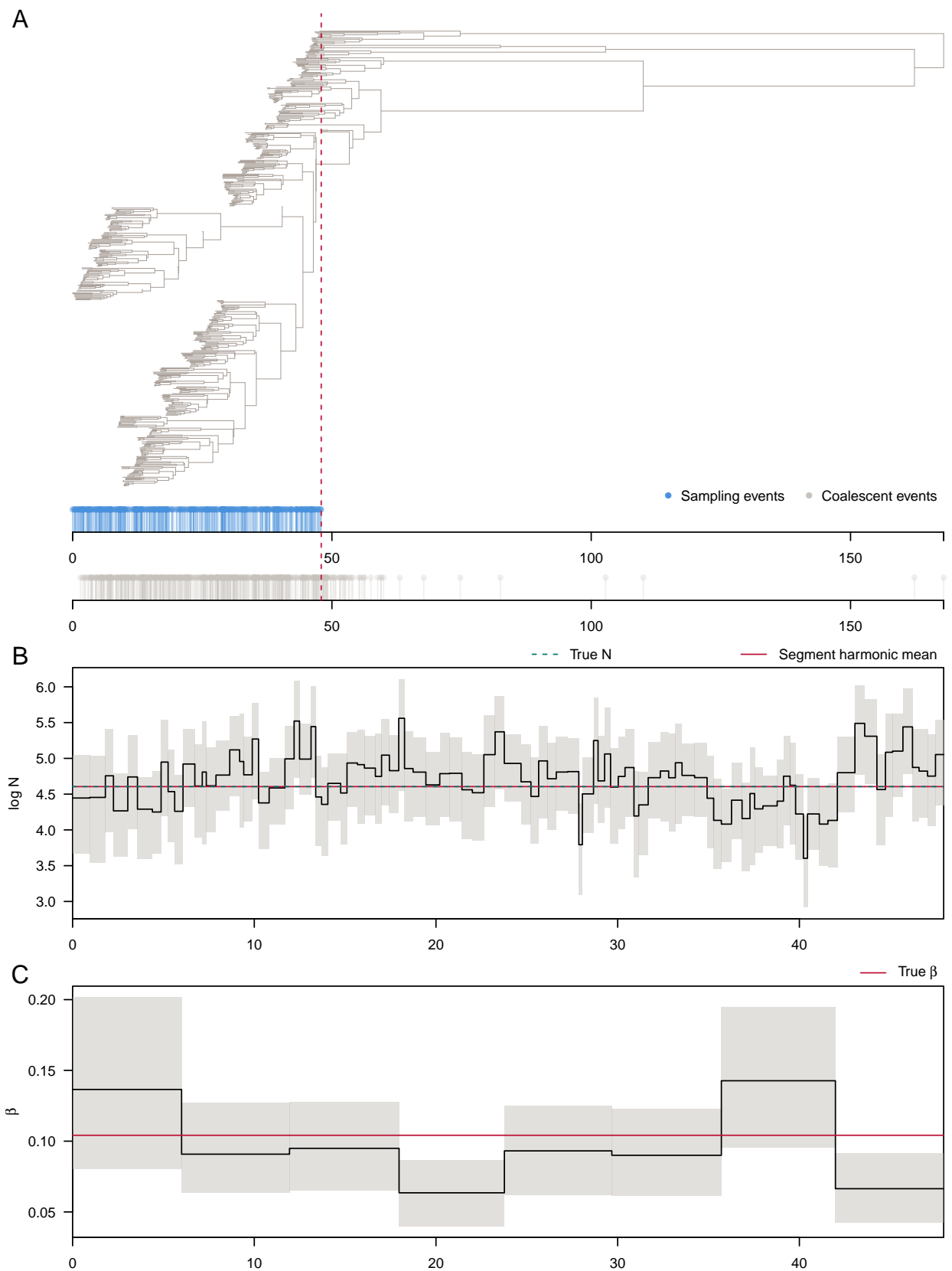


Figure 4: **Constant** (worst ranked simulation): (A) Simulated tree with sampling (blue) and coalescent (grey) events. (B) Median (solid black line) and HPD intervals (shaded areas) for the  $N$ -estimates between the most recent and most ancient samples. The dashed green line shows the true  $N$ -trajectory used to simulate the tree and the red line the harmonic mean of the true  $N$  during each segment. (C) Median (solid black line) and HPD intervals (shaded areas) for the sampling intensity (beta) estimates for each epoch. The red line shows the true beta used to simulate the tree.

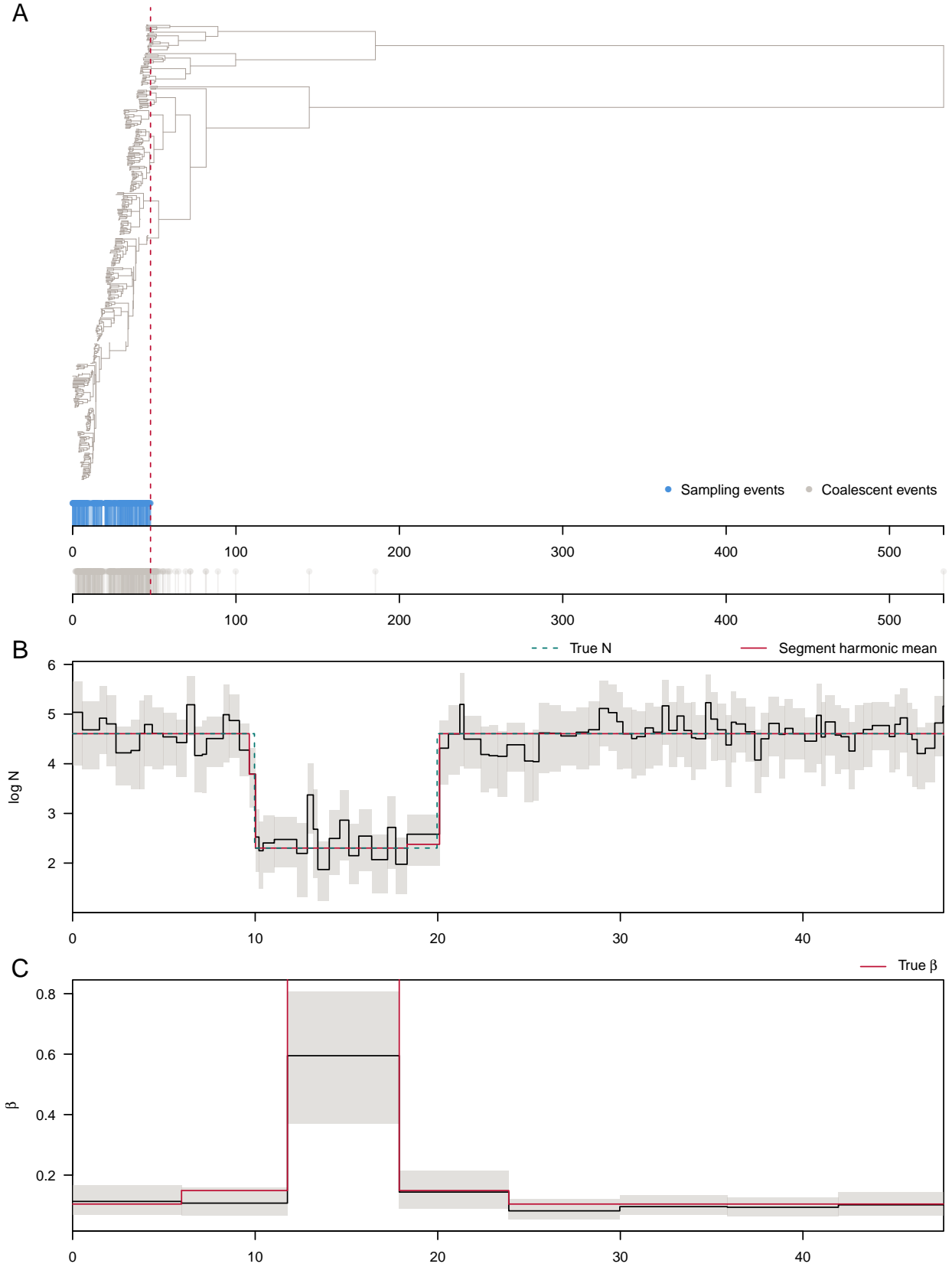


Figure 5: **Bottleneck** (best ranked simulation): (A) Simulated tree with sampling (blue) and coalescent (grey) events. (B) Median (solid black line) and HPD intervals (shaded areas) for the  $N$ -estimates between the most recent and most ancient samples. The dashed green line shows the true  $N$ -trajectory used to simulate the tree and the red line the harmonic mean of the true  $N$  during each segment. (C) Median (solid black line) and HPD intervals (shaded areas) for the sampling intensity (beta) estimates for each epoch. The red line shows the true beta used to simulate the tree.

