20190725nigata-test-simple

```
set.seed(1234)
```

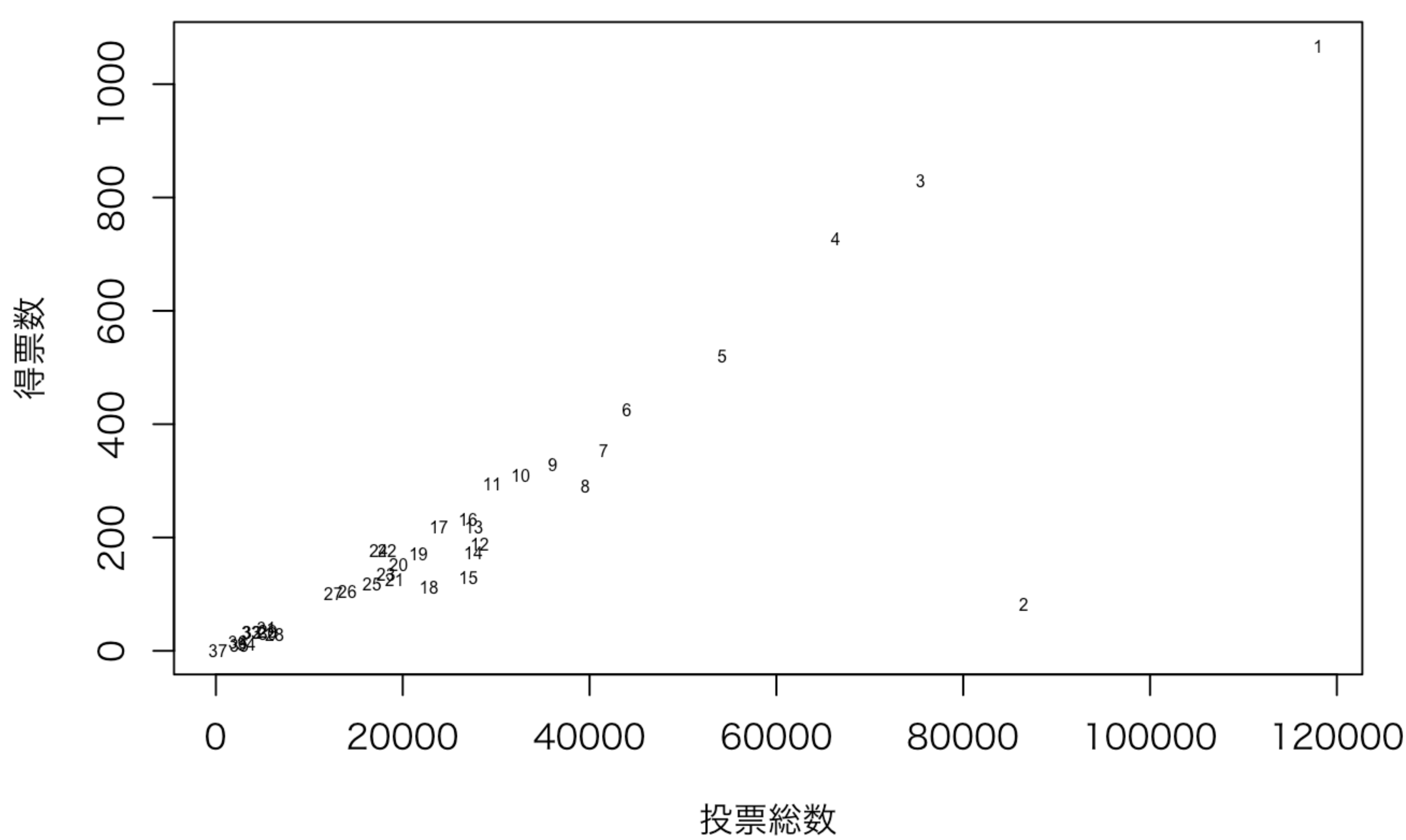
nigata data

read table & rounding to integers

```
dat <- read.csv("nigata.csv")
colnames(dat) <- c("city", "sosu", "tokuhyo")
data = list(N=nrow(dat), x=round(dat$tokuhyo), n=round(dat$sosu), city=as.characte
r(dat$city))
```

plot

```
plot(data$n, data$x, type="n", xlab="投票総数", ylab="得票数", family=family); text(d
ata$n, data$x, cex=0.5)
```



Computing posterior distributions (Bayesian inference)

stan

```
library(rstan)
```

```
## Loading required package: StanHeaders
```

```
## Loading required package: ggplot2
```

```
## rstan (Version 2.19.2, GitRev: 2e1f913d3ca3)
```

```
## For execution on a local, multicore CPU with excess RAM we recommend calling
## options(mc.cores = parallel::detectCores()).
## To avoid recompilation of unchanged Stan programs, we recommend calling
## rstan_options(auto_write = TRUE)
```

```
rstan_options(auto_write=TRUE)
options(mc.cores=parallel::detectCores())
```

fit

```
betabinom2 = stan_model("betabinom2.stan")
fit1 <- sampling(betabinom2, data=data, chains=8, warmup=2000, iter=20000)
```

stan diagnostics

```
fit1
```

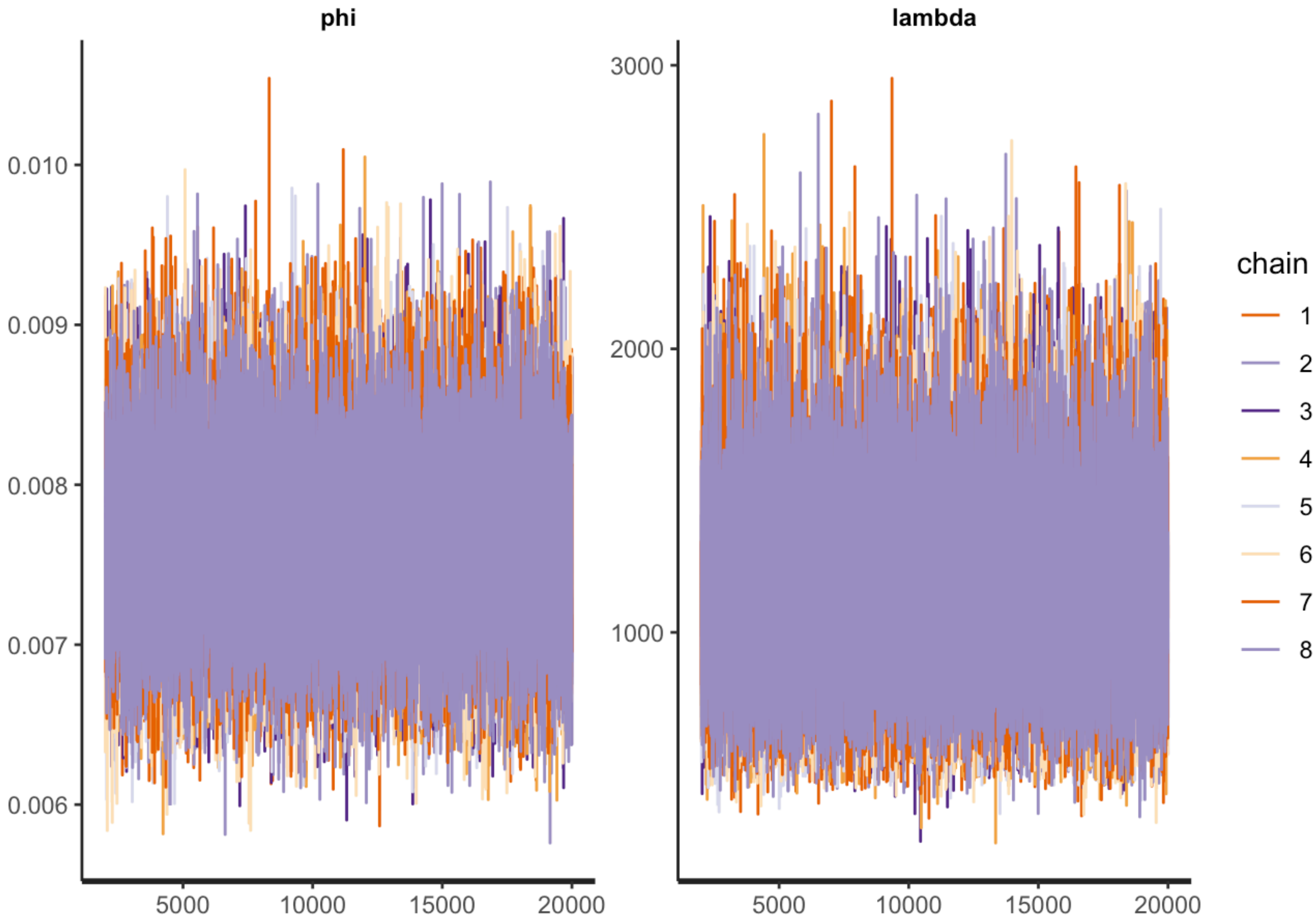
```
## Inference for Stan model: betabinom2.
## 8 chains, each with iter=20000; warmup=2000; thin=1;
## post-warmup draws per chain=18000, total post-warmup draws=144000.
##
##                 mean se_mean     sd      2.5%       25%       50%       75%
## p[1]            0.01    0.00   0.00      0.01      0.01      0.01      0.01
## p[2]            0.00    0.00   0.00      0.00      0.00      0.00      0.00
## p[3]            0.01    0.00   0.00      0.01      0.01      0.01      0.01
## p[4]            0.01    0.00   0.00      0.01      0.01      0.01      0.01
## p[5]            0.01    0.00   0.00      0.01      0.01      0.01      0.01
## p[6]            0.01    0.00   0.00      0.01      0.01      0.01      0.01
## p[7]            0.01    0.00   0.00      0.01      0.01      0.01      0.01
## p[8]            0.01    0.00   0.00      0.01      0.01      0.01      0.01
## p[9]            0.01    0.00   0.00      0.01      0.01      0.01      0.01
```

```
## p[10]         0.01    0.00   0.00      0.01      0.01      0.01      0.01
## p[11]         0.01    0.00   0.00      0.01      0.01      0.01      0.01
## p[12]         0.01    0.00   0.00      0.01      0.01      0.01      0.01
## p[13]         0.01    0.00   0.00      0.01      0.01      0.01      0.01
## p[14]         0.01    0.00   0.00      0.01      0.01      0.01      0.01
## p[15]         0.00    0.00   0.00      0.00      0.00      0.00      0.01
## p[16]         0.01    0.00   0.00      0.01      0.01      0.01      0.01
## p[17]         0.01    0.00   0.00      0.01      0.01      0.01      0.01
## p[18]         0.01    0.00   0.00      0.00      0.00      0.01      0.01
## p[19]         0.01    0.00   0.00      0.01      0.01      0.01      0.01
## p[20]         0.01    0.00   0.00      0.01      0.01      0.01      0.01
## p[21]         0.01    0.00   0.00      0.01      0.01      0.01      0.01
## p[22]         0.01    0.00   0.00      0.01      0.01      0.01      0.01
## p[23]         0.01    0.00   0.00      0.01      0.01      0.01      0.01
## p[24]         0.01    0.00   0.00      0.01      0.01      0.01      0.01
## p[25]         0.01    0.00   0.00      0.01      0.01      0.01      0.01
## p[26]         0.01    0.00   0.00      0.01      0.01      0.01      0.01
## p[27]         0.01    0.00   0.00      0.01      0.01      0.01      0.01
## p[28]         0.01    0.00   0.00      0.00      0.00      0.01      0.01
## p[29]         0.01    0.00   0.00      0.00      0.01      0.01      0.01
## p[30]         0.01    0.00   0.00      0.00      0.01      0.01      0.01
## p[31]         0.01    0.00   0.00      0.01      0.01      0.01      0.01
## p[32]         0.01    0.00   0.00      0.01      0.01      0.01      0.01
## p[33]         0.01    0.00   0.00      0.01      0.01      0.01      0.01
## p[34]         0.00    0.00   0.00      0.00      0.00      0.00      0.01
## p[35]         0.01    0.00   0.00      0.00      0.00      0.01      0.01
## p[36]         0.01    0.00   0.00      0.00      0.01      0.01      0.01
## p[37]         0.01    0.00   0.00      0.00      0.01      0.01      0.01
## phi           0.01    0.00   0.00      0.01      0.01      0.01      0.01
## lambda     1123.27    0.67 280.37    646.60    923.47   1098.67   1295.38
## alpha         8.55    0.00   2.10      4.99      7.06      8.35      9.83
## beta       1114.73    0.66 278.33    641.62    916.51   1090.23   1285.56
## x_rep[1]    902.10    0.85 322.81    382.00    672.00    865.00   1090.00
## x_rep[2]    660.90    0.62 236.83    279.00    492.00    633.00    798.00
## x_rep[3]    576.47    0.54 206.85    244.00    429.00    553.00    696.00
## x_rep[4]    507.04    0.48 182.03    214.00    377.00    486.00    613.00
## x_rep[5]    414.19    0.39 149.03    174.00    308.00    397.00    501.00
## x_rep[6]    336.23    0.32 121.20    141.00    250.00    322.00    407.00
## x_rep[7]    317.34    0.30 114.40    133.00    235.00    304.00    384.00
## x_rep[8]    302.31    0.29 109.14    127.00    225.00    290.00    366.00
## x_rep[9]    275.69    0.26  99.61    115.00    205.00    264.00    334.00
## x_rep[10]   249.38    0.24  90.24    104.00    185.00    239.00    302.00
## x_rep[11]   226.05    0.21  81.96     94.00    168.00    217.00    274.00
## x_rep[12]   215.77    0.21  78.21     90.00    160.00    207.00    261.00
## x_rep[13]   211.09    0.20  76.64     88.00    156.00    202.00    256.00
## x_rep[14]   210.77    0.20  76.40     88.00    156.00    202.00    255.00
## x_rep[15]   206.62    0.20  75.05     86.00    153.00    198.00    250.00
## x_rep[16]   206.23    0.20  74.84     86.00    153.00    198.00    250.00
## x_rep[17]   182.47    0.17  66.36     76.00    135.00    175.00    221.00
## x_rep[18]   174.39    0.17  63.50     72.00    129.00    167.00    211.00
## x_rep[19]   165.75    0.16  60.46     69.00    123.00    159.00    201.00
## x_rep[20]   149.48    0.14  54.63     61.00    110.00    143.00    181.00
## x_rep[21]   146.22    0.14  53.45     60.00    108.00    140.00    177.00
## x_rep[22]   140.11    0.14  51.32     58.00    103.00    134.00    170.00
```