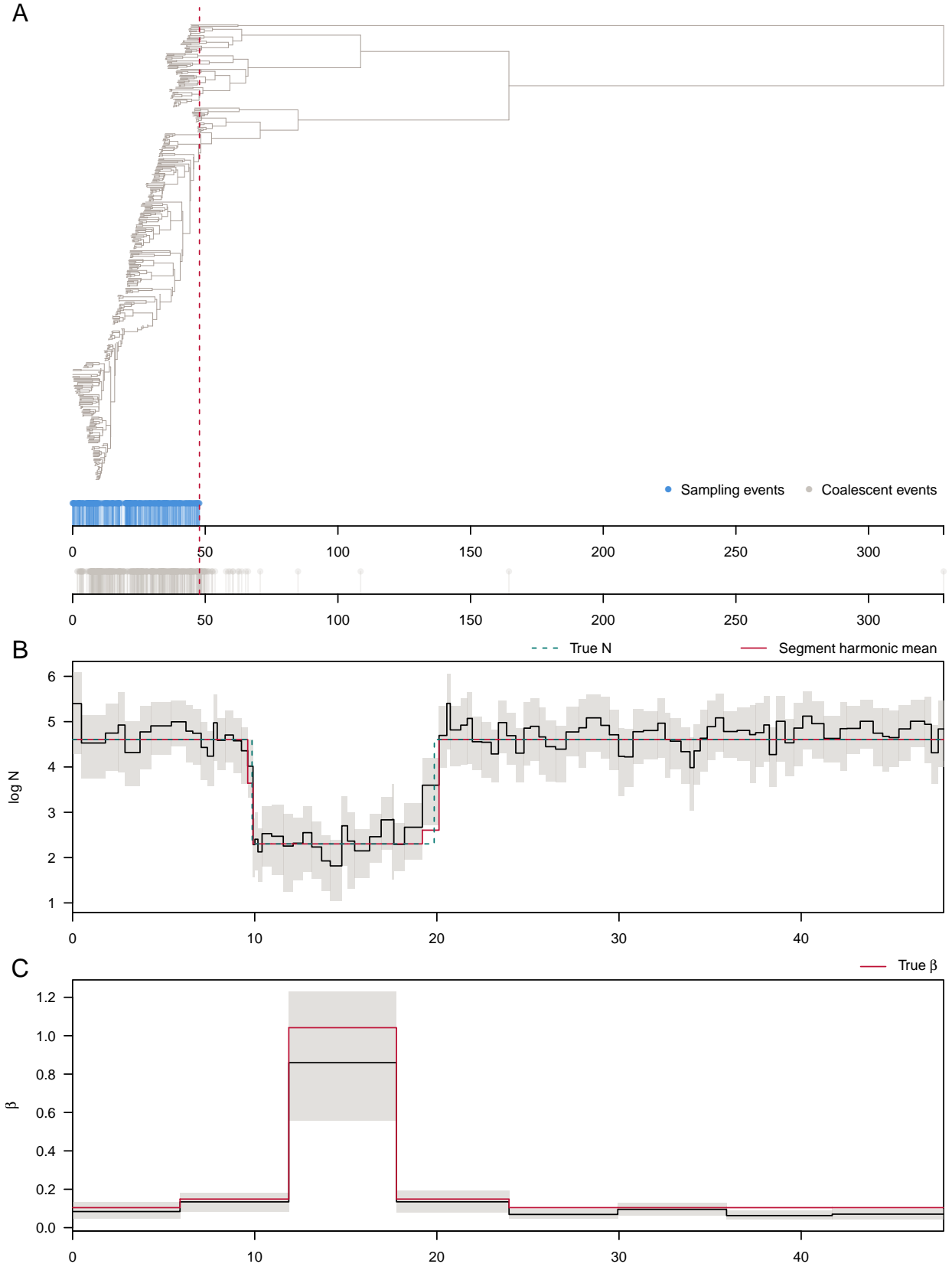


Figure 6: **Bottleneck** (median ranked simulation): (A) Simulated tree with sampling (blue) and coalescent (grey) events. (B) Median (solid black line) and HPD intervals (shaded areas) for the  $N$ -estimates between the most recent and most ancient samples. The dashed green line shows the true  $N$ -trajectory used to simulate the tree and the red line the harmonic mean of the true  $N$  during each segment. (C) Median (solid black line) and HPD intervals (shaded areas) for the sampling intensity (beta) estimates for each epoch. The red line shows the true beta used to simulate the tree.



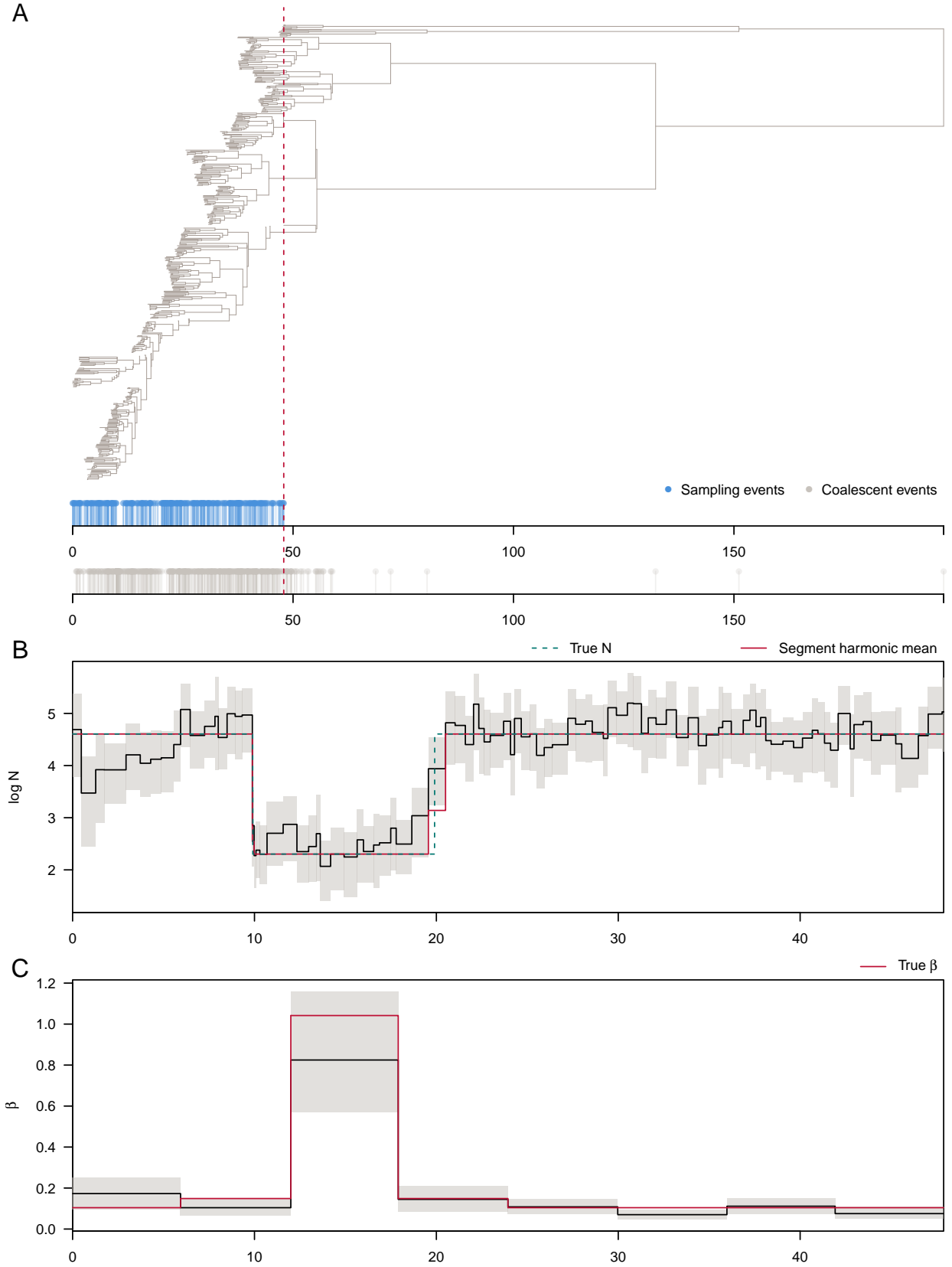


Figure 7: **Bottleneck** (worst ranked simulation): (A) Simulated tree with sampling (blue) and coalescent (grey) events. (B) Median (solid black line) and HPD intervals (shaded areas) for the  $N$ -estimates between the most recent and most ancient samples. The dashed green line shows the true  $N$ -trajectory used to simulate the tree and the red line the harmonic mean of the true  $N$  during each segment. (C) Median (solid black line) and HPD intervals (shaded areas) for the sampling intensity (beta) estimates for each epoch. The red line shows the true beta used to simulate the tree.

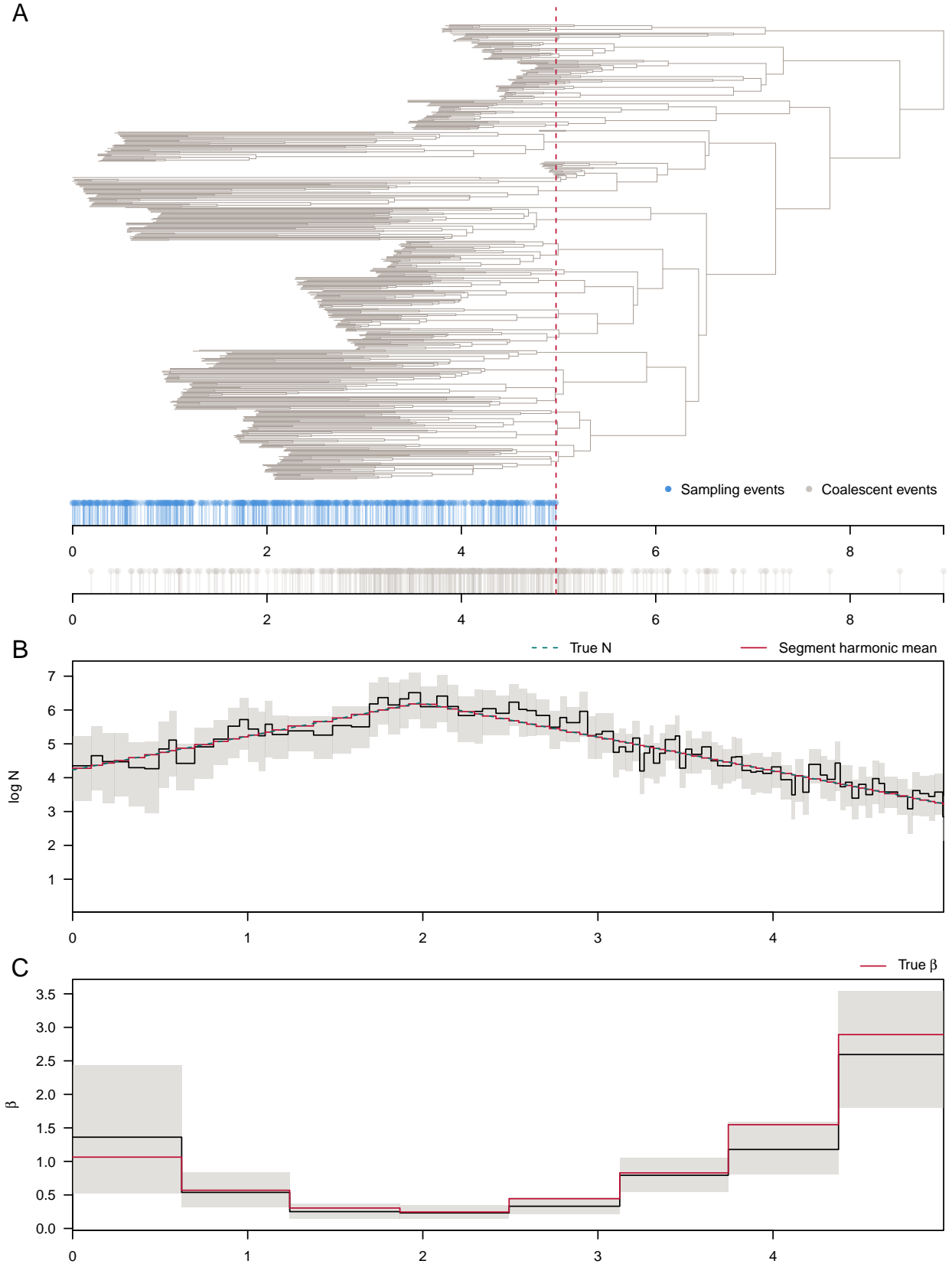


Figure 8: **Boom-bust** (best ranked simulation): (A) Simulated tree with sampling (blue) and coalescent (grey) events. (B) Median (solid black line) and HPD intervals (shaded areas) for the  $N$ -estimates between the most recent and most ancient samples. The dashed green line shows the true  $N$ -trajectory used to simulate the tree and the red line the harmonic mean of the true  $N$  during each segment. (C) Median (solid black line) and HPD intervals (shaded areas) for the sampling intensity (beta) estimates for each epoch. The red line shows the true beta used to simulate the tree.

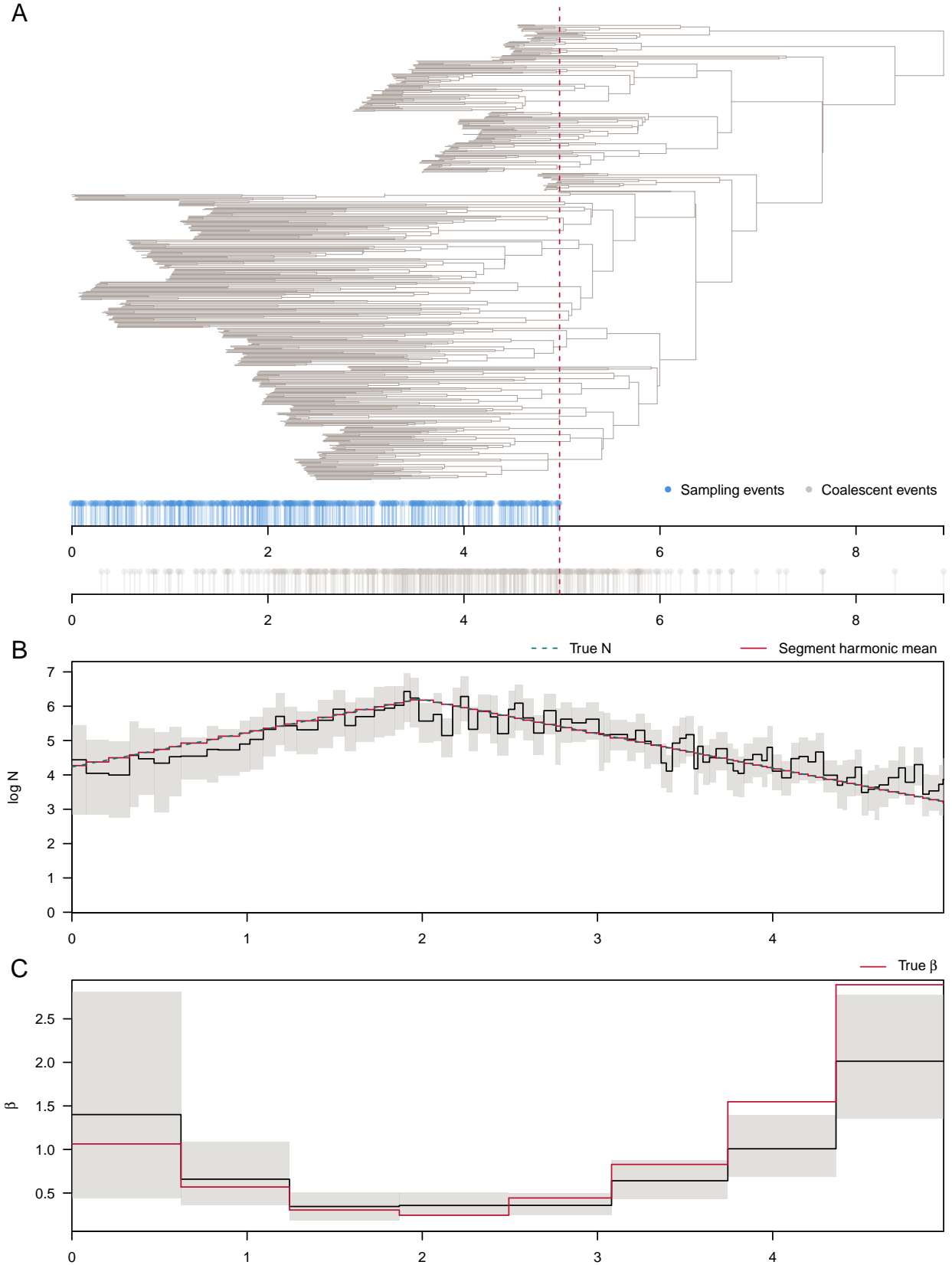


Figure 9: **Boom-bust** (median ranked simulation): (A) Simulated tree with sampling (blue) and coalescent (grey) events. (B) Median (solid black line) and HPD intervals (shaded areas) for the  $N$ -estimates between the most recent and most ancient samples. The dashed green line shows the true  $N$ -trajectory used to simulate the tree and the red line the harmonic mean of the true  $N$  during each segment. (C) Median (solid black line) and HPD intervals (shaded areas) for the sampling intensity (beta) estimates for each epoch. The red line shows the true beta used to simulate the tree.