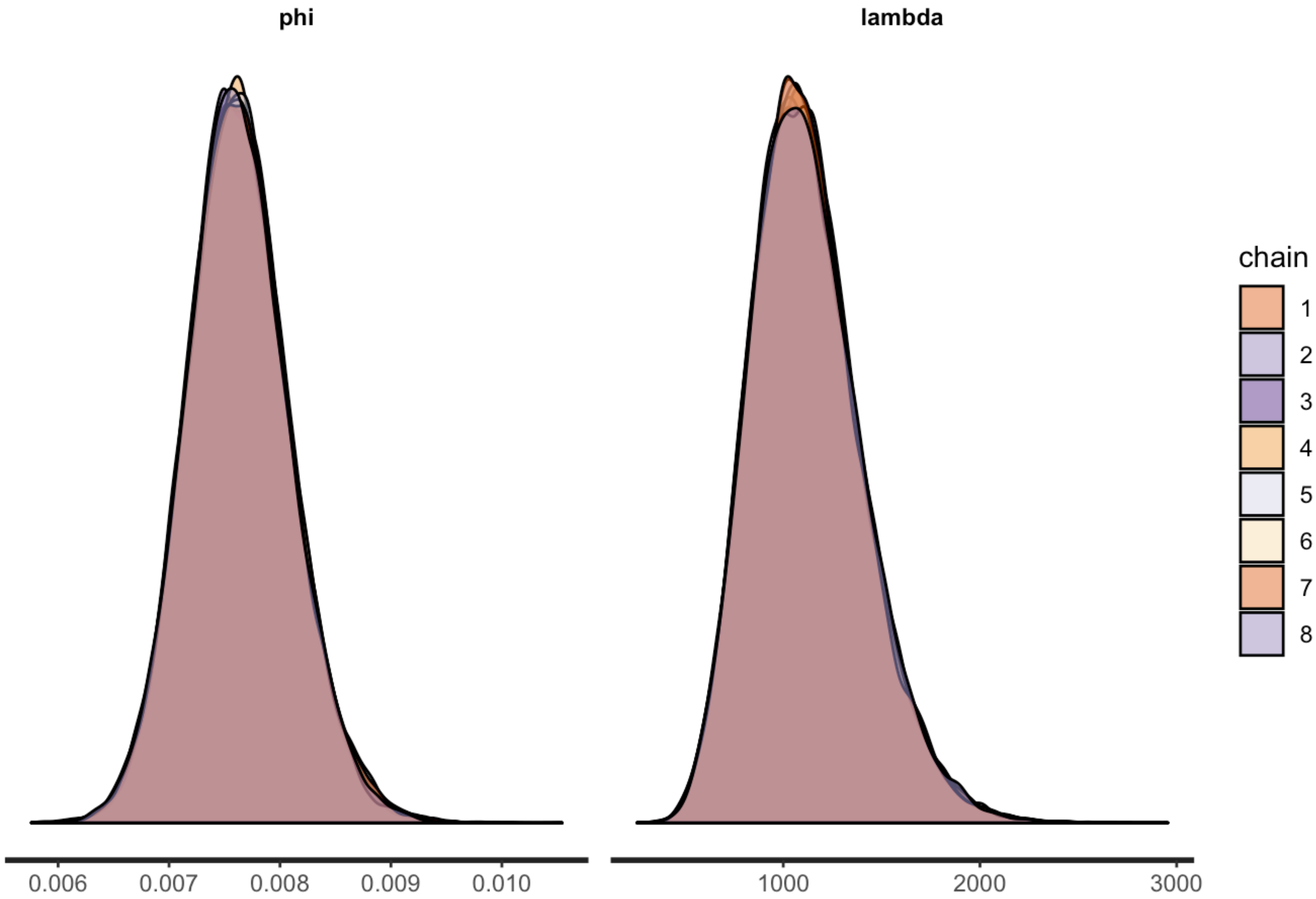
```
## x_rep[23]    139.25    0.13  50.96     57.00    103.00    133.00    169.00
## x_rep[24]    133.19    0.13  48.81     55.00     98.00    128.00    162.00
## x_rep[25]    127.74    0.12  46.91     52.00     94.00    122.00    155.00
## x_rep[26]    107.59    0.10  39.76     43.00     79.00    103.00    131.00
## x_rep[27]     96.19    0.09  35.63     39.00     71.00     92.00    117.00
## x_rep[28]     48.03    0.05  18.44     18.00     35.00     46.00     59.00
## x_rep[29]     42.41    0.04  16.44     16.00     31.00     41.00     52.00
## x_rep[30]     42.38    0.04  16.39     16.00     31.00     41.00     52.00
## x_rep[31]     41.38    0.04  16.09     16.00     30.00     39.00     51.00
## x_rep[32]     29.68    0.03  11.91     11.00     21.00     28.00     37.00
## x_rep[33]     28.65    0.03  11.50     10.00     20.00     27.00     35.00
## x_rep[34]     25.04    0.03  10.23      9.00     18.00     24.00     31.00
## x_rep[35]     19.14    0.02   8.10      6.00     13.00     18.00     24.00
## x_rep[36]     17.78    0.02   7.59      6.00     12.00     17.00     22.00
## x_rep[37]      1.73    0.00   1.45      0.00      1.00      1.00      3.00
## lp__      -46080.65    0.02   4.48 -46090.33 -46083.46 -46080.33 -46077.47
##               97.5%  n_eff Rhat
## p[1]           0.01 251242    1
## p[2]           0.00 243459    1
## p[3]           0.01 263989    1
## p[4]           0.01 256447    1
## p[5]           0.01 258196    1
## p[6]           0.01 261860    1
## p[7]           0.01 261094    1
## p[8]           0.01 260181    1
## p[9]           0.01 264776    1
## p[10]          0.01 249604    1
## p[11]          0.01 257052    1
## p[12]          0.01 253736    1
## p[13]          0.01 266589    1
## p[14]          0.01 257041    1
## p[15]          0.01 259572    1
## p[16]          0.01 254716    1
## p[17]          0.01 251930    1
## p[18]          0.01 258953    1
## p[19]          0.01 256887    1
## p[20]          0.01 256434    1
## p[21]          0.01 252297    1
## p[22]          0.01 258417    1
## p[23]          0.01 242746    1
## p[24]          0.01 261879    1
## p[25]          0.01 259031    1
## p[26]          0.01 263776    1
## p[27]          0.01 252740    1
## p[28]          0.01 247501    1
## p[29]          0.01 257782    1
## p[30]          0.01 256643    1
## p[31]          0.01 258634    1
## p[32]          0.01 249935    1
## p[33]          0.01 256786    1
## p[34]          0.01 235431    1
## p[35]          0.01 235602    1
## p[36]          0.01 265218    1
## p[37]          0.01 241934    1
```

```
## phi            0.01 190093    1
## lambda      1740.10 176397    1
## alpha         13.18 181941    1
## beta        1727.18 176368    1
## x_rep[1]    1635.00 145779    1
## x_rep[2]    1200.00 145293    1
## x_rep[3]    1046.00 145797    1
## x_rep[4]     921.00 145536    1
## x_rep[5]     753.00 145095    1
## x_rep[6]     612.00 145330    1
## x_rep[7]     577.00 144995    1
## x_rep[8]     551.00 145779    1
## x_rep[9]     502.00 145650    1
## x_rep[10]    454.00 145168    1
## x_rep[11]    412.00 145743    1
## x_rep[12]    394.00 145494    1
## x_rep[13]    386.00 145399    1
## x_rep[14]    384.00 145247    1
## x_rep[15]    377.00 145173    1
## x_rep[16]    377.00 145553    1
## x_rep[17]    333.00 145725    1
## x_rep[18]    319.00 145149    1
## x_rep[19]    303.00 145542    1
## x_rep[20]    274.00 145677    1
## x_rep[21]    267.00 144457    1
## x_rep[22]    257.00 144320    1
## x_rep[23]    255.00 145595    1
## x_rep[24]    244.00 145015    1
## x_rep[25]    234.00 145353    1
## x_rep[26]    198.00 145091    1
## x_rep[27]    177.00 145488    1
## x_rep[28]     90.00 144234    1
## x_rep[29]     80.00 144661    1
## x_rep[30]     80.00 145197    1
## x_rep[31]     78.00 145724    1
## x_rep[32]     57.00 144688    1
## x_rep[33]     55.00 143997    1
## x_rep[34]     48.00 143840    1
## x_rep[35]     38.00 145349    1
## x_rep[36]     35.00 145465    1
## x_rep[37]      5.00 142802    1
## lp__      -46072.84  55503    1
##
## Samples were drawn using NUTS(diag_e) at Thu Jul 25 22:08:54 2019.
## For each parameter, n_eff is a crude measure of effective sample size,
## and Rhat is the potential scale reduction factor on split chains (at
## convergence, Rhat=1).
```

```
stan_trace(fit1, pars=c("phi", "lambda"))
```

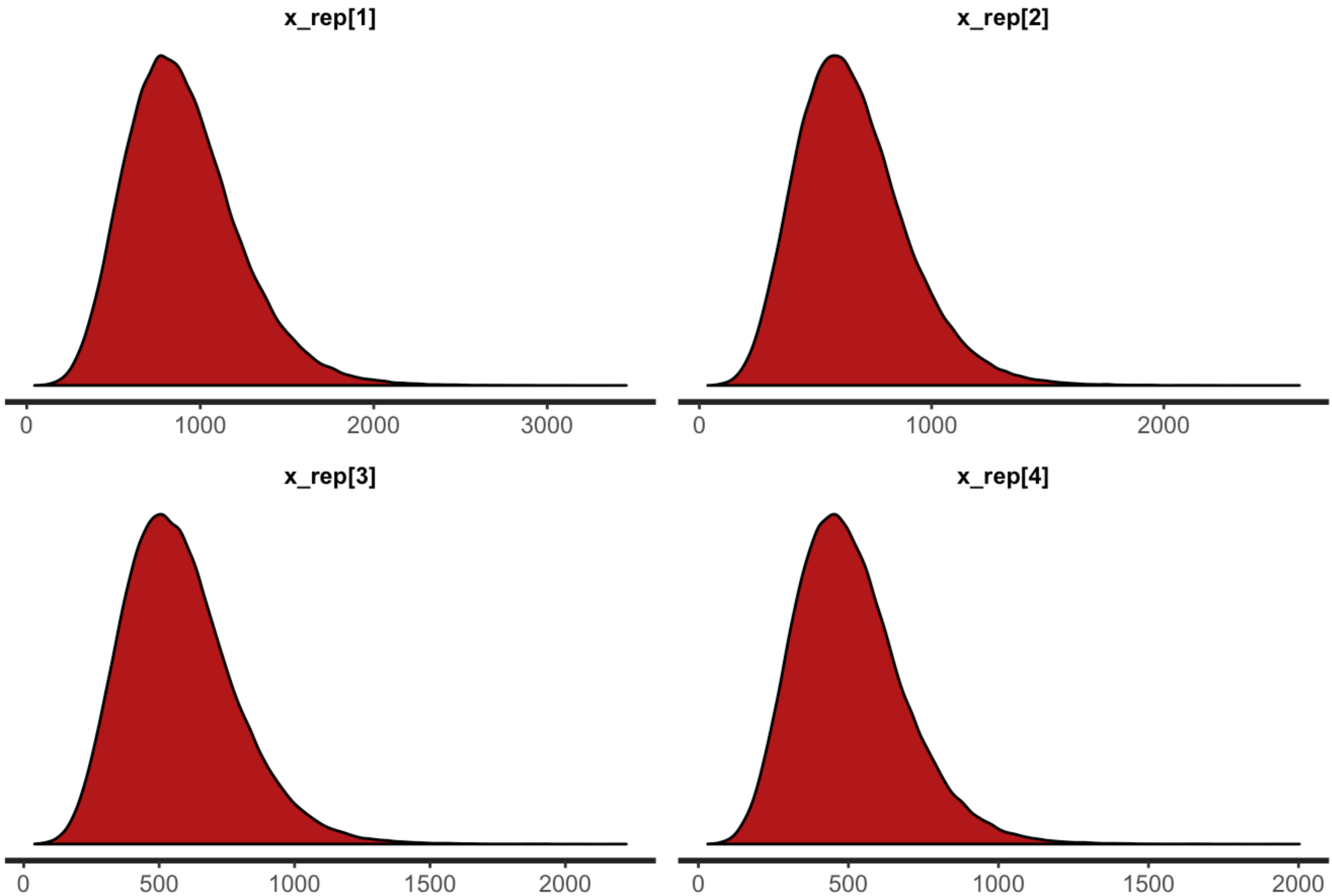



```
stan_dens(fit1, pars=c("phi", "lambda"), separate_chains = TRUE)
```




```
#stan_hist(fit1)
```

```
stan_dens(fit1, pars=c("x_rep[1]","x_rep[2]","x_rep[3]","x_rep[4]"))
```



stan summary

```
ss = summary(fit1)$summary
ss
```

```
##                  mean      se_mean           sd         2.5%
## p[1]      9.027564e-03 5.468381e-07 2.740972e-04  8.498803e-03
## p[2]      1.033630e-03 2.238705e-07 1.104612e-04  8.286858e-04
## p[3]      1.095313e-02 7.333778e-07 3.768087e-04  1.022731e-02
## p[4]      1.090355e-02 7.907186e-07 4.004245e-04  1.013024e-02
## p[5]      9.552117e-03 8.171308e-07 4.152083e-04  8.760113e-03
## p[6]      9.631574e-03 8.996663e-07 4.603794e-04  8.749744e-03
## p[7]      8.477437e-03 8.687129e-07 4.438894e-04  7.626780e-03
## p[8]      7.365070e-03 8.287809e-07 4.227439e-04  6.559868e-03
## p[9]      9.076986e-03 9.564051e-07 4.921312e-04  8.141175e-03
## p[10]     9.436361e-03 1.056550e-06 5.278566e-04  8.432813e-03
## p[11]     9.885800e-03 1.110815e-06 5.631863e-04  8.812125e-03
## p[12]     6.729767e-03 9.485803e-07 4.778211e-04  5.827885e-03
## p[13]     7.880343e-03 1.014447e-06 5.237824e-04  6.888172e-03
## p[14]     6.327830e-03 9.248105e-07 4.688716e-04  5.443739e-03
## p[15]     4.885544e-03 8.187505e-07 4.171388e-04  4.101306e-03
## p[16]     8.556493e-03 1.085539e-06 5.478644e-04  7.517749e-03
## p[17]     9.143560e-03 1.196634e-06 6.006221e-04  7.997626e-03
## p[18]     5.033790e-03 8.996820e-07 4.578251e-04  4.171346e-03
## p[19]     7.916062e-03 1.154586e-06 5.851909e-04  6.808004e-03
```

```
## p[20]      7.762350e-03 1.212096e-06 6.137976e-04  6.604233e-03
## p[21]      6.641148e-03 1.133440e-06 5.693181e-04  5.571843e-03
## p[22]      9.587760e-03 1.379238e-06 7.011318e-04  8.261239e-03
## p[23]      7.469914e-03 1.255569e-06 6.186094e-04  6.310511e-03
## p[24]      1.000293e-02 1.432942e-06 7.332959e-04  8.612981e-03
## p[25]      7.094744e-03 1.237796e-06 6.299778e-04  5.915820e-03
## p[26]      7.472290e-03 1.359386e-06 6.981686e-04  6.166681e-03
## p[27]      8.063841e-03 1.522513e-06 7.654159e-04  6.633074e-03
## p[28]      5.201162e-03 1.687245e-06 8.393952e-04  3.685080e-03
## p[29]      6.366600e-03 1.920907e-06 9.752882e-04  4.596393e-03
## p[30]      5.930339e-03 1.860641e-06 9.425989e-04  4.226009e-03
## p[31]      7.582476e-03 2.115777e-06 1.076000e-03  5.615465e-03
## p[32]      8.100374e-03 2.551096e-06 1.275381e-03  5.806722e-03
## p[33]      8.536778e-03 2.617384e-06 1.326335e-03  6.139914e-03
## p[34]      4.664977e-03 2.163547e-06 1.049780e-03  2.821586e-03
## p[35]      5.375918e-03 2.542852e-06 1.234271e-03  3.201770e-03
## p[36]      6.817960e-03 2.741277e-06 1.411738e-03  4.329337e-03
## p[37]      7.070688e-03 4.819623e-06 2.370618e-03  3.177532e-03
## phi        7.631260e-03 1.063055e-06 4.634877e-04  6.762524e-03
## lambda     1.123273e+03 6.675457e-01 2.803666e+02  6.465952e+02
## alpha      8.546168e+00 4.913963e-03 2.096027e+00  4.992686e+00
## beta       1.114727e+03 6.627510e-01 2.783301e+02  6.416213e+02
## x_rep[1]   9.021016e+02 8.454746e-01 3.228108e+02  3.820000e+02
## x_rep[2]   6.608983e+02 6.213286e-01 2.368334e+02  2.790000e+02
## x_rep[3]   5.764729e+02 5.417403e-01 2.068546e+02  2.440000e+02
## x_rep[4]   5.070435e+02 4.771633e-01 1.820340e+02  2.140000e+02
## x_rep[5]   4.141929e+02 3.912348e-01 1.490265e+02  1.740000e+02
## x_rep[6]   3.362312e+02 3.179248e-01 1.211999e+02  1.410000e+02
## x_rep[7]   3.173394e+02 3.004422e-01 1.144031e+02  1.330000e+02
## x_rep[8]   3.023051e+02 2.858376e-01 1.091357e+02  1.270000e+02
## x_rep[9]   2.756924e+02 2.609951e-01 9.960632e+01  1.150000e+02
## x_rep[10]  2.493838e+02 2.368577e-01 9.024489e+01  1.040000e+02
## x_rep[11]  2.260497e+02 2.147000e-01 8.196460e+01  9.400000e+01
## x_rep[12]  2.157695e+02 2.050519e-01 7.821426e+01  9.000000e+01
## x_rep[13]  2.110930e+02 2.009914e-01 7.664050e+01  8.800000e+01
## x_rep[14]  2.107725e+02 2.004655e-01 7.640004e+01  8.800000e+01
## x_rep[15]  2.066183e+02 1.969790e-01 7.505221e+01  8.600000e+01
## x_rep[16]  2.062263e+02 1.961551e-01 7.483604e+01  8.600000e+01
## x_rep[17]  1.824659e+02 1.738460e-01 6.636375e+01  7.600000e+01
## x_rep[18]  1.743938e+02 1.666799e-01 6.350245e+01  7.200000e+01
## x_rep[19]  1.657495e+02 1.584749e-01 6.045809e+01  6.900000e+01
## x_rep[20]  1.494791e+02 1.431237e-01 5.462699e+01  6.100000e+01
## x_rep[21]  1.462186e+02 1.406398e-01 5.345370e+01  6.000000e+01
## x_rep[22]  1.401096e+02 1.350927e-01 5.132103e+01  5.800000e+01
## x_rep[23]  1.392528e+02 1.335584e-01 5.096184e+01  5.700000e+01
## x_rep[24]  1.331905e+02 1.281643e-01 4.880610e+01  5.500000e+01
## x_rep[25]  1.277430e+02 1.230301e-01 4.690543e+01  5.200000e+01
## x_rep[26]  1.075862e+02 1.043916e-01 3.976363e+01  4.300000e+01
## x_rep[27]  9.619394e+01 9.342279e-02 3.563415e+01  3.900000e+01
## x_rep[28]  4.803183e+01 4.855563e-02 1.844053e+01  1.800000e+01
## x_rep[29]  4.241133e+01 4.323340e-02 1.644352e+01  1.600000e+01
## x_rep[30]  4.237845e+01 4.302002e-02 1.639268e+01  1.600000e+01
## x_rep[31]  4.137953e+01 4.215326e-02 1.609153e+01  1.600000e+01
## x_rep[32]  2.968418e+01 3.131338e-02 1.191097e+01  1.100000e+01
```

```
## x_rep[33]  2.865074e+01 3.029935e-02 1.149767e+01  1.000000e+01
## x_rep[34]  2.503776e+01 2.697837e-02 1.023187e+01  9.000000e+00
## x_rep[35]  1.913653e+01 2.123409e-02 8.095421e+00  6.000000e+00
## x_rep[36]  1.777644e+01 1.990433e-02 7.591485e+00  6.000000e+00
## x_rep[37]  1.726493e+00 3.831794e-03 1.448004e+00  0.000000e+00
## lp__      -4.608065e+04 1.901816e-02 4.480501e+00 -4.609033e+04
##                    25%          50%          75%        97.5%
## p[1]       8.840896e-03 9.025209e-03 9.211096e-03 9.570870e-03
## p[2]       9.569742e-04 1.029850e-03 1.106287e-03 1.261326e-03
## p[3]       1.069730e-02 1.094777e-02 1.120490e-02 1.170646e-02
## p[4]       1.063061e-02 1.089816e-02 1.117126e-02 1.170371e-02
## p[5]       9.268517e-03 9.545596e-03 9.828279e-03 1.038575e-02
## p[6]       9.315706e-03 9.624361e-03 9.939958e-03 1.055274e-02
## p[7]       8.173365e-03 8.470785e-03 8.773496e-03 9.368297e-03
## p[8]       7.075830e-03 7.357146e-03 7.644780e-03 8.217058e-03
## p[9]       8.739472e-03 9.068260e-03 9.404751e-03 1.006662e-02
## p[10]      9.075336e-03 9.427192e-03 9.786614e-03 1.049548e-02
## p[11]      9.501760e-03 9.874718e-03 1.025863e-02 1.102480e-02
## p[12]      6.400070e-03 6.716746e-03 7.046807e-03 7.697257e-03
## p[13]      7.519539e-03 7.868192e-03 8.226470e-03 8.942855e-03
## p[14]      6.004131e-03 6.315858e-03 6.639860e-03 7.277641e-03
## p[15]      4.597766e-03 4.874122e-03 5.161349e-03 5.734882e-03
## p[16]      8.179026e-03 8.545970e-03 8.919562e-03 9.662947e-03
## p[17]      8.732407e-03 9.132230e-03 9.538594e-03 1.035603e-02
## p[18]      4.718800e-03 5.020803e-03 5.334278e-03 5.966861e-03
## p[19]      7.514555e-03 7.901319e-03 8.302087e-03 9.104900e-03
## p[20]      7.339878e-03 7.746485e-03 8.167819e-03 9.006960e-03
## p[21]      6.248334e-03 6.626130e-03 7.016314e-03 7.798294e-03
## p[22]      9.109610e-03 9.569688e-03 1.004914e-02 1.101779e-02
## p[23]      7.043000e-03 7.450912e-03 7.877145e-03 8.729048e-03
## p[24]      9.504729e-03 9.984264e-03 1.048205e-02 1.149669e-02
## p[25]      6.659229e-03 7.073298e-03 7.512386e-03 8.380621e-03
## p[26]      6.990965e-03 7.449284e-03 7.930903e-03 8.907550e-03
## p[27]      7.532579e-03 8.040620e-03 8.567259e-03 9.630023e-03
## p[28]      4.613900e-03 5.156569e-03 5.743177e-03 6.965960e-03
## p[29]      5.685748e-03 6.319473e-03 6.992864e-03 8.419186e-03
## p[30]      5.268569e-03 5.880937e-03 6.541040e-03 7.910182e-03
## p[31]      6.832811e-03 7.531173e-03 8.277488e-03 9.835416e-03
## p[32]      7.204491e-03 8.030386e-03 8.920667e-03 1.080036e-02
## p[33]      7.607449e-03 8.471971e-03 9.392542e-03 1.130853e-02
## p[34]      3.924112e-03 4.593235e-03 5.329346e-03 6.913748e-03
## p[35]      4.503980e-03 5.292252e-03 6.150824e-03 8.035983e-03
## p[36]      5.821566e-03 6.722974e-03 7.708070e-03 9.835863e-03
## p[37]      5.375513e-03 6.823650e-03 8.478326e-03 1.242472e-02
## phi        7.318054e-03 7.615209e-03 7.926142e-03 8.594684e-03
## lambda     9.234686e+02 1.098674e+03 1.295378e+03 1.740101e+03
## alpha      7.055235e+00 8.351488e+00 9.827840e+00 1.318278e+01
## beta       9.165092e+02 1.090226e+03 1.285563e+03 1.727184e+03
## x_rep[1]   6.720000e+02 8.650000e+02 1.090000e+03 1.635000e+03
## x_rep[2]   4.920000e+02 6.330000e+02 7.980000e+02 1.200000e+03
## x_rep[3]   4.290000e+02 5.530000e+02 6.960000e+02 1.046000e+03
## x_rep[4]   3.770000e+02 4.860000e+02 6.130000e+02 9.210000e+02
## x_rep[5]   3.080000e+02 3.970000e+02 5.010000e+02 7.530000e+02
## x_rep[6]   2.500000e+02 3.220000e+02 4.070000e+02 6.120000e+02
```

```
## x_rep[7]    2.350000e+02  3.040000e+02  3.840000e+02  5.770000e+02
## x_rep[8]    2.250000e+02  2.900000e+02  3.660000e+02  5.510000e+02
## x_rep[9]    2.050000e+02  2.640000e+02  3.340000e+02  5.020000e+02
## x_rep[10]   1.850000e+02  2.390000e+02  3.020000e+02  4.540000e+02
## x_rep[11]   1.680000e+02  2.170000e+02  2.740000e+02  4.120000e+02
## x_rep[12]   1.600000e+02  2.070000e+02  2.610000e+02  3.940000e+02
## x_rep[13]   1.560000e+02  2.020000e+02  2.560000e+02  3.860000e+02
## x_rep[14]   1.560000e+02  2.020000e+02  2.550000e+02  3.840000e+02
## x_rep[15]   1.530000e+02  1.980000e+02  2.500000e+02  3.770000e+02
## x_rep[16]   1.530000e+02  1.980000e+02  2.500000e+02  3.770000e+02
## x_rep[17]   1.350000e+02  1.750000e+02  2.210000e+02  3.330000e+02
## x_rep[18]   1.290000e+02  1.670000e+02  2.110000e+02  3.190000e+02
## x_rep[19]   1.230000e+02  1.590000e+02  2.010000e+02  3.030000e+02
## x_rep[20]   1.100000e+02  1.430000e+02  1.810000e+02  2.740000e+02
## x_rep[21]   1.080000e+02  1.400000e+02  1.770000e+02  2.670000e+02
## x_rep[22]   1.030000e+02  1.340000e+02  1.700000e+02  2.570000e+02
## x_rep[23]   1.030000e+02  1.330000e+02  1.690000e+02  2.550000e+02
## x_rep[24]   9.800000e+01  1.280000e+02  1.620000e+02  2.440000e+02
## x_rep[25]   9.400000e+01  1.220000e+02  1.550000e+02  2.340000e+02
## x_rep[26]   7.900000e+01  1.030000e+02  1.310000e+02  1.980000e+02
## x_rep[27]   7.100000e+01  9.200000e+01  1.170000e+02  1.770000e+02
## x_rep[28]   3.500000e+01  4.600000e+01  5.900000e+01  9.000000e+01
## x_rep[29]   3.100000e+01  4.100000e+01  5.200000e+01  8.000000e+01
## x_rep[30]   3.100000e+01  4.100000e+01  5.200000e+01  8.000000e+01
## x_rep[31]   3.000000e+01  3.900000e+01  5.100000e+01  7.800000e+01
## x_rep[32]   2.100000e+01  2.800000e+01  3.700000e+01  5.700000e+01
## x_rep[33]   2.000000e+01  2.700000e+01  3.500000e+01  5.500000e+01
## x_rep[34]   1.800000e+01  2.400000e+01  3.100000e+01  4.800000e+01
## x_rep[35]   1.300000e+01  1.800000e+01  2.400000e+01  3.800000e+01
## x_rep[36]   1.200000e+01  1.700000e+01  2.200000e+01  3.500000e+01
## x_rep[37]   1.000000e+00  1.000000e+00  3.000000e+00  5.000000e+00
## lp__       -4.608346e+04 -4.608033e+04 -4.607747e+04 -4.607284e+04
##                 n_eff      Rhat
## p[1]        251241.60 0.9999655
## p[2]        243459.13 1.0000150
## p[3]        263989.24 0.9999814
## p[4]        256446.81 0.9999685
## p[5]        258195.69 0.9999924
## p[6]        261859.80 0.9999669
## p[7]        261094.07 0.9999922
## p[8]        260180.84 0.9999726
## p[9]        264775.62 0.9999802
## p[10]       249604.24 0.9999645
## p[11]       257051.69 0.9999737
## p[12]       253736.18 0.9999704
## p[13]       266589.43 0.9999737
## p[14]       257040.97 0.9999665
## p[15]       259572.13 0.9999652
## p[16]       254715.59 0.9999632
## p[17]       251930.05 0.9999864
## p[18]       258953.12 0.9999597
## p[19]       256887.41 0.9999676
## p[20]       256434.43 0.9999876
## p[21]       252297.42 0.9999780
```

```
## p[22]      258416.77 0.9999771
## p[23]      242746.07 0.9999763
## p[24]      261879.31 0.9999661
## p[25]      259031.39 0.9999635
## p[26]      263775.84 0.9999669
## p[27]      252739.52 0.9999578
## p[28]      247500.75 0.9999896
## p[29]      257782.44 0.9999831
## p[30]      256642.67 0.9999830
## p[31]      258633.54 0.9999880
## p[32]      249934.73 0.9999619
## p[33]      256786.11 0.9999816
## p[34]      235431.19 0.9999968
## p[35]      235602.00 0.9999569
## p[36]      265217.57 0.9999708
## p[37]      241934.01 0.9999696
## phi        190092.57 1.0000202
## lambda     176396.68 1.0000104
## alpha      181940.70 0.9999950
## beta       176367.93 1.0000105
## x_rep[1]   145779.00 1.0000087
## x_rep[2]   145292.53 1.0000017
## x_rep[3]   145796.83 1.0000006
## x_rep[4]   145536.14 1.0000049
## x_rep[5]   145094.88 0.9999993
## x_rep[6]   145330.26 1.0000055
## x_rep[7]   144995.26 1.0000036
## x_rep[8]   145779.08 0.9999951
## x_rep[9]   145649.51 1.0000049
## x_rep[10] 145167.74 0.9999991
## x_rep[11] 145743.30 1.0000130
## x_rep[12] 145493.79 0.9999985
## x_rep[13] 145399.06 1.0000001
## x_rep[14] 145247.28 1.0000052
## x_rep[15] 145173.49 1.0000004
## x_rep[16] 145553.44 0.9999990
## x_rep[17] 145724.51 0.9999920
## x_rep[18] 145149.17 1.0000026
## x_rep[19] 145541.87 0.9999952
## x_rep[20] 145677.11 1.0000078
## x_rep[21] 144457.20 1.0000042
## x_rep[22] 144320.18 1.0000049
## x_rep[23] 145595.50 1.0000087
## x_rep[24] 145015.43 1.0000072
## x_rep[25] 145352.82 0.9999986
## x_rep[26] 145091.20 1.0000084
## x_rep[27] 145487.96 1.0000026
## x_rep[28] 144233.97 1.0000101
## x_rep[29] 144660.86 1.0000187
## x_rep[30] 145197.38 0.9999971
## x_rep[31] 145724.48 1.0000000
## x_rep[32] 144688.49 1.0000149
## x_rep[33] 143996.78 0.9999959
## x_rep[34] 143839.73 0.9999910
```

```
## x_rep[35] 145348.89 1.0000056
## x_rep[36] 145465.02 1.0000094
## x_rep[37] 142802.32 1.0000092
## lp__       55502.94 1.0000325
```

parameter estimates of beta distribution (for p)

```
phi1 = ss["phi","mean"]  # posterior mean of phi
lambda1 = ss["lambda","mean"]  # posterior mean of lambda
alpha1 = lambda1*phi1
beta1 = lambda1*(1-phi1)
beta_mean <- function(alpha,beta) alpha/(alpha+beta)
beta_var <- function(alpha,beta) alpha*beta/((alpha+beta)^2*(alpha+beta+1))
```

```
phi1
```

```
## [1] 0.00763126
```

```
lambda1
```

```
## [1] 1123.273
```

```
alpha1
```

```
## [1] 8.57199
```

```
beta1
```

```
## [1] 1114.701
```

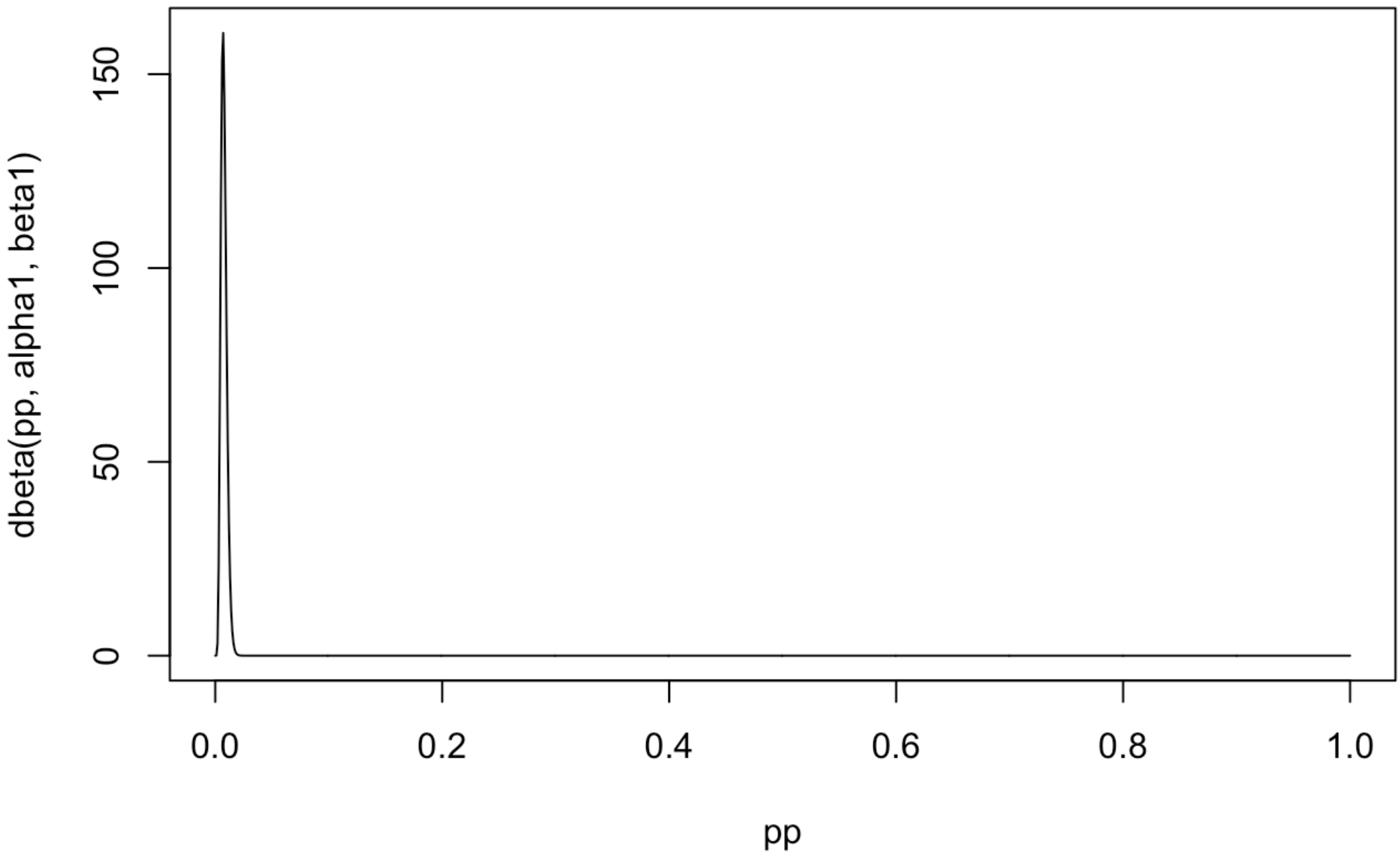
```
beta_mean(alpha1,beta1) # mean of p
```

```
## [1] 0.00763126
```

```
sqrt(beta_var(alpha1,beta1)) # sd of p
```

```
## [1] 0.002595367
```

```
pp = seq(0,1,length=1000)
plot(pp,dbeta(pp,alpha1,beta1),type="l") # distribution of p
```



extract posterior distributions (used later)