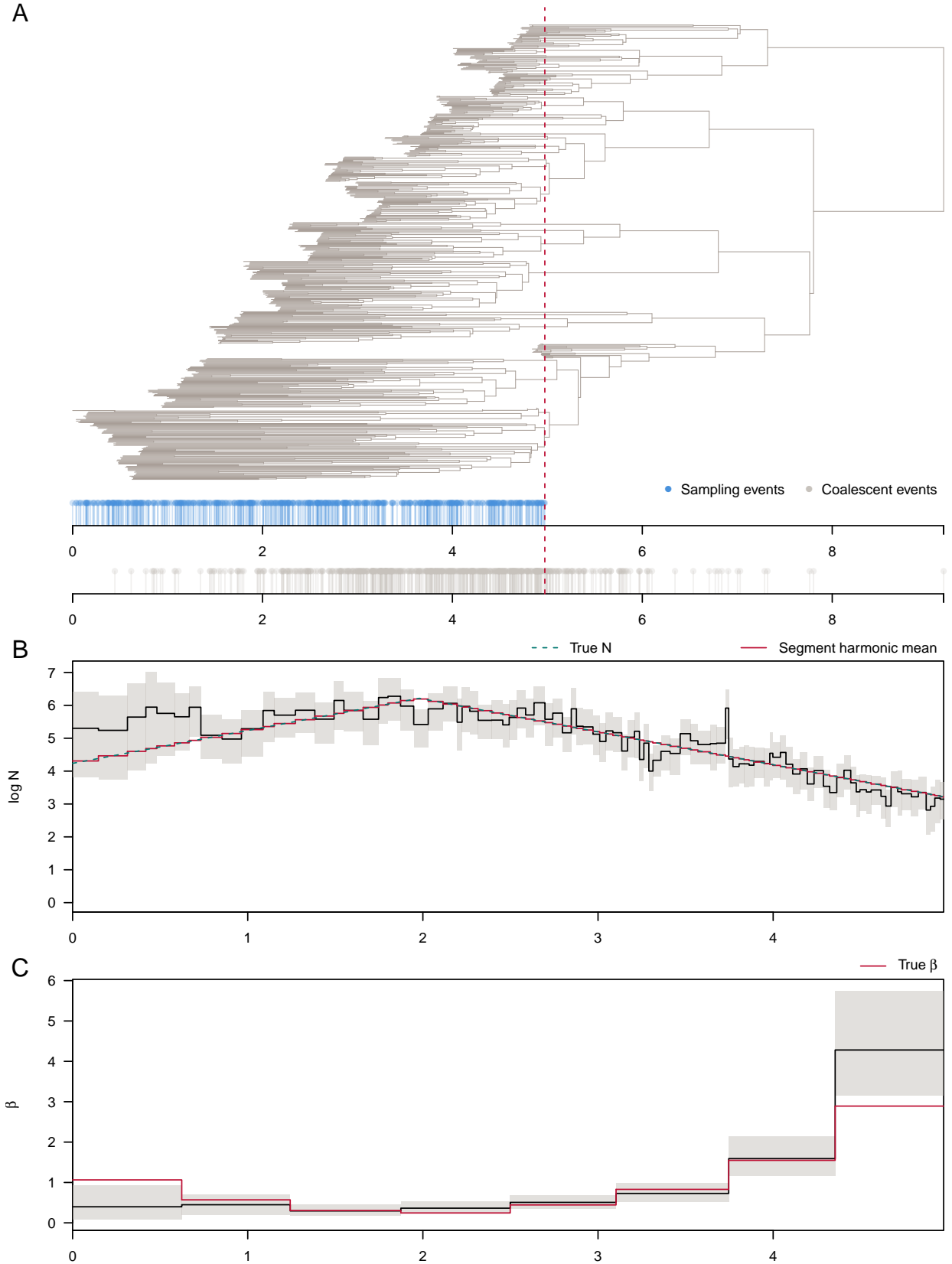


Figure 10: **Boom-bust** (worst ranked simulation): (A) Simulated tree with sampling (blue) and coalescent (grey) events. (B) Median (solid black line) and HPD intervals (shaded areas) for the  $N$ -estimates between the most recent and most ancient samples. The dashed green line shows the true  $N$ -trajectory used to simulate the tree and the red line the harmonic mean of the true  $N$  during each segment. (C) Median (solid black line) and HPD intervals (shaded areas) for the sampling intensity (beta) estimates for each epoch. The red line shows the true beta used to simulate the tree.

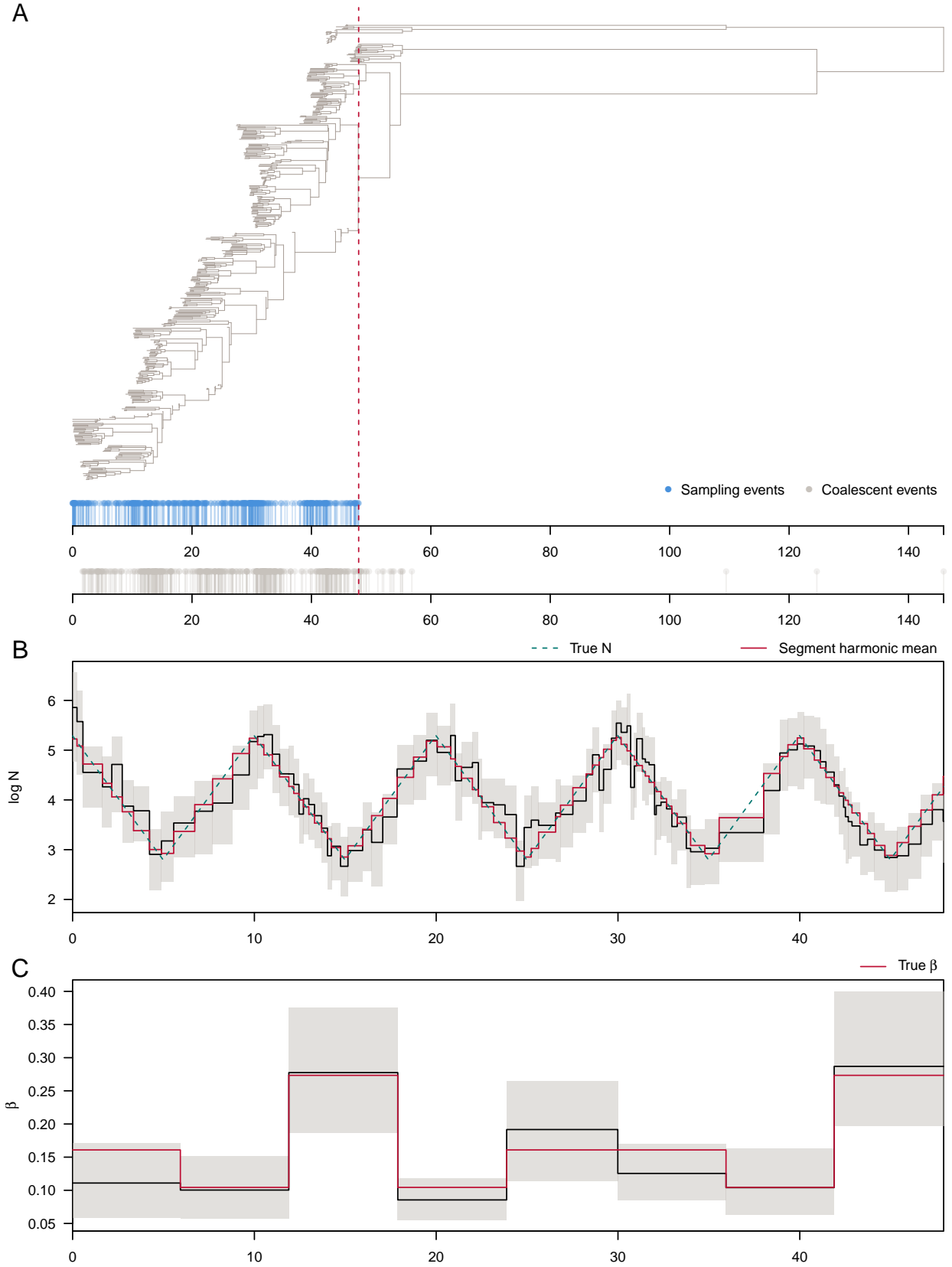


Figure 11: **Cyclical** (best ranked simulation): (A) Simulated tree with sampling (blue) and coalescent (grey) events. (B) Median (solid black line) and HPD intervals (shaded areas) for the  $N$ -estimates between the most recent and most ancient samples. The dashed green line shows the true  $N$ -trajectory used to simulate the tree and the red line the harmonic mean of the true  $N$  during each segment. (C) Median (solid black line) and HPD intervals (shaded areas) for the sampling intensity (beta) estimates for each epoch. The red line shows the true beta used to simulate the tree.