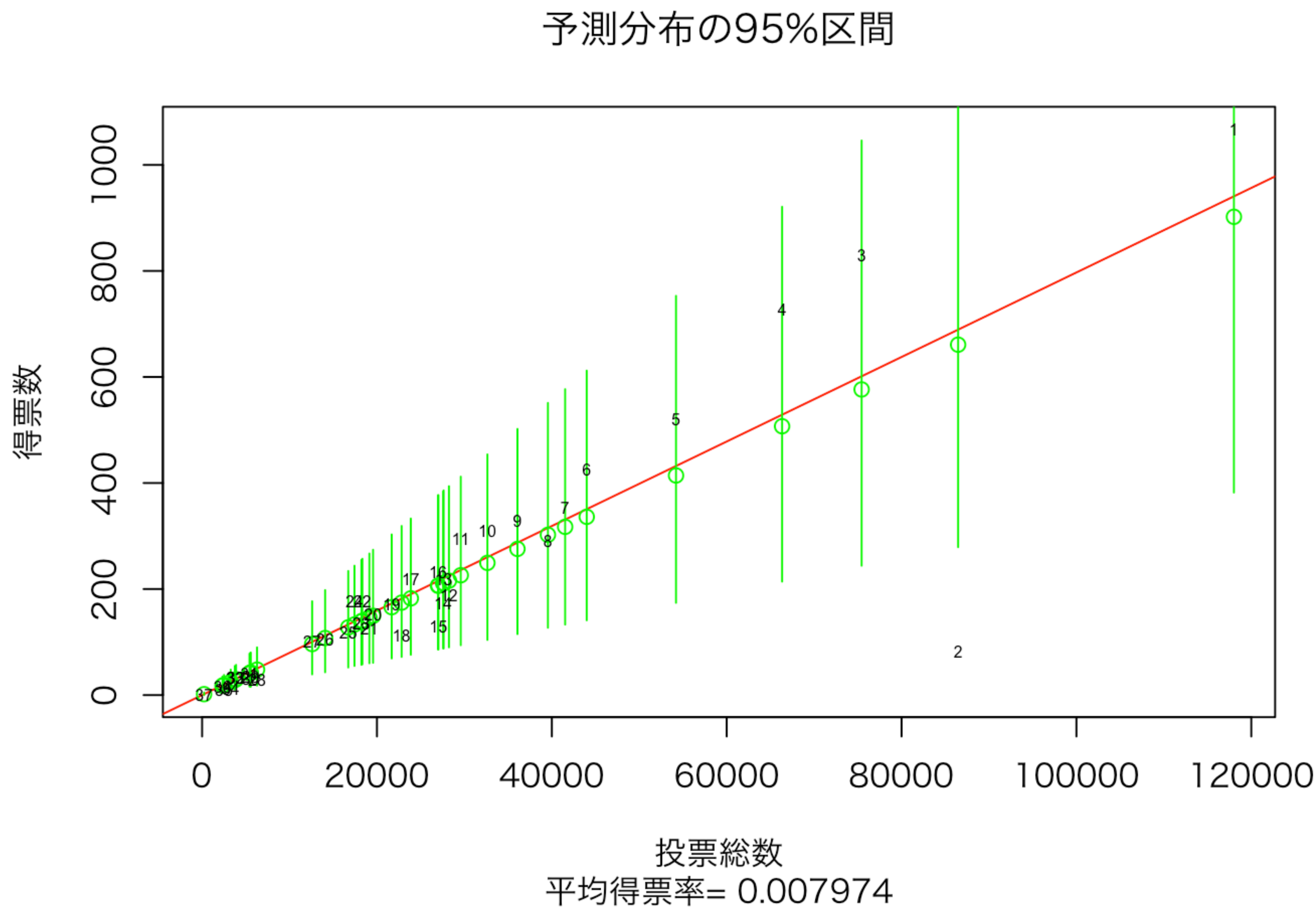
```
ex1 <- rstan::extract(fit1)
names(ex1)
```

```
## [1] "p"      "phi"    "lambda" "alpha"  "beta"   "x_rep"  "lp__"
```

results

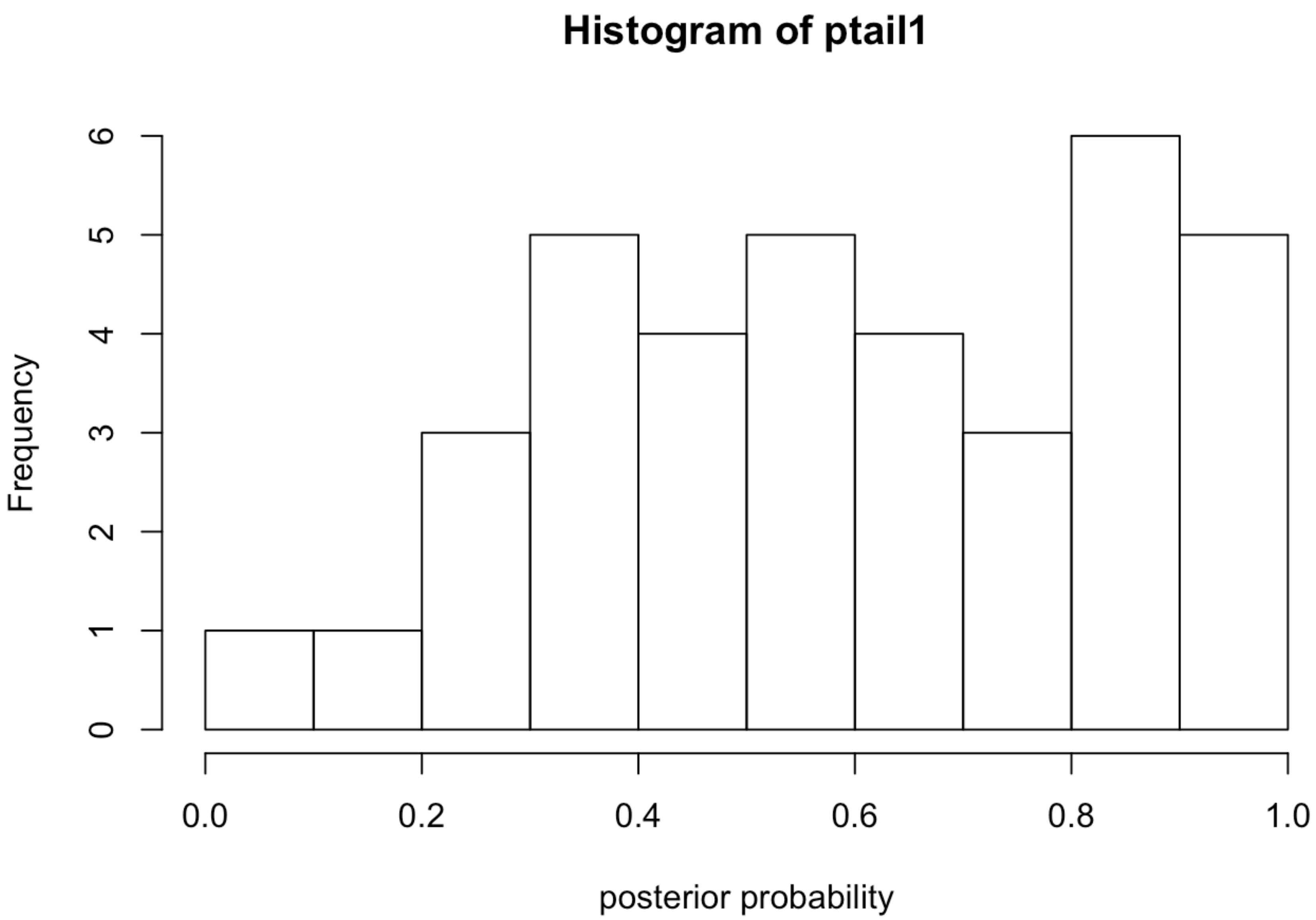
data points and posterior predictive distribution

```
p0=sum(data$x)/sum(data$n)
plot(data$n, data$x, type="n", xlab="投票総数", ylab="得票数", main="予測分布の95%区間"
, sub=paste("平均得票率=",signif(p0,4)),family=family)
#abline(a=0,b=phi1, col="red") # parameter estimates (=mean)
abline(a=0,b=p0, col="red") # = x/n
x_conf <- ss[paste("x_rep[",1:data$N,"]",sep=""), c("2.5%","97.5%","50%","mean")]
segments(data$n,x_conf[,1],data$n,x_conf[,2],col="green")
points(data$n, x_conf[,4],col="green" )
text(data$n, data$x, cex=0.5)
```



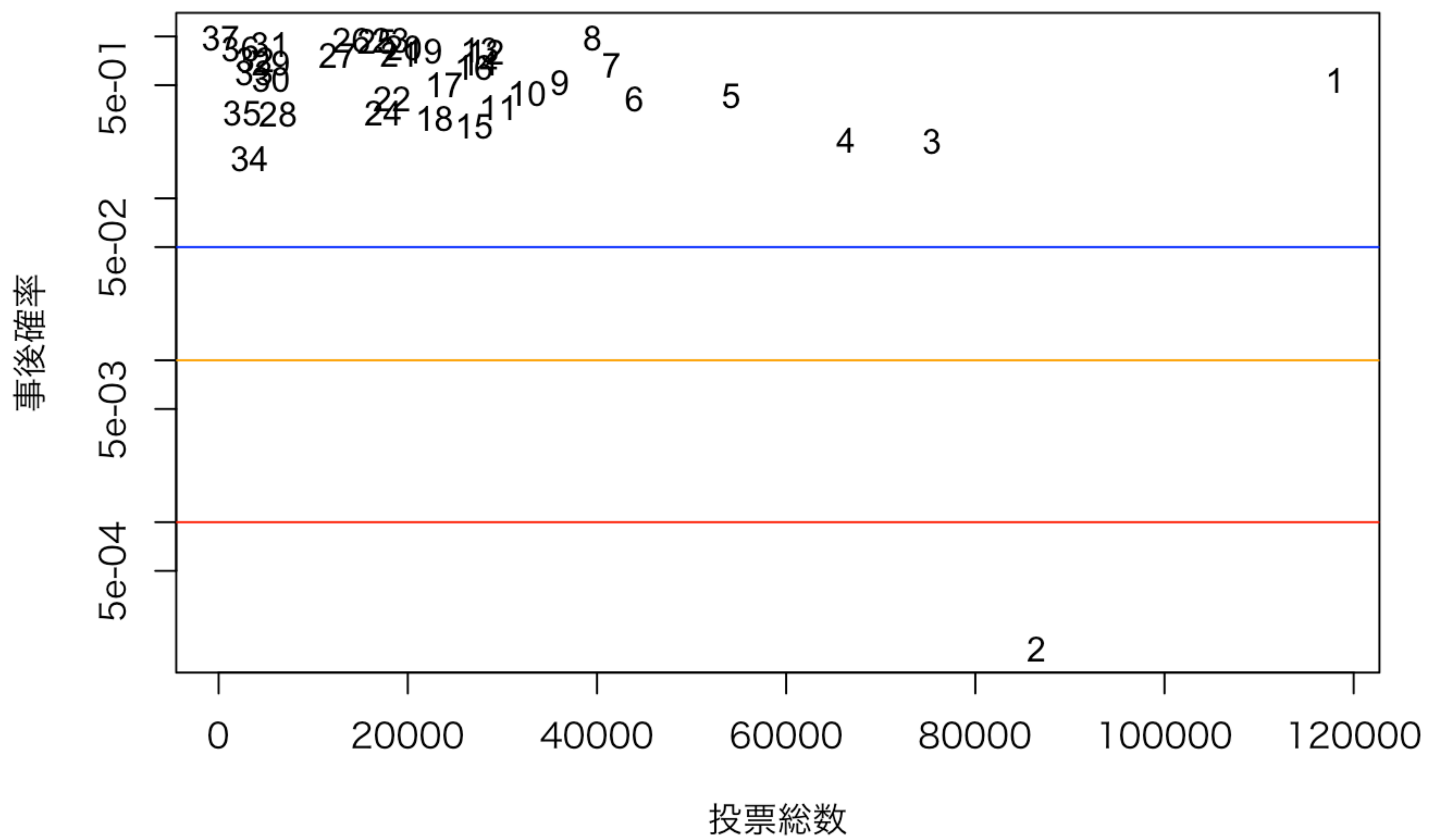
tail probability of posterior predictive distribution

```
ptail1 <- c()
for(i in 1:data$N) ptail1[i] = mean(ex1$x_rep[,i] <= data$x[i])  # lower tail
ptail1 <- 2*pmin(ptail1,1-ptail1) # posterior tail probability (two-tailed)
hist(ptail1,nclass=10,xlab="posterior probability")
```



plot of posterior tail probability

```
plot(data$n, ptail1, log="y", type="n", xlab="投票総数", ylab="事後確率", family=fami
ly)
text(data$n, ptail1);
abline(h=0.05,col="blue") # 5%
abline(h=0.01,col="orange") # 1%
abline(h=0.001,col="red")  # 0.1%
```



VGAM includes beta-binomial distribution

```
library(VGAM)
```

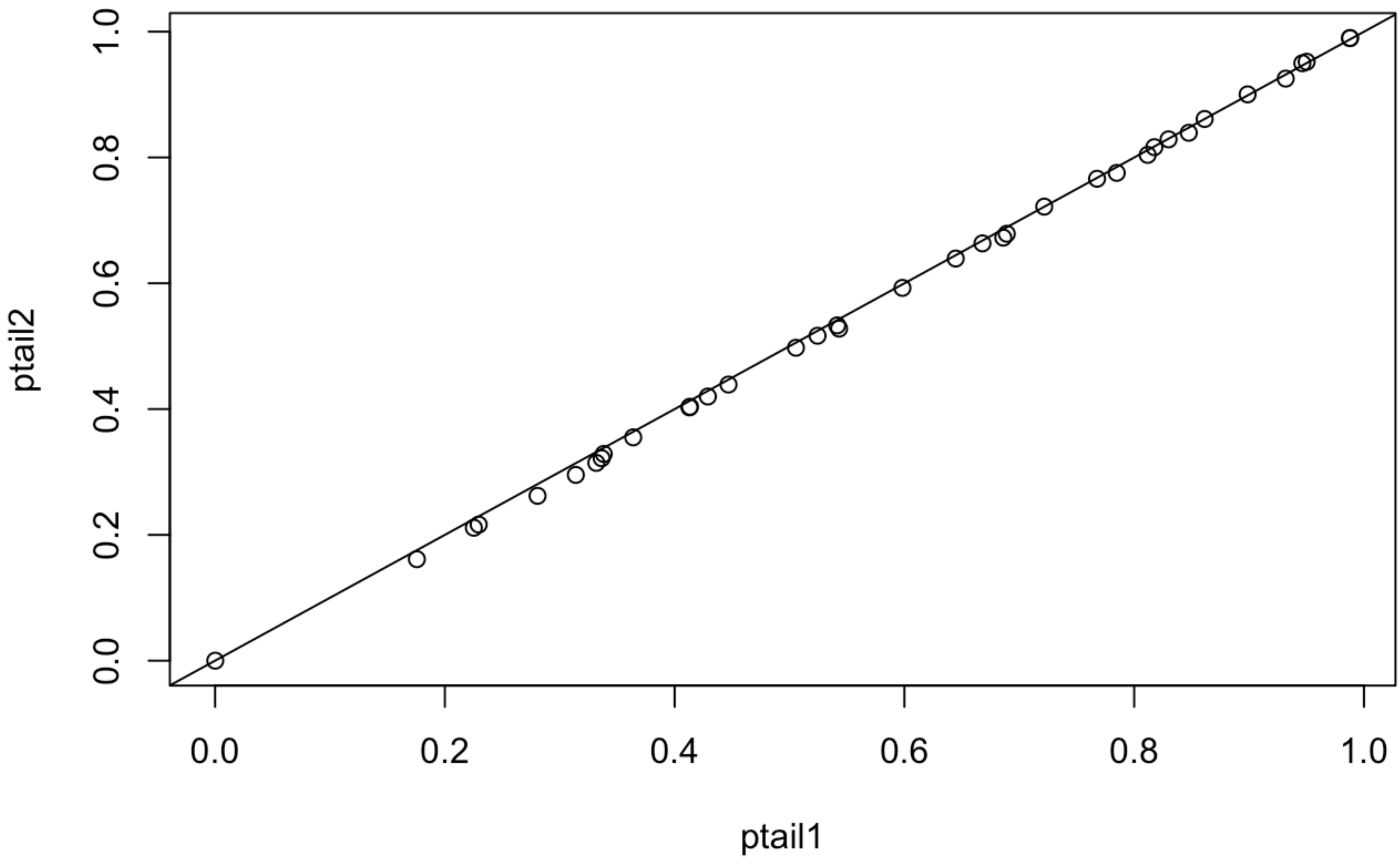
```
## Loading required package: stats4
```

```
## Loading required package: splines
```