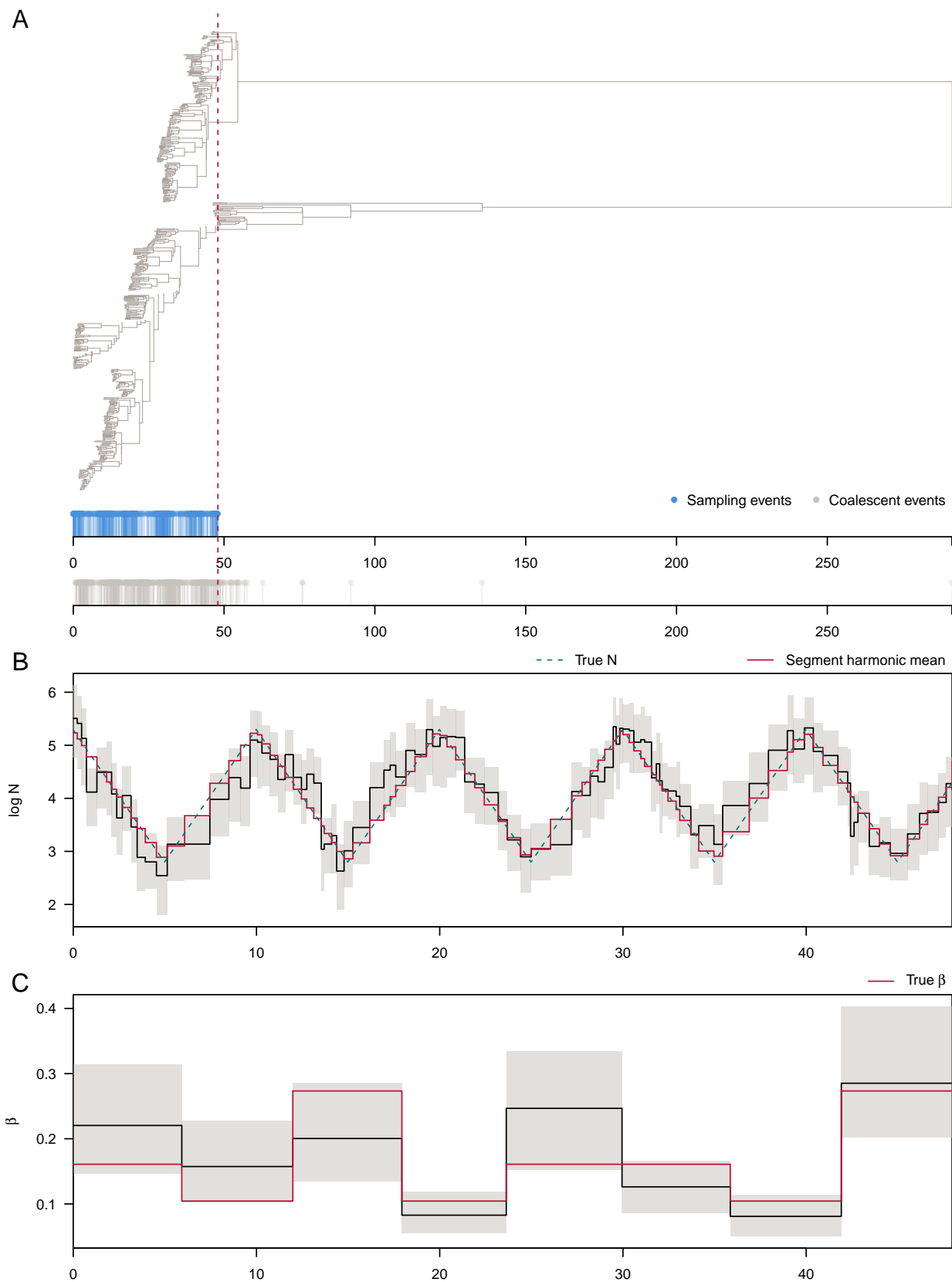
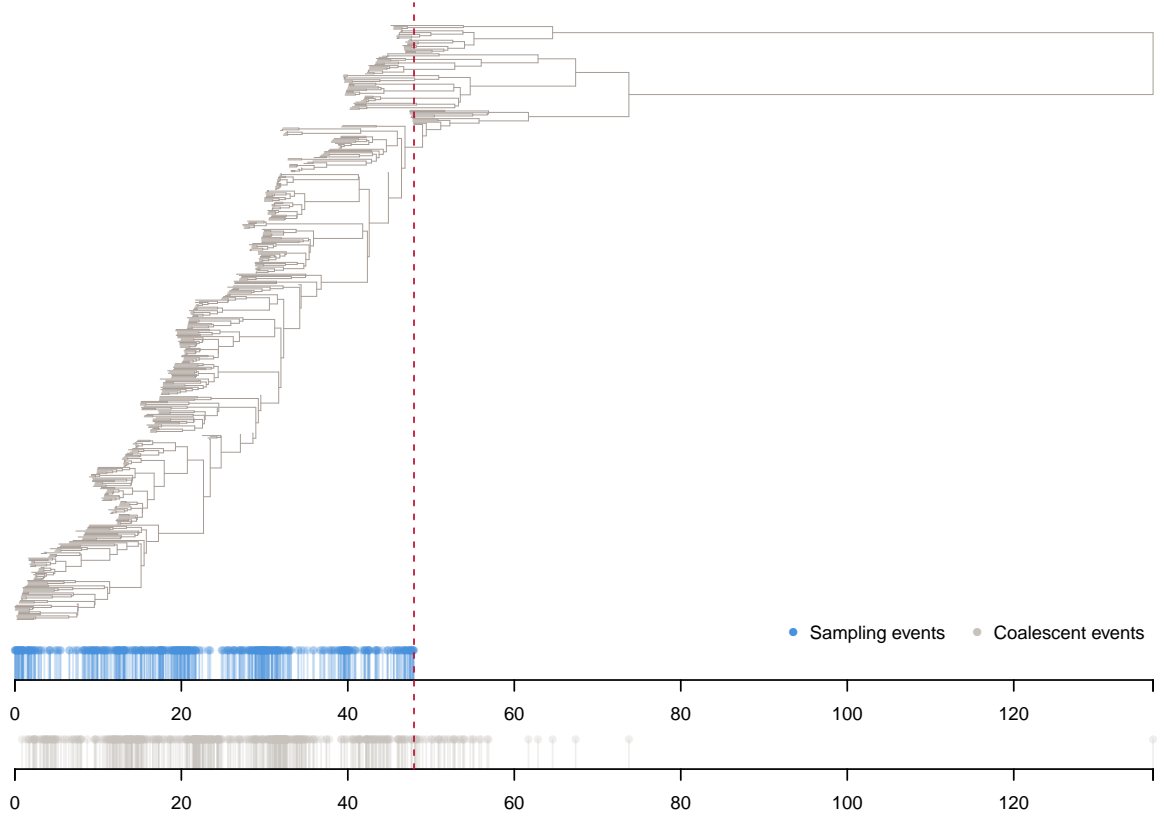
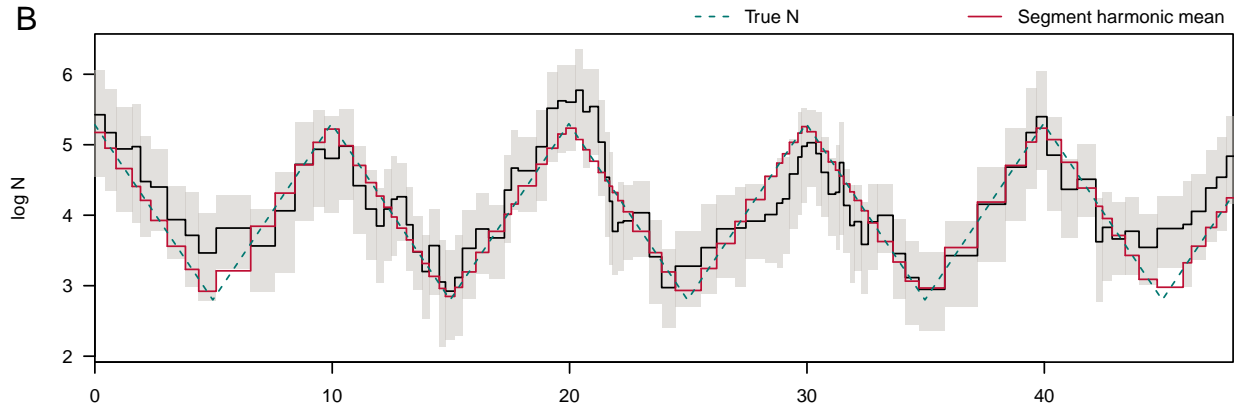


Figure 12: **Cyclical** (median ranked simulation): (A) Simulated tree with sampling (blue) and coalescent (grey) events. (B) Median (solid black line) and HPD intervals (shaded areas) for the  $N$ -estimates between the most recent and most ancient samples. The dashed green line shows the true  $N$ -trajectory used to simulate the tree and the red line the harmonic mean of the true  $N$  during each segment. (C) Median (solid black line) and HPD intervals (shaded areas) for the sampling intensity (beta) estimates for each epoch. The red line shows the true beta used to simulate the tree.

A



B



C

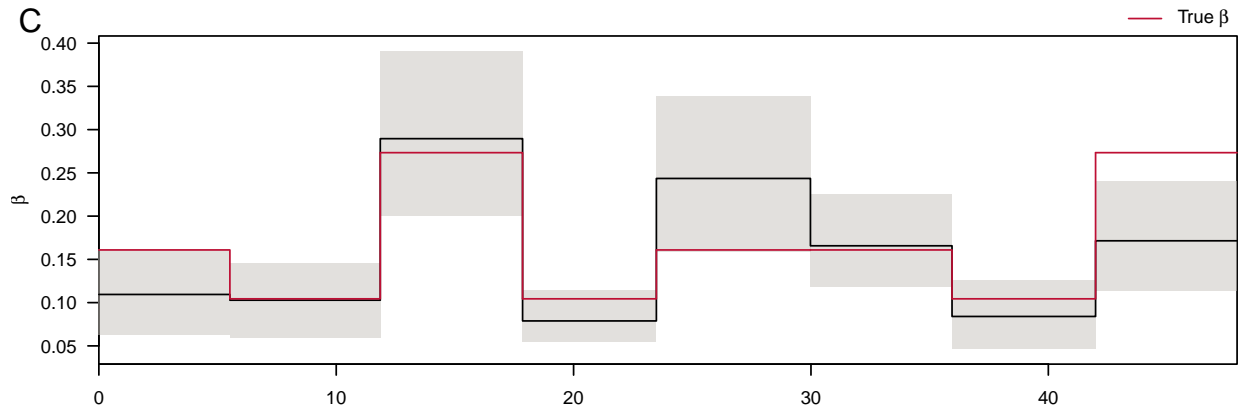
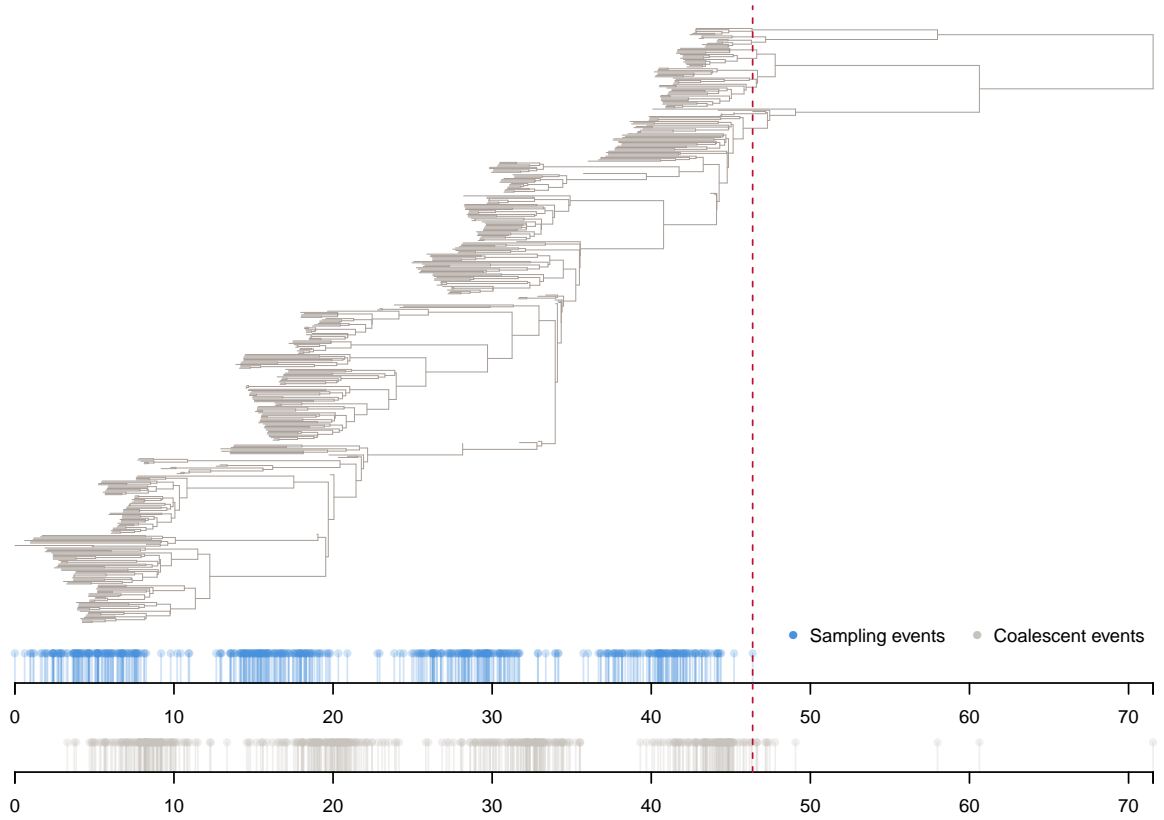
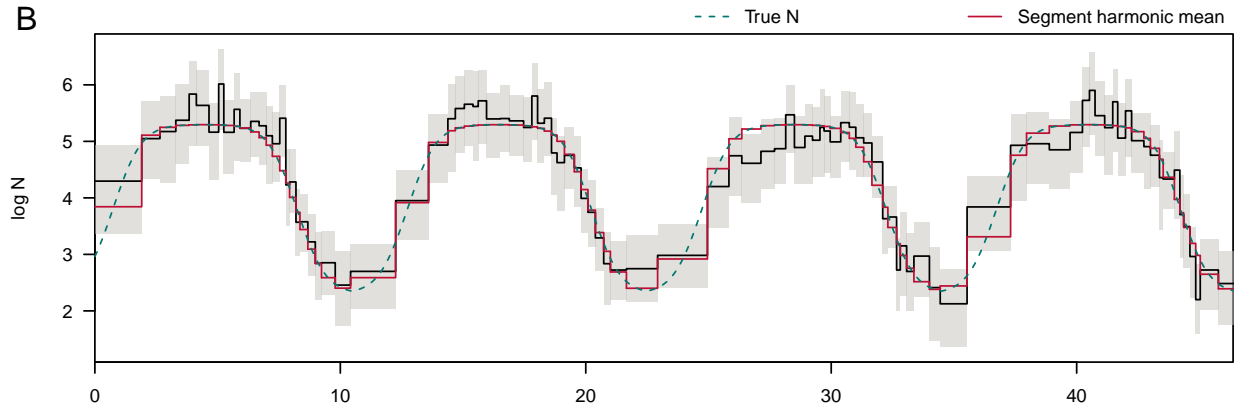


Figure 13: **Cyclical** (worst ranked simulation): (A) Simulated tree with sampling (blue) and coalescent (grey) events. (B) Median (solid black line) and HPD intervals (shaded areas) for the  $N$ -estimates between the most recent and most ancient samples. The dashed green line shows the true  $N$ -trajectory used to simulate the tree and the red line the harmonic mean of the true  $N$  during each segment. (C) Median (solid black line) and HPD intervals (shaded areas) for the sampling intensity (beta) estimates for each epoch. The red line shows the true beta used to simulate the tree.

A



B



C

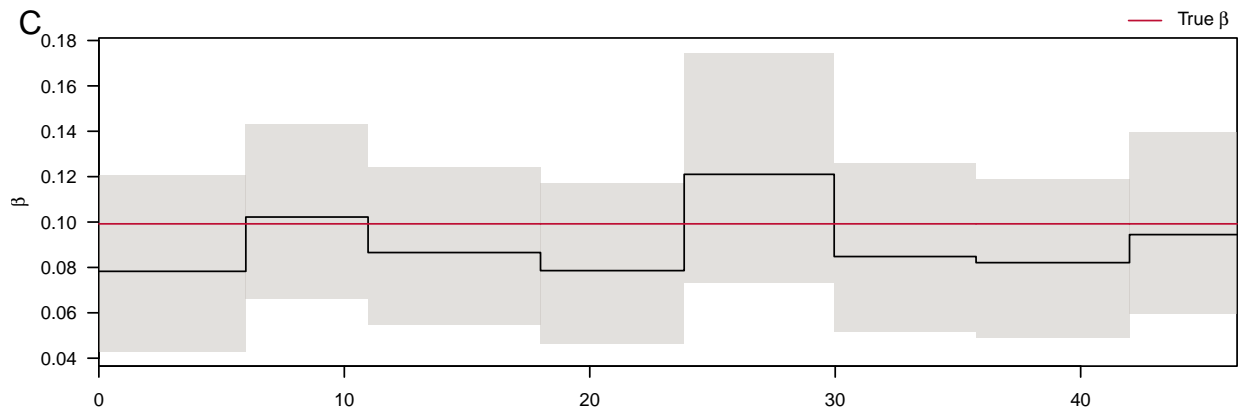
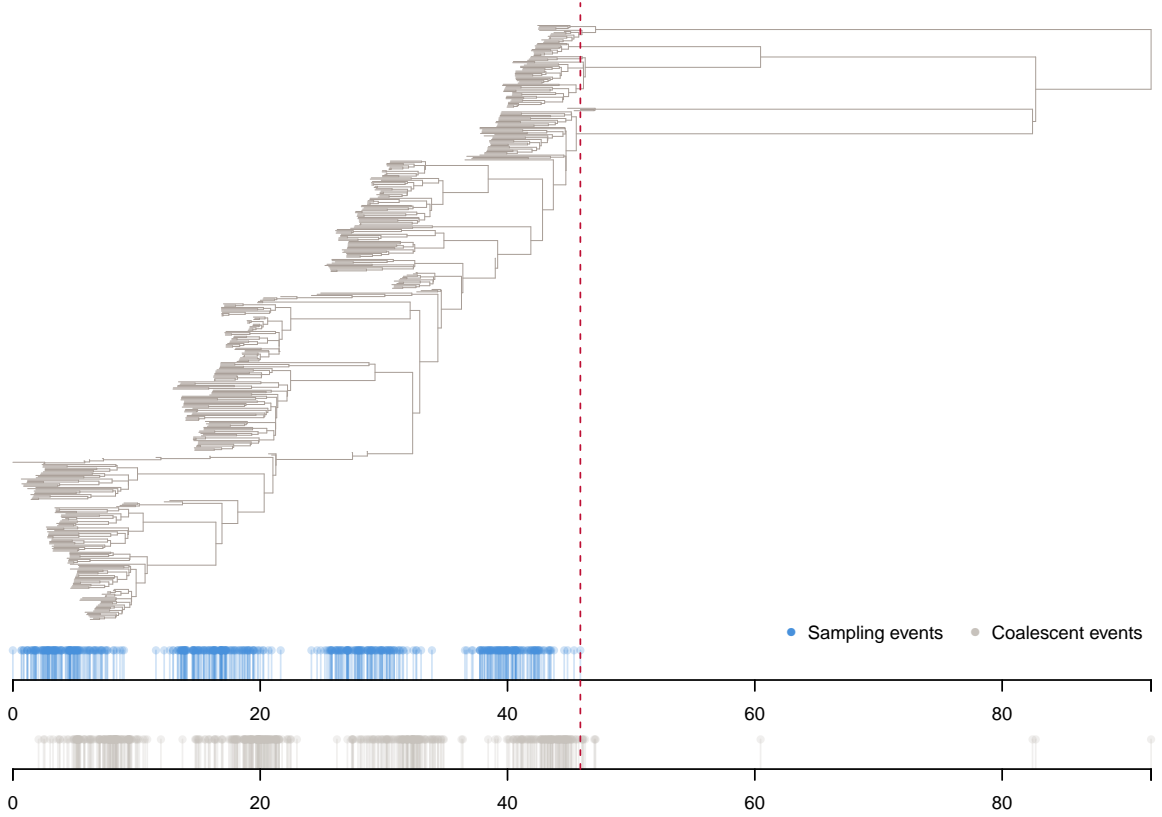


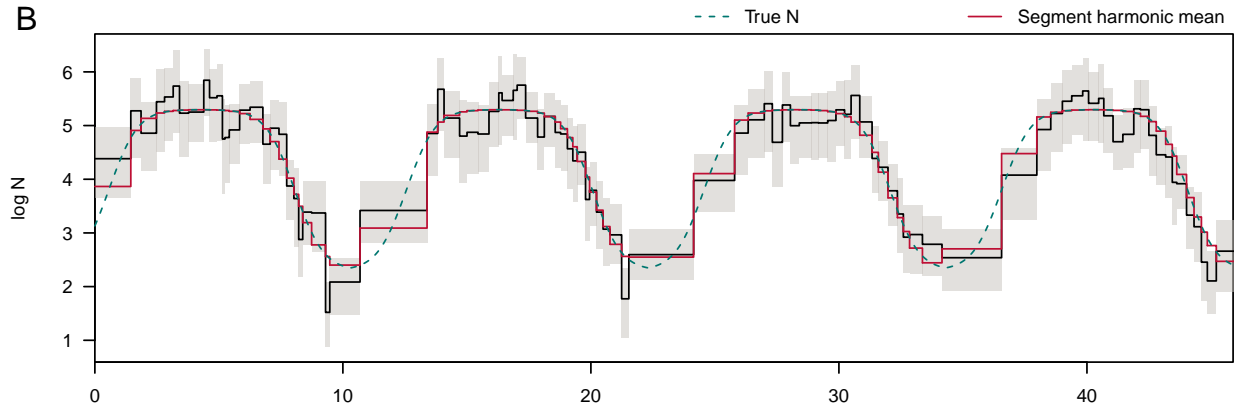
Figure 14: **Logistic** (best ranked simulation): (A) Simulated tree with sampling (blue) and coalescent (grey) events. (B) Median (solid black line) and HPD intervals (shaded areas) for the  $N$ -estimates between the most recent and most ancient samples. The dashed green line shows the true  $N$ -trajectory used to simulate the tree and the red line the harmonic mean of the true  $N$  during each segment. (C) Median (solid black line) and HPD intervals (shaded areas) for the sampling intensity (beta) estimates for each epoch. The red line shows the true beta used to simulate the tree.