tail probabilities of beta-binomial using the estimated parameter value

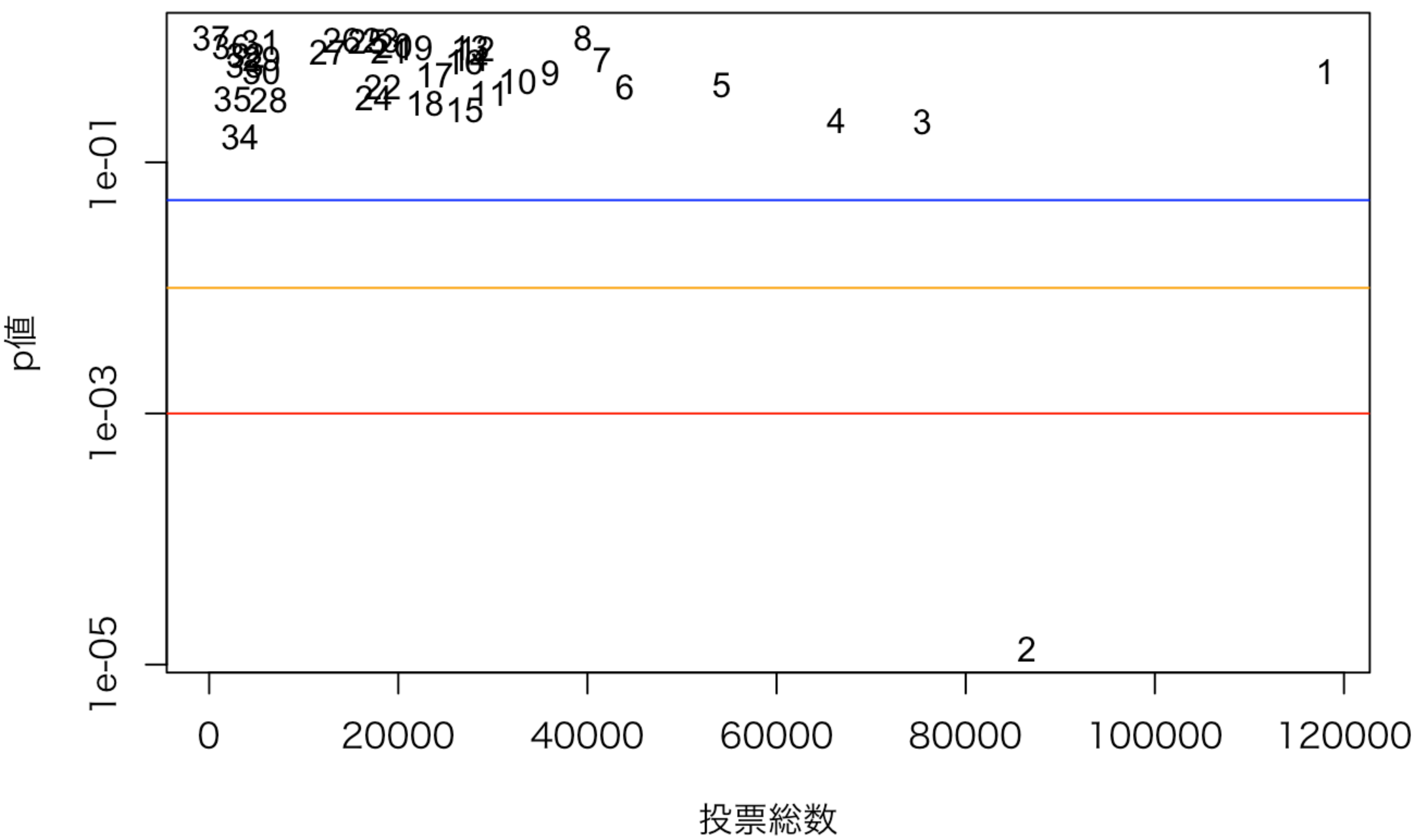
```
ptail2 = pbetabinom.ab(data$x,data$n,alpha1,beta1)
ptail2 <- 2*pmin(ptail2,1-ptail2) # p-value (two-tailed)
hist(ptail2,nclass=10,xlab="p-value") # check if uniform on (0,1)
```


```
plot(ptail1,ptail2); abline(0,1)
```



plot of frequntist p-value (based on the estimated parameters by stan)

```
plot(data$n, ptail2, log="y", type="n", xlab="投票総数", ylab="p値", family=family)
text(data$n, ptail2);
abline(h=0.05,col="blue") # 5%
abline(h=0.01,col="orange") # 1%
abline(h=0.001,col="red")  # 0.1%
```



summary table of p-values

```
phi1
```

```
## [1] 0.00763126
```

```
lambda1
```

```
## [1] 1123.273
```

```
alpha1
```

```
## [1] 8.57199
```

```
beta1
```

```
## [1] 1114.701
```

```
cbind(as.character(data$city), ptail1, ptail2)
```

```
##                    ptail1                   ptail2
##  [1,] "長岡市"   "0.541486111111111"    "0.533034497858158"
##  [2,] "上越市"   "0.000166666666666667" "1.35212852818374e-05"
##  [3,] "中央区"   "0.225236111111111"    "0.211286126979409"
##  [4,] "西区"     "0.229458333333333"    "0.216392919242591"
##  [5,] "東区"     "0.428916666666667"    "0.419975328419225"
##  [6,] "三条市"   "0.413347222222222"    "0.403675340388824"
##  [7,] "新発田市" "0.667930555555555"    "0.663417976154221"
##  [8,] "柏崎市"   "0.987916666666667"    "0.989736273309983"
##  [9,] "燕市"     "0.524388888888889"    "0.516590410785719"
## [10,] "秋葉区"   "0.446888888888889"    "0.438989658443659"
## [11,] "北区"     "0.363944444444444"    "0.355041559630298"
## [12,] "村上市"   "0.811736111111111"    "0.804060613268268"
## [13,] "南魚沼市" "0.829916666666667"    "0.828793345096877"
## [14,] "十日町市" "0.686069444444444"    "0.672559017970147"
## [15,] "佐渡市"   "0.280694444444444"    "0.262087718436888"
## [16,] "江南区"   "0.644652777777778"    "0.639326783608089"
## [17,] "西蒲区"   "0.505597222222222"    "0.497472845277565"
## [18,] "糸魚川市" "0.314013888888889"    "0.295324349551976"
## [19,] "五泉市"   "0.817555555555556"    "0.816358344969879"
## [20,] "阿賀野市" "0.861319444444445"    "0.861162249253763"
## [21,] "魚沼市"   "0.784805555555556"    "0.775499452507736"
## [22,] "見附市"   "0.412902777777778"    "0.402690720144685"
## [23,] "小千谷市" "0.950125"             "0.952145741735418"
## [24,] "南区"     "0.338263888888889"    "0.328598258984664"
## [25,] "妙高市"   "0.931875"             "0.925371162791766"
## [26,] "胎内市"   "0.946361111111111"    "0.949823252158155"
## [27,] "加茂市"   "0.767666666666667"    "0.766145139672933"
## [28,] "阿賀町"   "0.331847222222222"    "0.314430311109931"
## [29,] "聖籠町"   "0.689097222222222"    "0.67871724054185"
## [30,] "田上町"   "0.543152777777778"    "0.527886110419607"
## [31,] "津南町"   "0.898708333333333"    "0.900298486012659"
## [32,] "弥彦村"   "0.721708333333333"    "0.721820651192607"
## [33,] "湯沢町"   "0.598291666666667"    "0.592661502755018"
## [34,] "関川村"   "0.175638888888889"    "0.161352769588204"
## [35,] "刈羽村"   "0.336486111111111"    "0.321867690828018"
## [36,] "出雲崎町" "0.8475"               "0.839244845842987"
## [37,] "粟島浦村" "0.987805555555556"    "0.989887001551361"
```

fitting the ordinary binomial distribution (THIS IS NOT A VALID ANALYSIS)

p

```
(x = sum(data$x))
```

```
## [1] 8009
```

```
(n = sum(data$n))
```

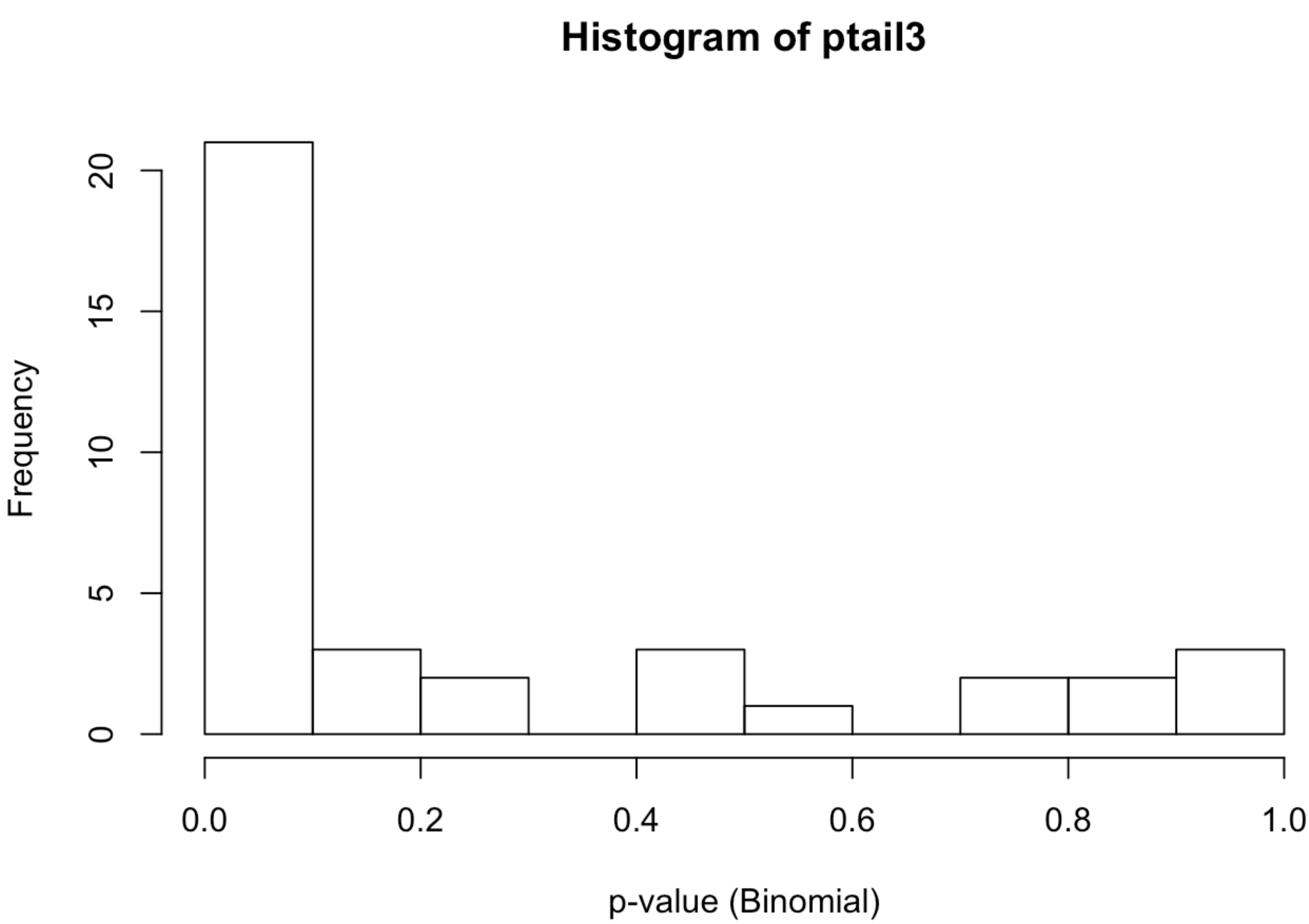
```
## [1] 1004439
```

```
(p= x/n)
```

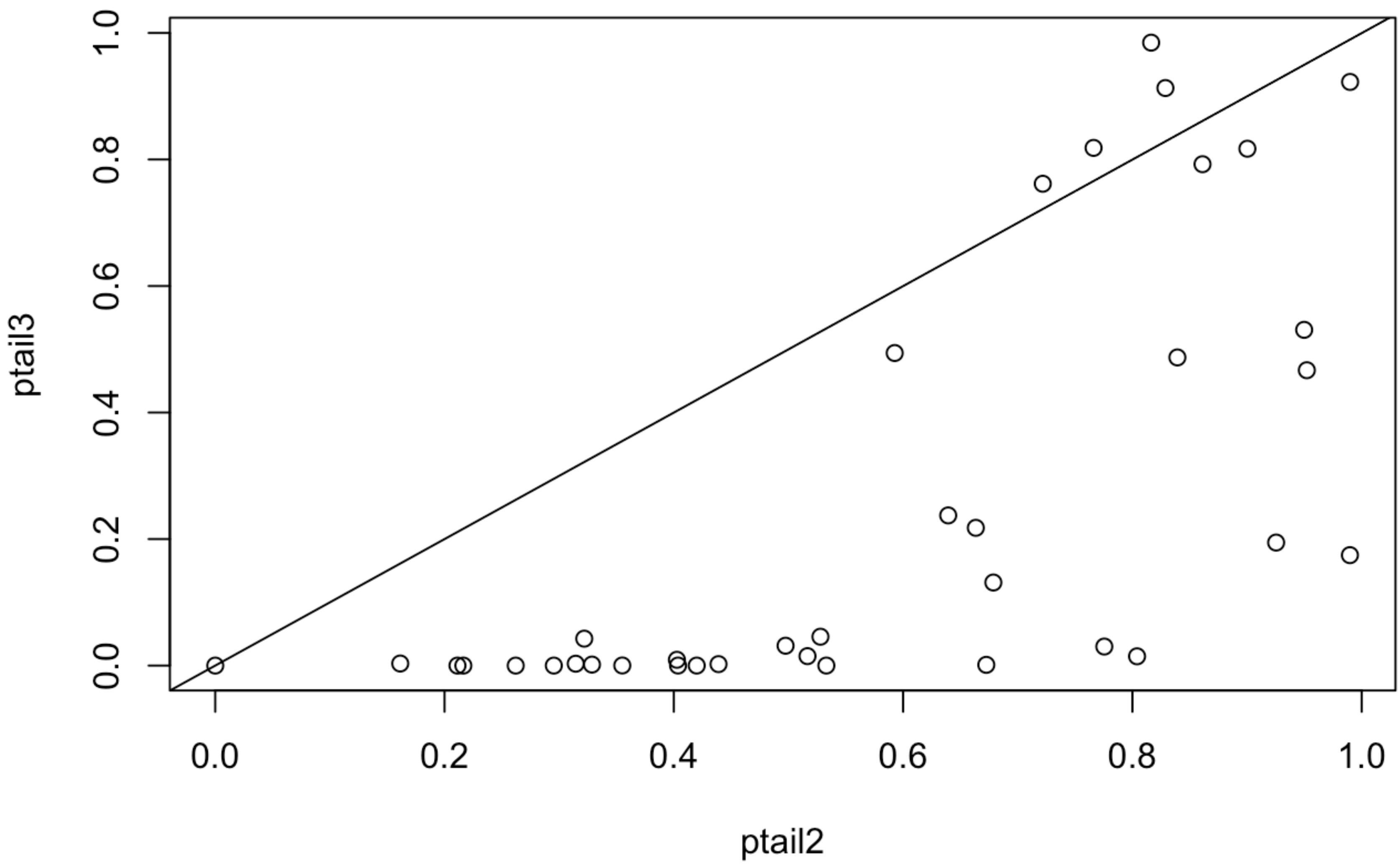
```
## [1] 0.007973605
```

tail probabilities of observed values (p-values) : DONT USE THIS!!!

```
ptail3 = pbinom(data$x,data$n,p)
ptail3 <- 2*pmin(ptail3,1-ptail3) # p-value (two-tailed) with Binomial
hist(ptail3,nclass=10,xlab="p-value (Binomial)") # check if uniform on (0,1)
```




```
plot(ptail2,ptail3); abline(0,1)
```