A



B



C

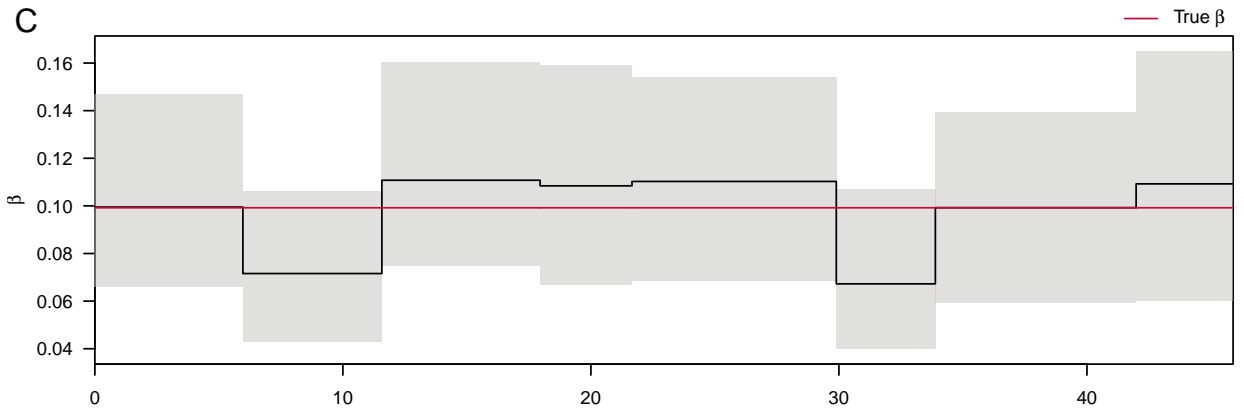


Figure 15: **Logistic** (best ranked simulation): (A) Simulated tree with sampling (blue) and coalescent (grey) events. (B) Median (solid black line) and HPD intervals (shaded areas) for the  $N$ -estimates between the most recent and most ancient samples. The dashed green line shows the true  $N$ -trajectory used to simulate the tree and the red line the harmonic mean of the true  $N$  during each segment. (C) Median (solid black line) and HPD intervals (shaded areas) for the sampling intensity (beta) estimates for each epoch. The red line shows the true beta used to simulate the tree.

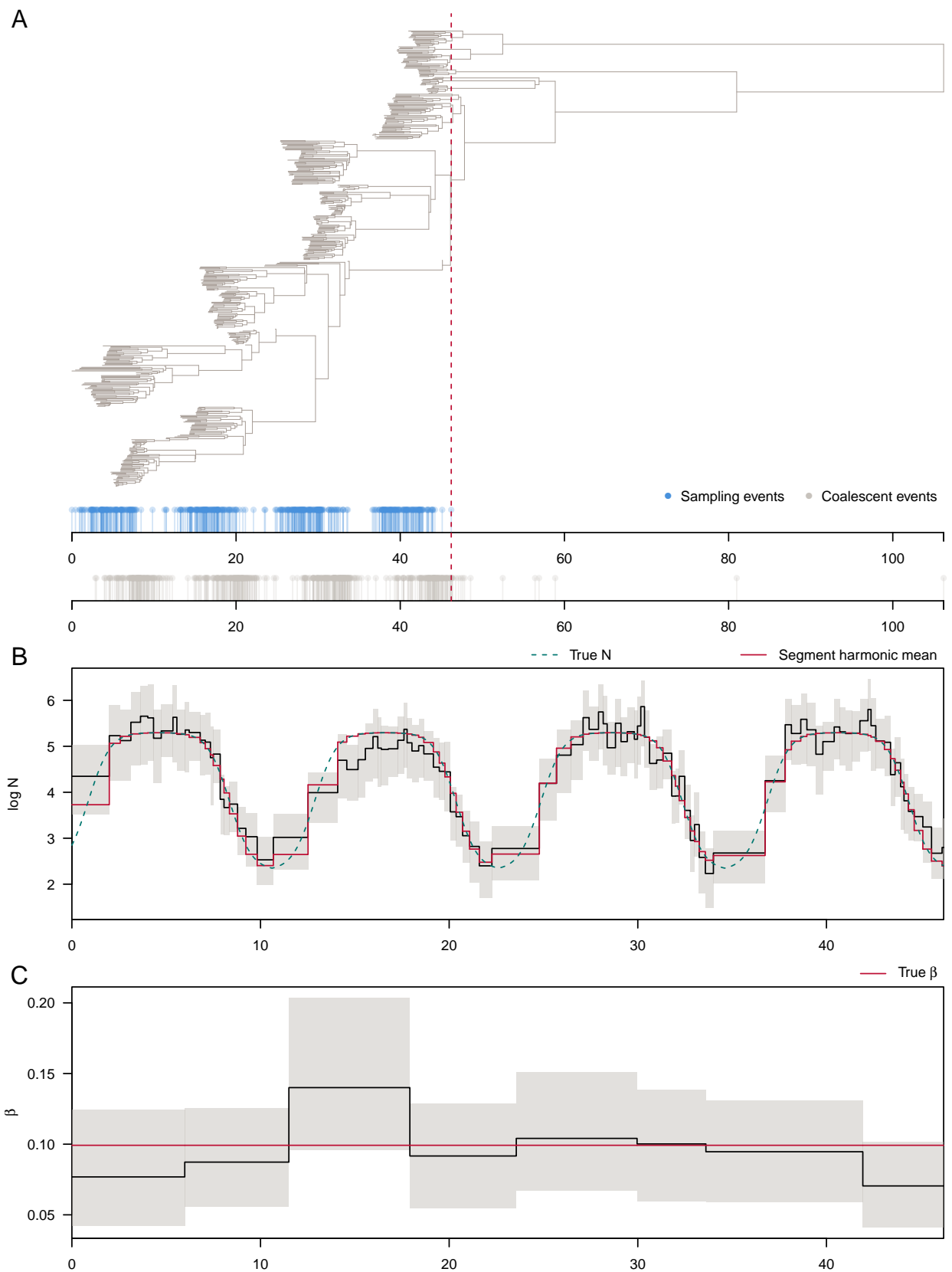
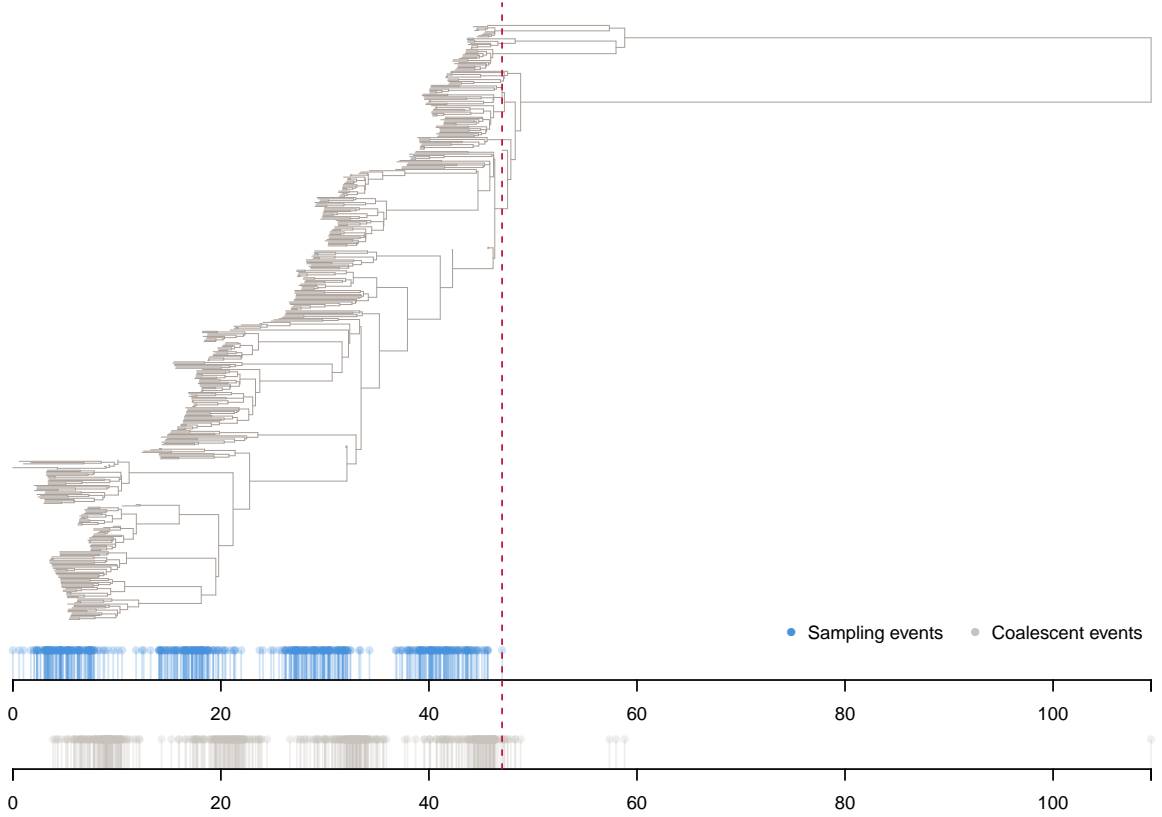
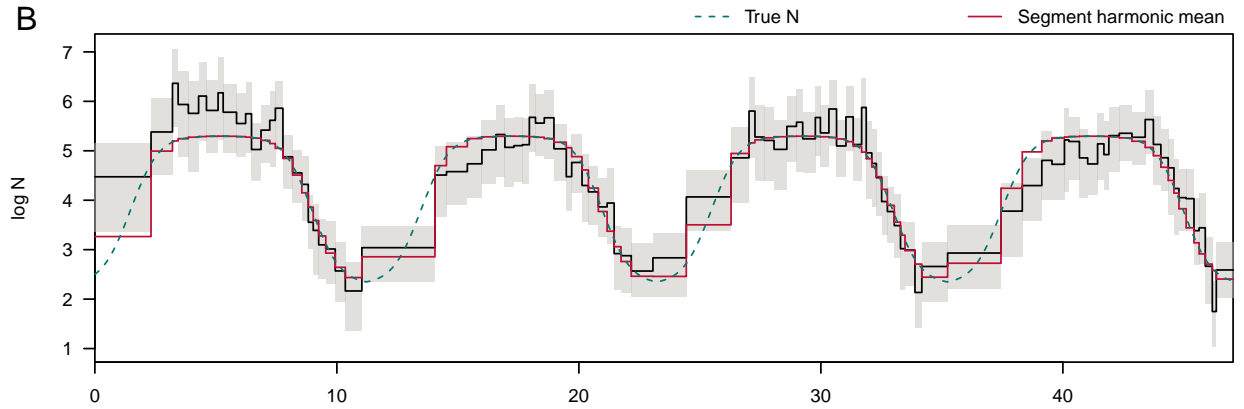