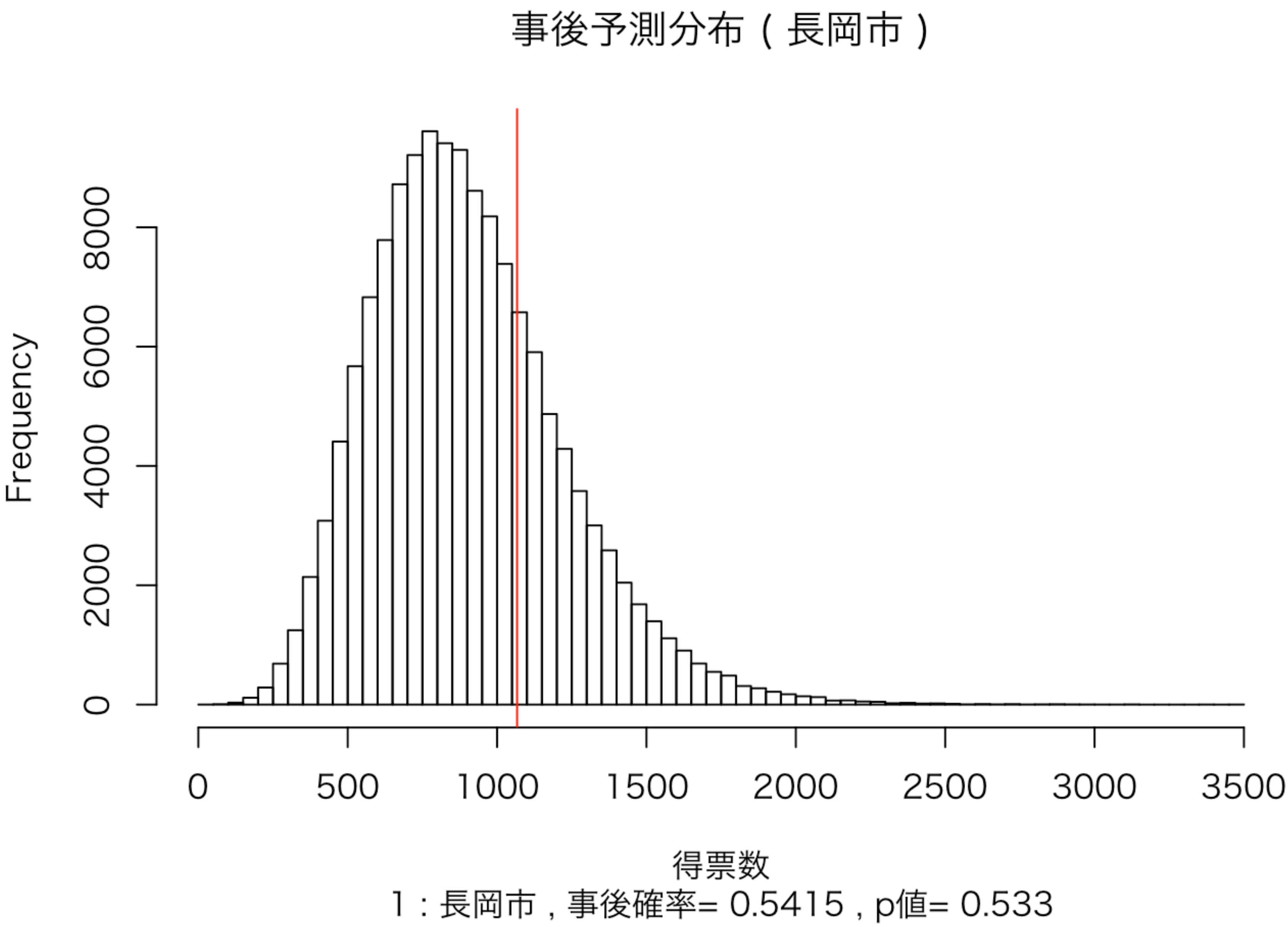


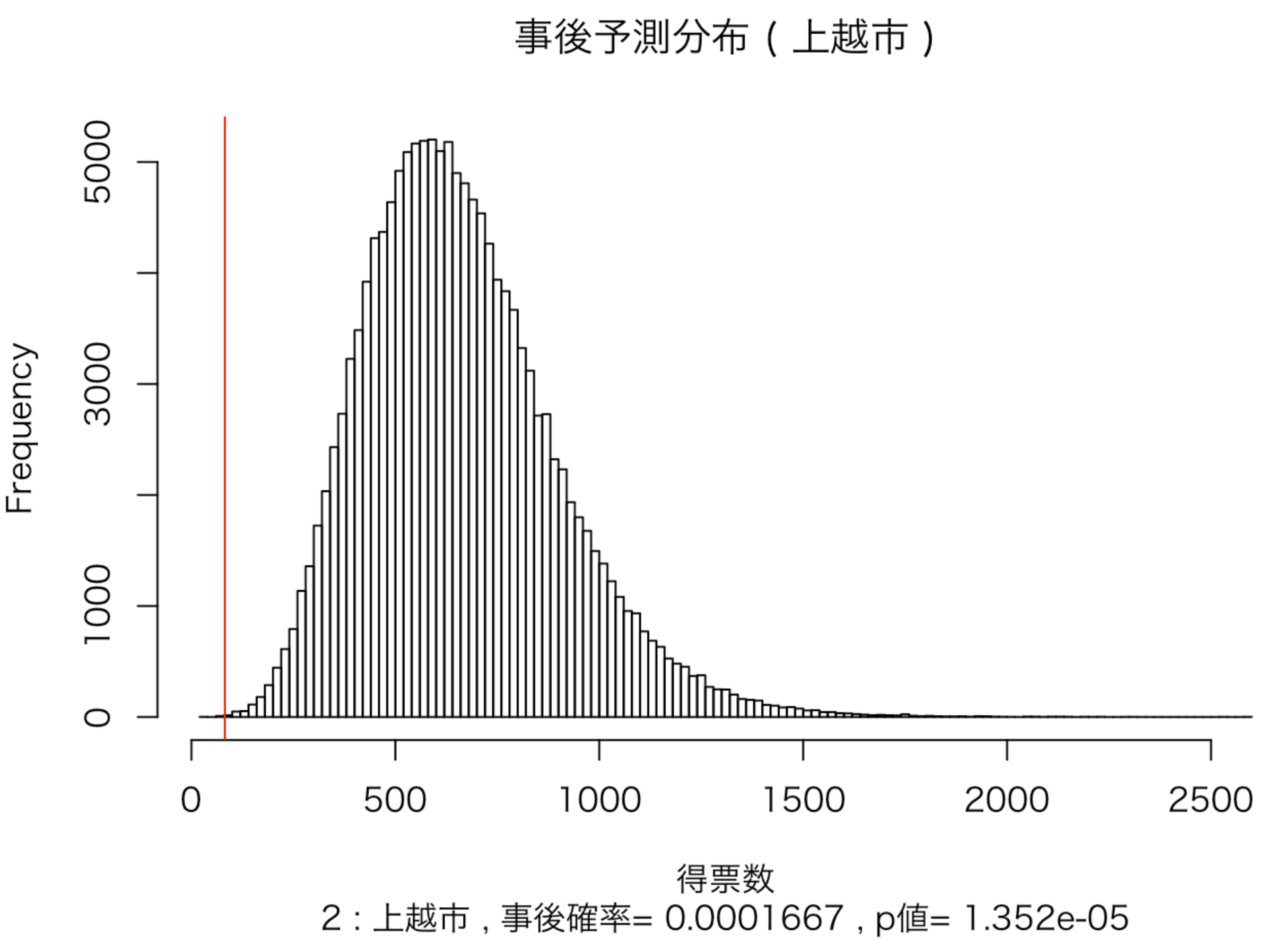

```
ptail3
```

```
##  [1]  4.928394e-05 1.205873e-190  0.000000e+00  2.220446e-16  3.494165e-05
##  [6]  8.329335e-05  2.177306e-01  1.745646e-01  1.492489e-02  2.293801e-03
## [11]  1.707704e-04  1.464160e-02  9.129030e-01  1.167704e-03  2.254622e-10
## [16]  2.373768e-01  3.139326e-02  2.846726e-08  9.846748e-01  7.925077e-01
## [21]  3.008091e-02  9.151586e-03  4.668626e-01  1.572925e-03  1.944645e-01
## [26]  5.306942e-01  8.182928e-01  2.954428e-03  1.313150e-01  4.561573e-02
## [31]  8.169958e-01  7.616075e-01  4.940411e-01  3.254725e-03  4.256557e-02
## [36]  4.870894e-01  9.225547e-01
```

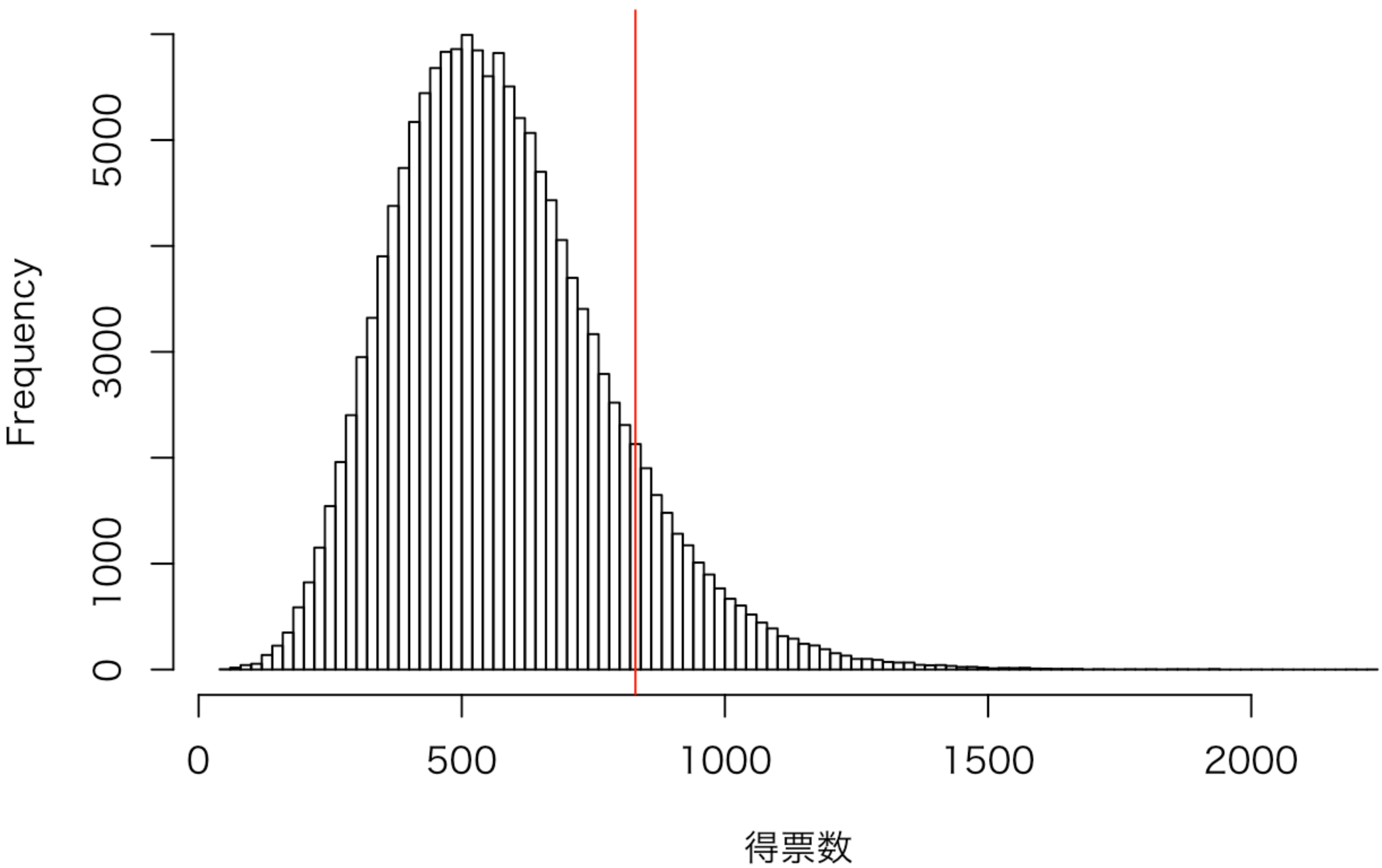
posterior predictive distributions of all x's

```
for(i in 1:data$N) {
  hist(ex1$x_rep[,i], nclass=100, xlab="得票数", main=paste("事後予測分布 (",data$cit
y[i],")"), sub=paste(i,":", data$city[i],", 事後確率=", signif(ptail1[i],4), ", p値=
", signif(ptail2[i],4)), family= family) # histogram of posterior distribution
  abline(v = data$x[i], col="red" ) # observed value
}
```


事後予測分布（長岡市）
Frequency
0
2000
4000
6000
8000
0
500
1000
1500
2000
2500
3000
3500
得票数
1：長岡市，事後確率= 0.5415，p値= 0.533

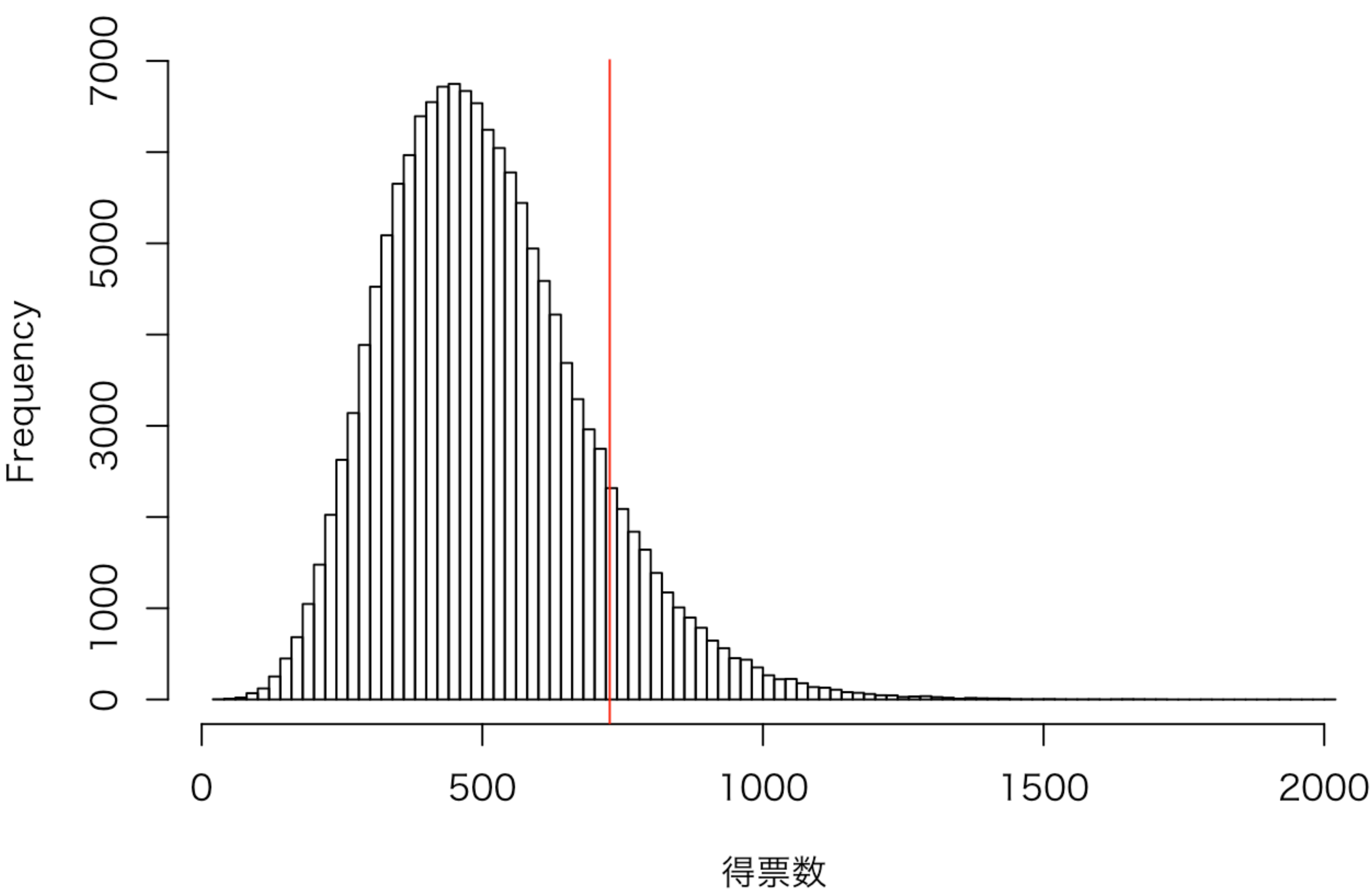

事後予測分布（上越市）
Frequency
0
1000
3000
5000
0
500
1000
1500
2000
2500
得票数
2：上越市，事後確率= 0.0001667，p値= 1.352e-05

事後予測分布（中央区）



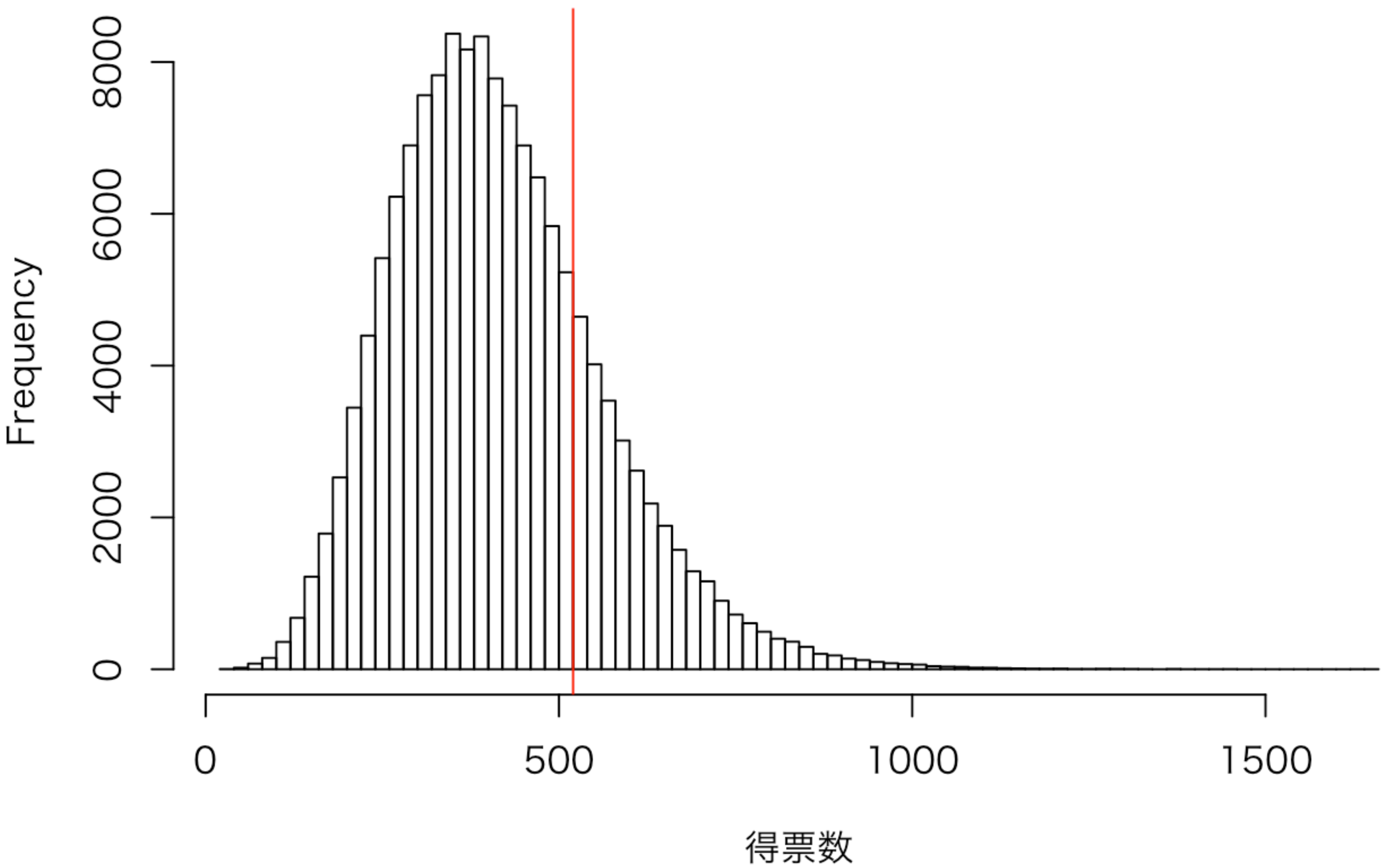
3 : 中央区 , 事後確率= 0.2252 , p値= 0.2113

事後予測分布（西区）



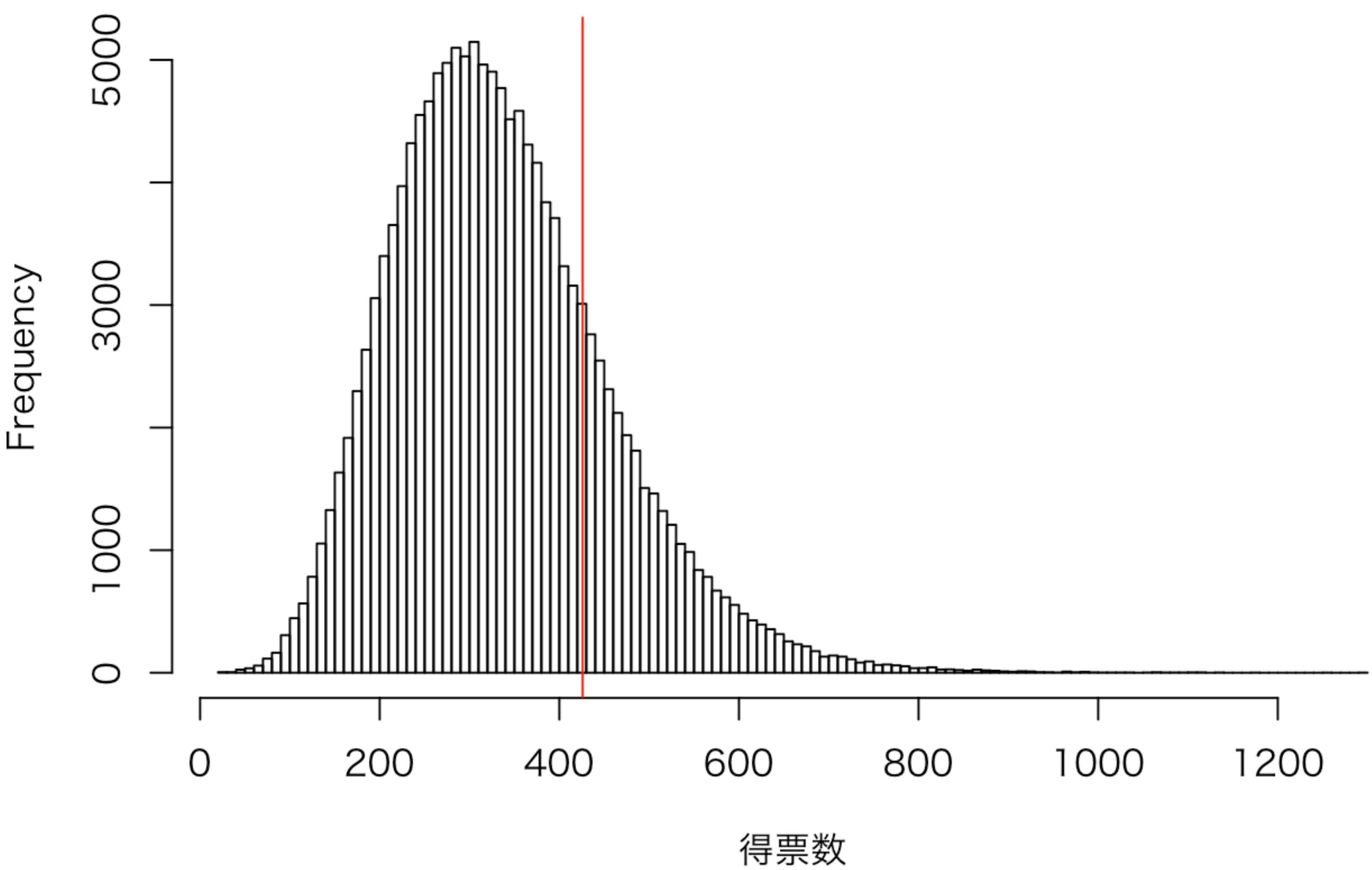
4 : 西区 , 事後確率= 0.2295 , p値= 0.2164

事後予測分布（東区）



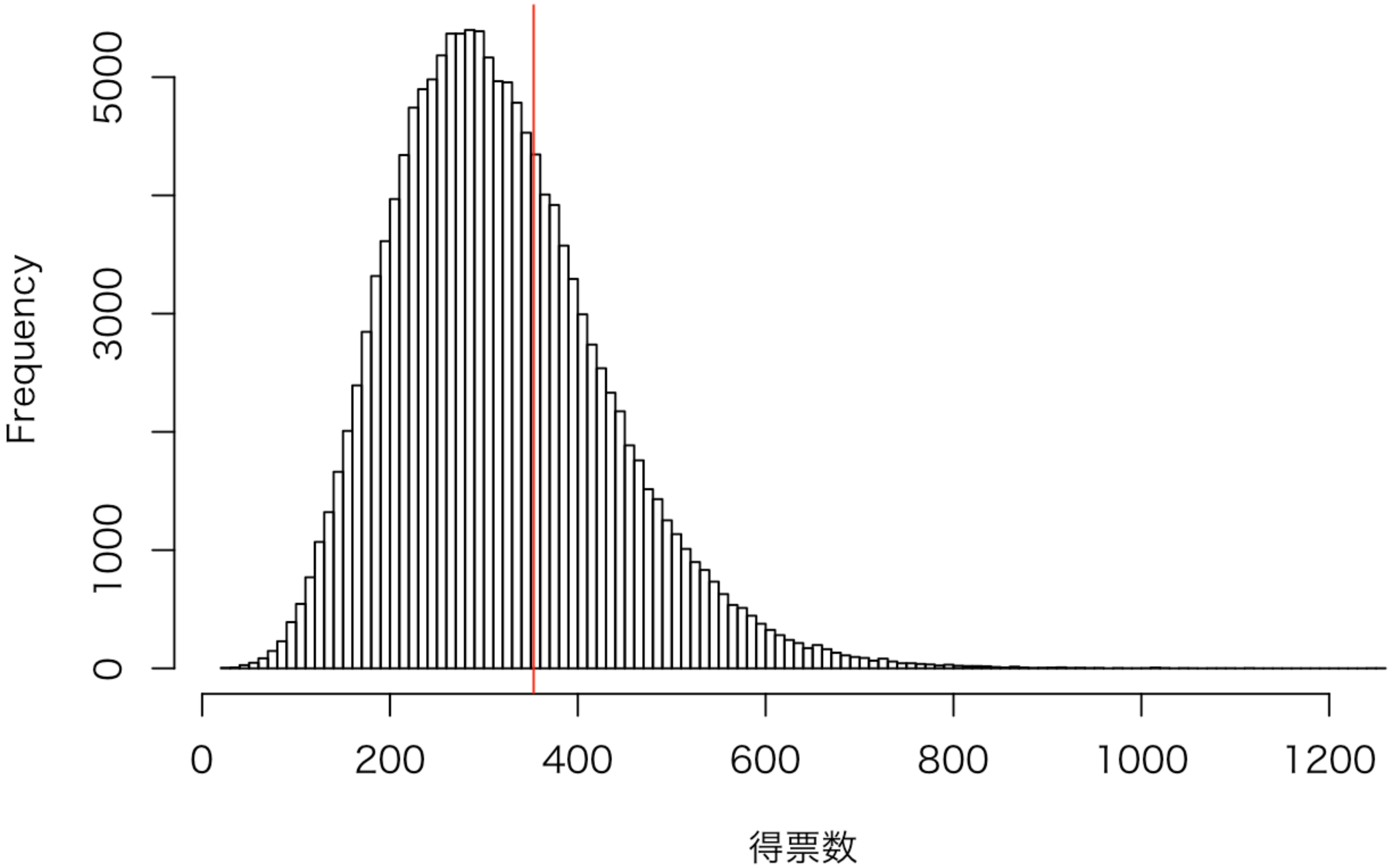
5：東区，事後確率= 0.4289，p値= 0.42

事後予測分布（三条市）



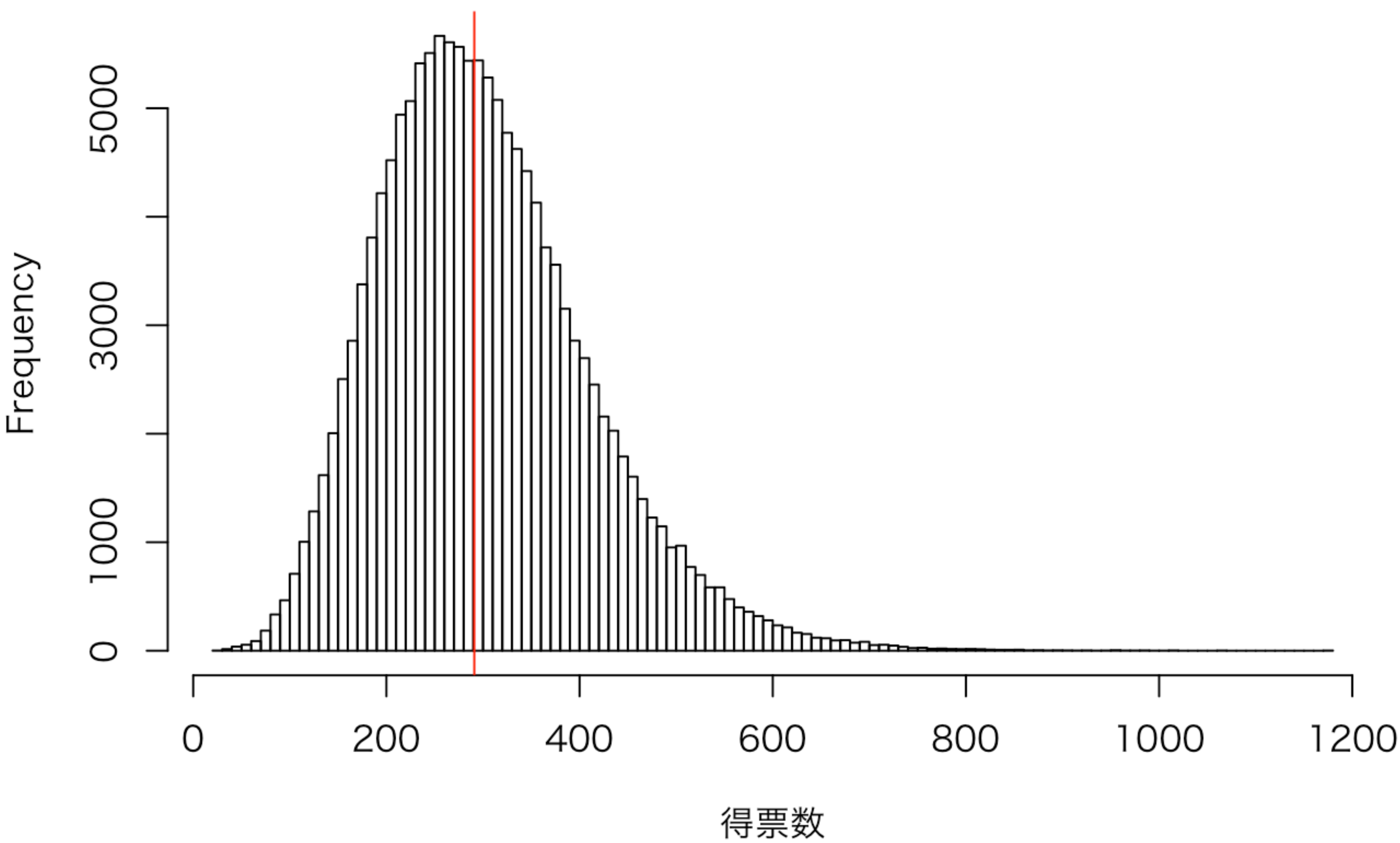
6：三条市，事後確率= 0.4133，p値= 0.4037

事後予測分布（新発田市）

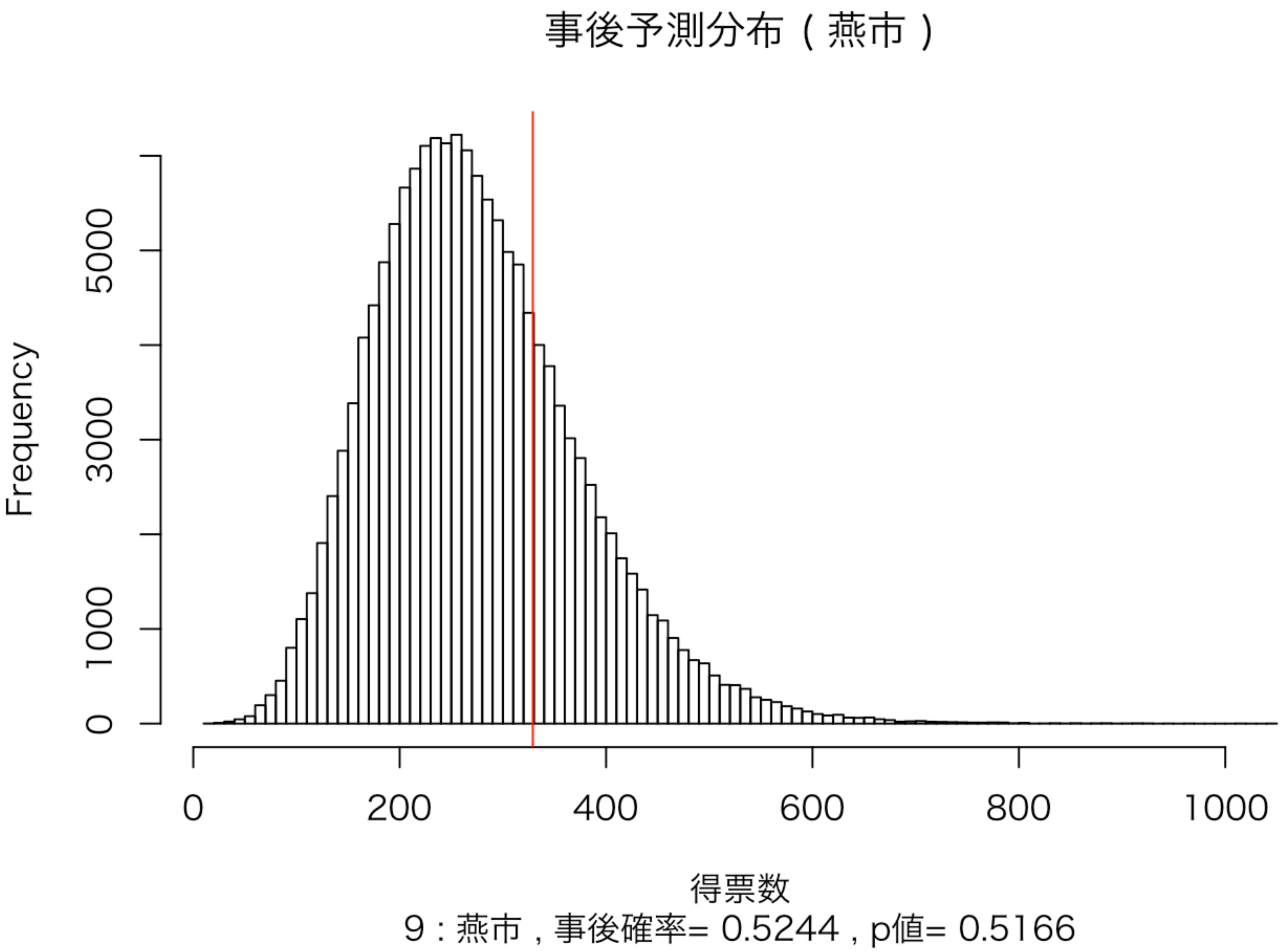


7：新発田市，事後確率= 0.6679，p値= 0.6634