Figure 16: **Logistic** (best ranked simulation): (A) Simulated tree with sampling (blue) and coalescent (grey) events. (B) Median (solid black line) and HPD intervals (shaded areas) for the  $N$ -estimates between the most recent and most ancient samples. The dashed green line shows the true  $N$ -trajectory used to simulate the tree and the red line the harmonic mean of the true  $N$  during each segment. (C) Median (solid black line) and HPD intervals (shaded areas) for the sampling intensity (beta) estimates for each epoch. The red line shows the true beta used to simulate the tree.

A



B



C

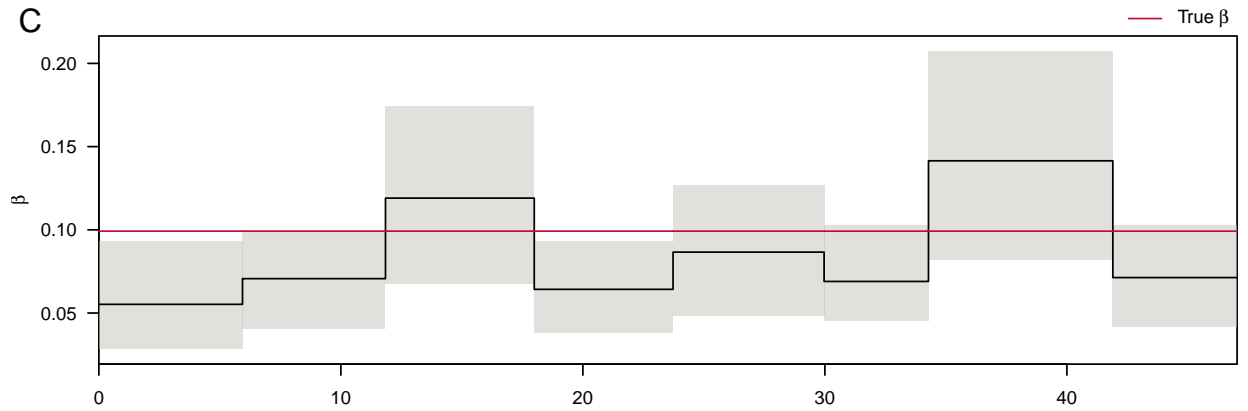


Figure 17: **Logistic** (median ranked simulation): (A) Simulated tree with sampling (blue) and coalescent (grey) events. (B) Median (solid black line) and HPD intervals (shaded areas) for the N-estimates between the most recent and most ancient samples. The dashed green line shows the true N-trajectory used to simulate the tree and the red line the harmonic mean of the true N during each segment. (C) Median (solid black line) and HPD intervals (shaded areas) for the sampling intensity (beta) estimates for each epoch. The red line shows the true beta used to simulate the tree.

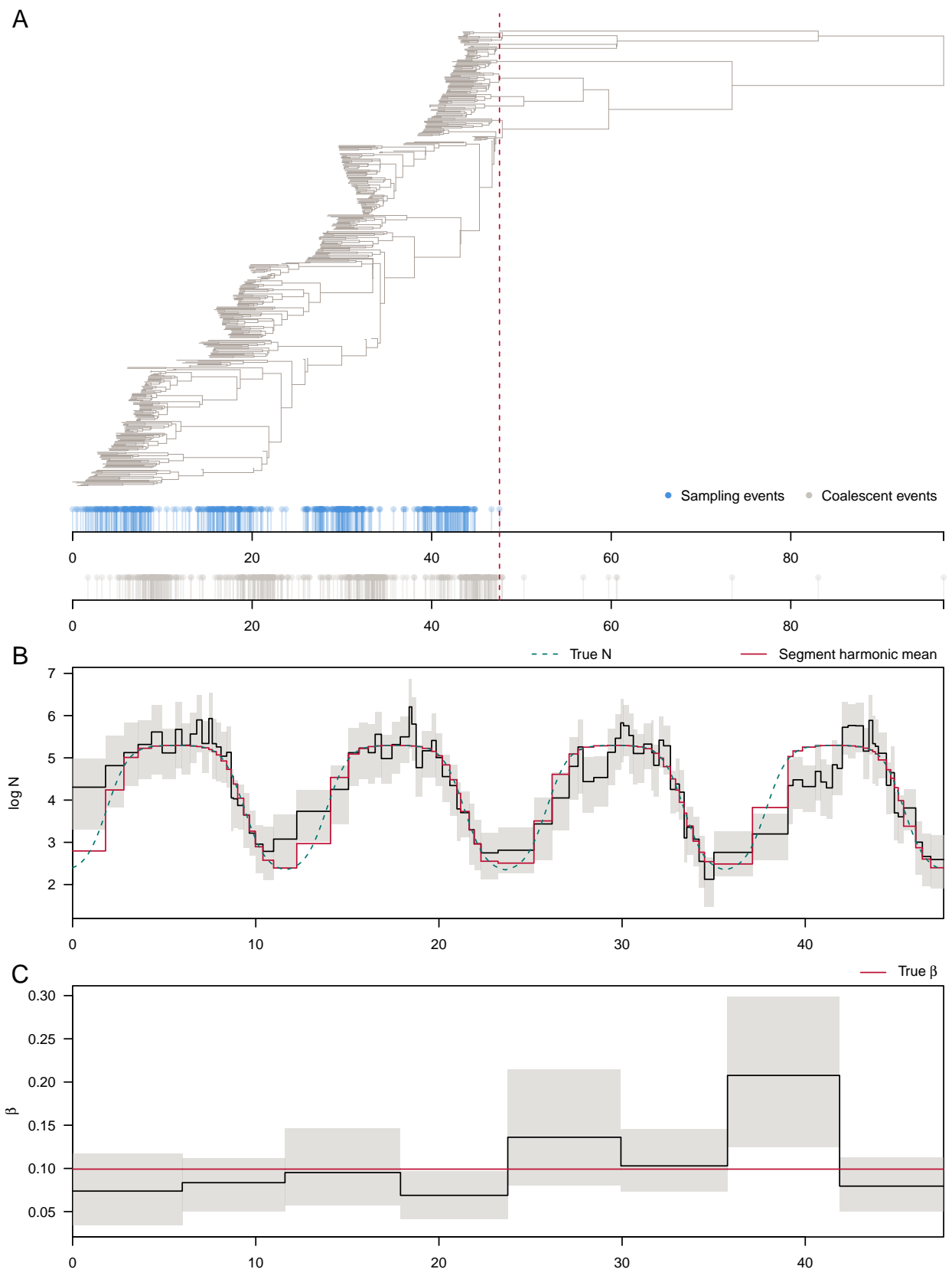


Figure 18: **Logistic** (worst ranked simulation): (A) Simulated tree with sampling (blue) and coalescent (grey) events. (B) Median (solid black line) and HPD intervals (shaded areas) for the  $N$ -estimates between the most recent and most ancient samples. The dashed green line shows the true  $N$ -trajectory used to simulate the tree and the red line the harmonic mean of the true  $N$  during each segment. (C) Median (solid black line) and HPD intervals (shaded areas) for the sampling intensity (beta) estimates for each epoch. The red line shows the true beta used to simulate the tree.

## 4 Session info

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## Running under: macOS Sierra 10.12.6
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## BLAS: /Library/Frameworks/R.framework/Versions/3.5/Resources/lib/libRblas.0.dylib
## LAPACK: /Library/Frameworks/R.framework/Versions/3.5/Resources/lib/libRlapack.dylib
##
## locale:
## [1] en_GB.UTF-8/en_GB.UTF-8/en_GB.UTF-8/C/en_GB.UTF-8/en_GB.UTF-8
##
## attached base packages:
## [1] stats      graphics  grDevices  utils      datasets  methods    base
##
## other attached packages:
## [1] ape_5.3          coda_0.19-3      beastio_0.2.0
## [4] phylodyn_0.9.0   bdskytools_0.0.1.0
##
## loaded via a namespace (and not attached):
## [1] Rcpp_1.0.1        codetools_0.2-16  lattice_0.20-38
## [4] digest_0.6.19     grid_3.5.1        nlme_3.1-139
## [7] magrittr_1.5      evaluate_0.13     highr_0.8
## [10] stringi_1.4.3     rmarkdown_1.12    RColorBrewer_1.1-2
## [13] tools_3.5.1       stringr_1.4.0     parallel_3.5.1
## [16] xfun_0.6          yaml_2.2.0        compiler_3.5.1
## [19] htmltools_0.3.6   knitr_1.22
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