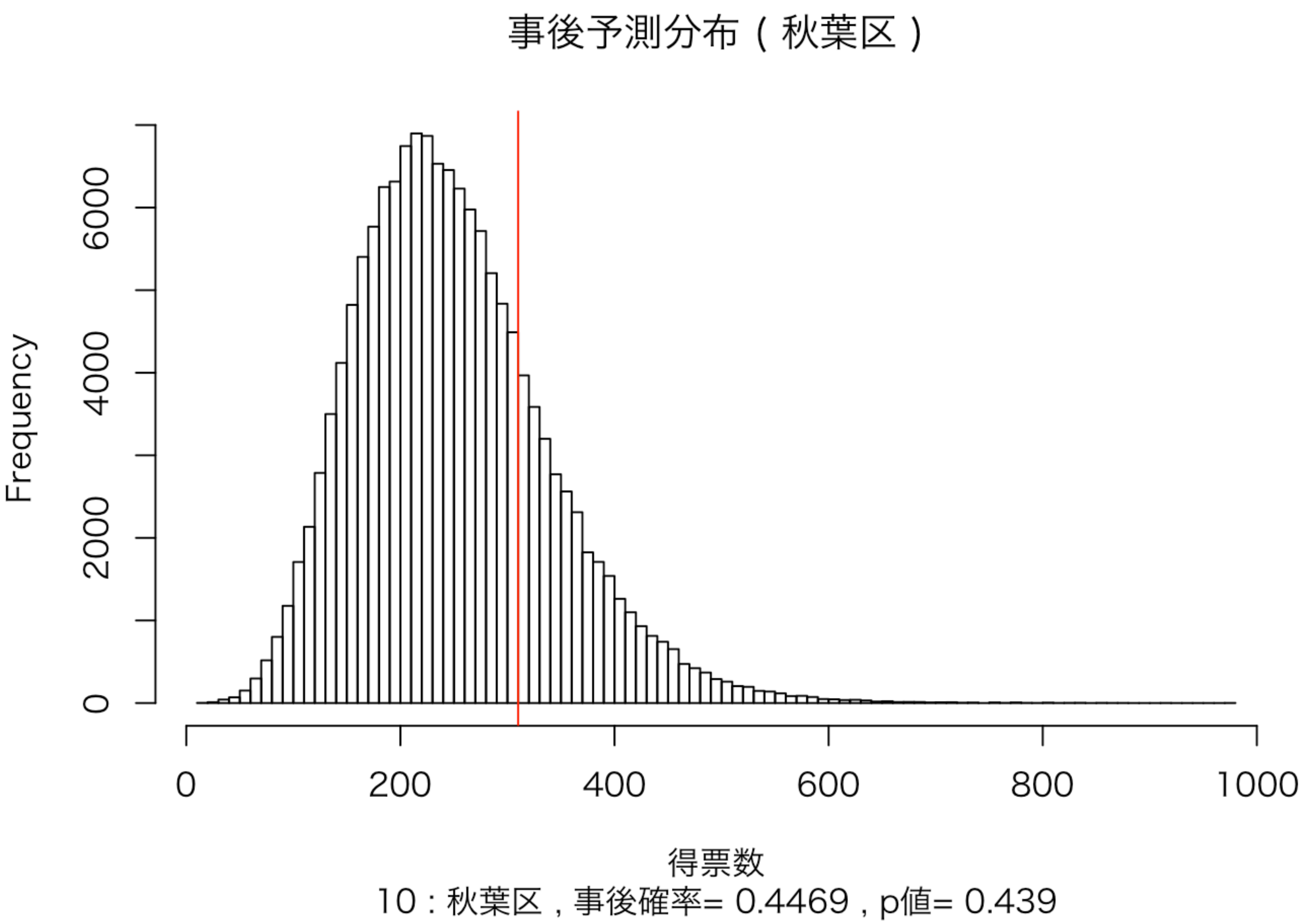
事後予測分布（柏崎市）



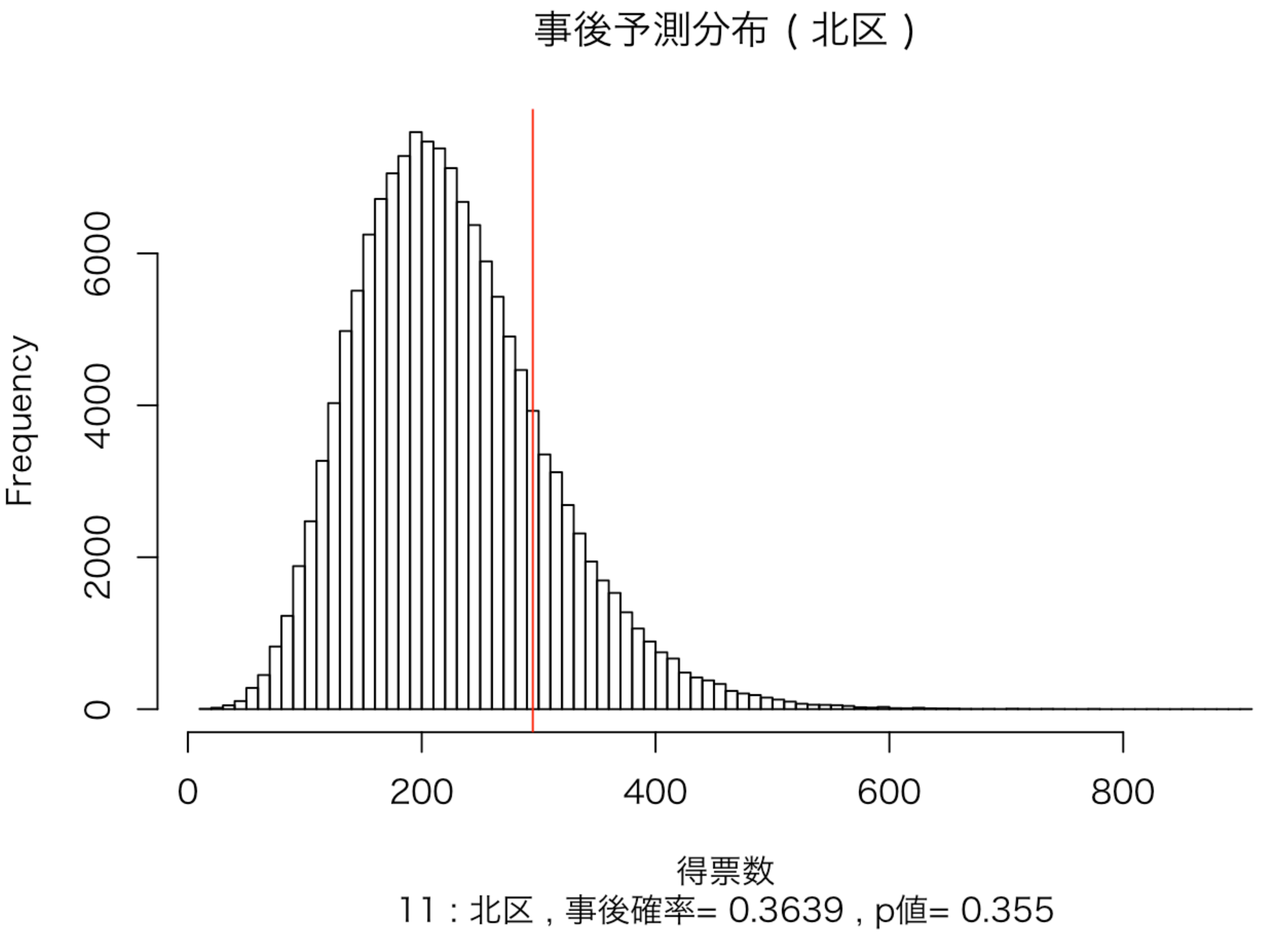
8：柏崎市，事後確率= 0.9879，p値= 0.9897

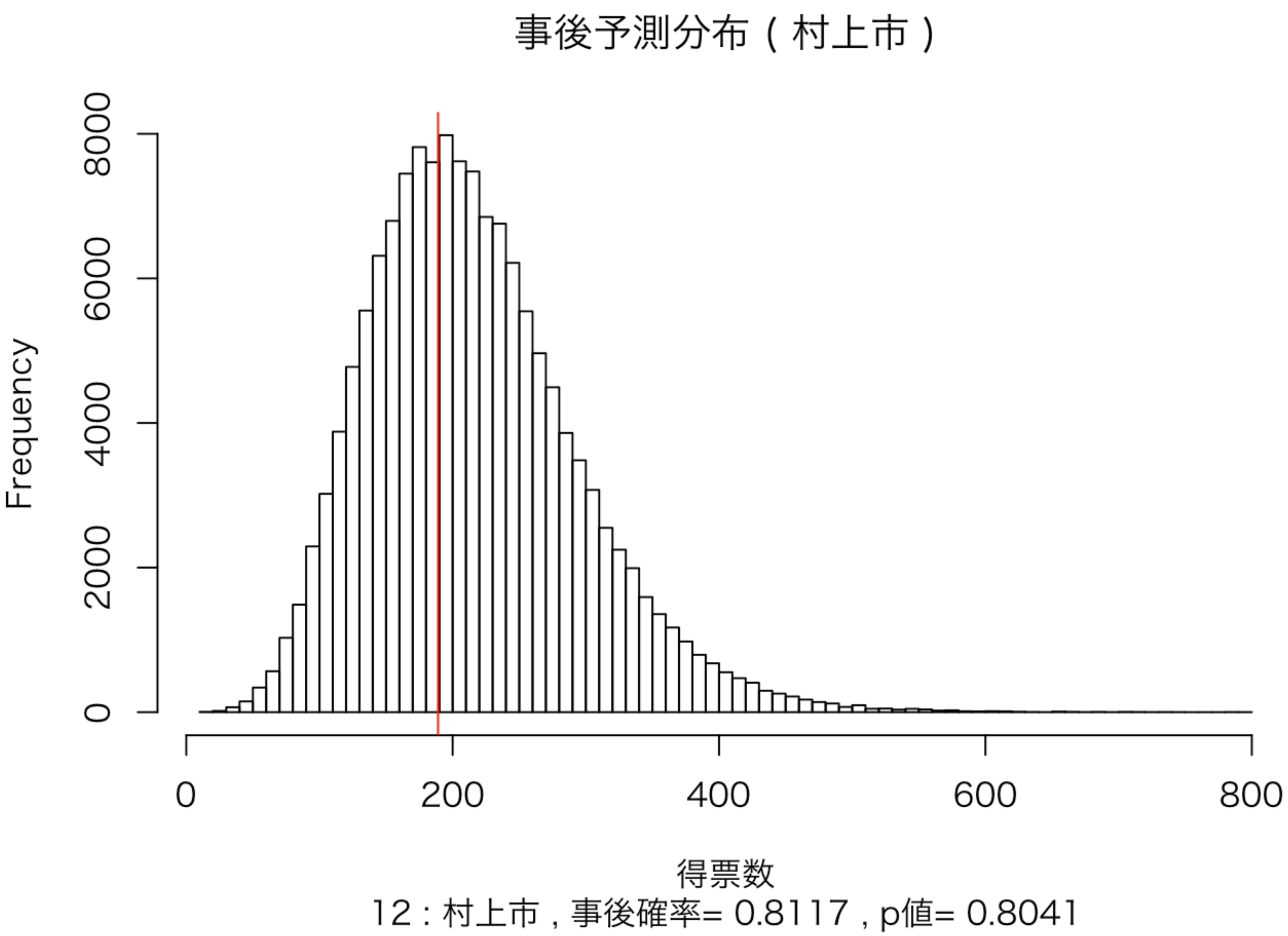


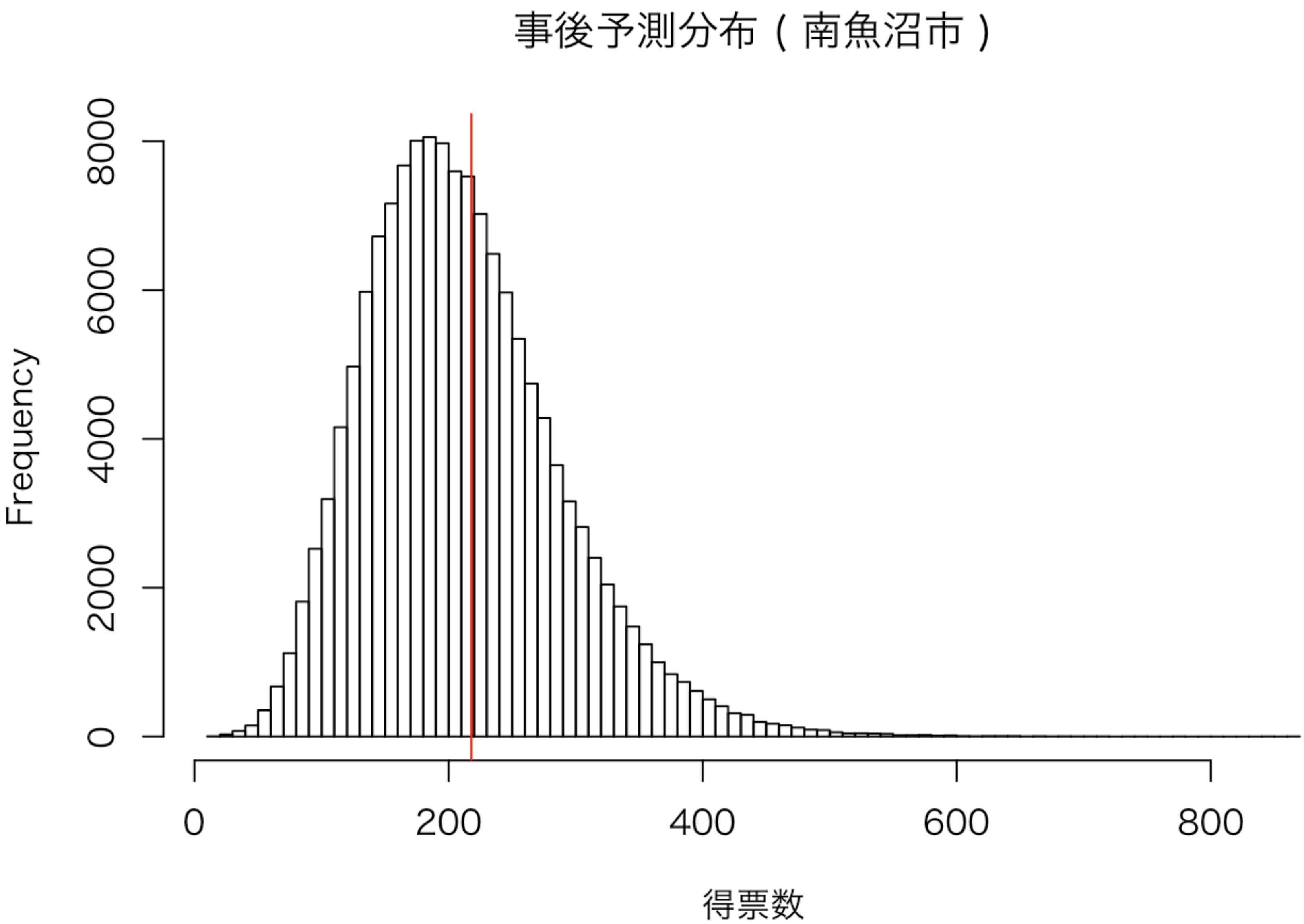
事後予測分布（燕市）
Frequency
0
1000
3000
5000
0
200
400
600
800
1000
得票数
9：燕市，事後確率= 0.5244，p値= 0.5166



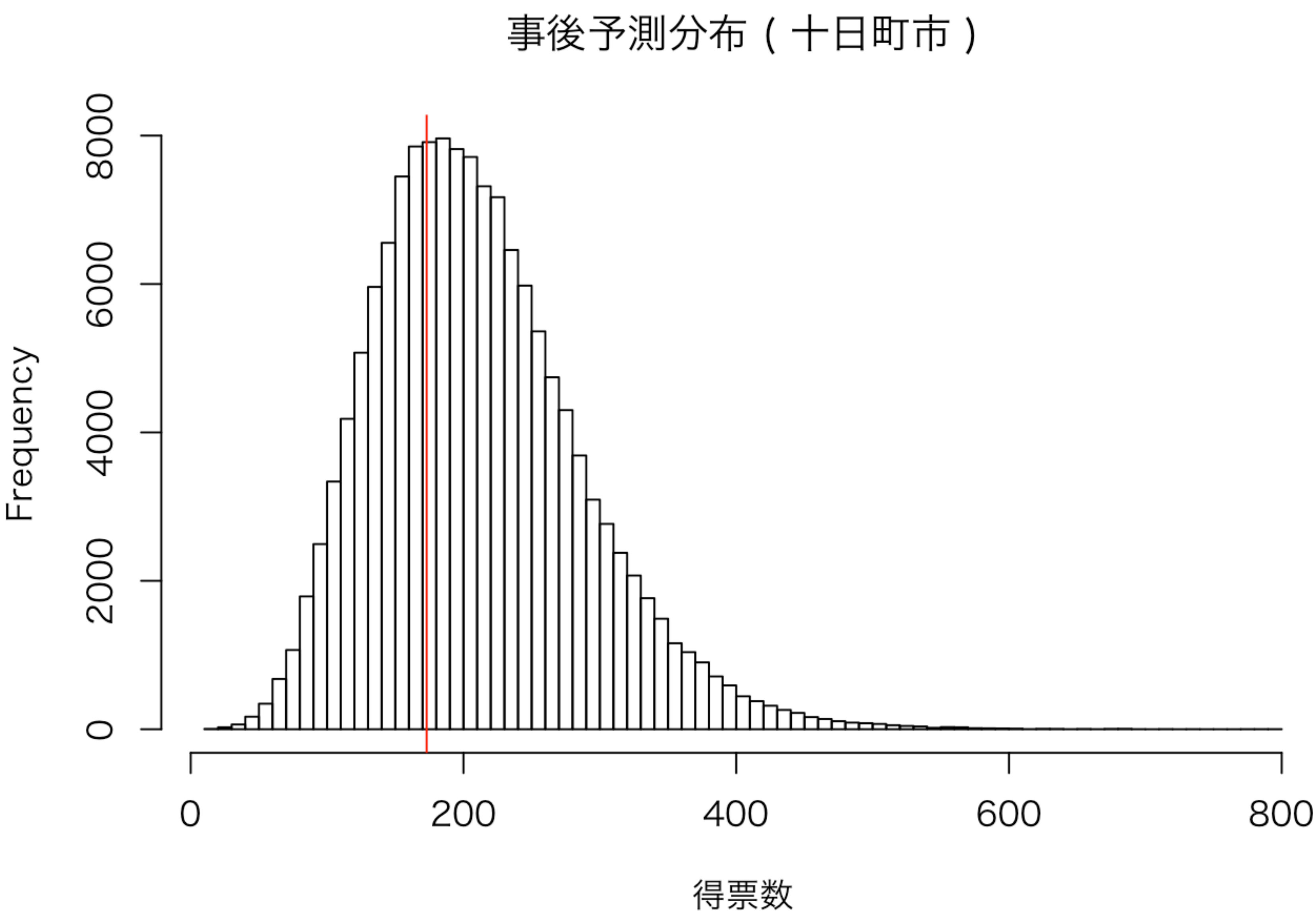
事後予測分布（秋葉区）
Frequency
0
2000
4000
6000
0
200
400
600
800
1000
得票数
10：秋葉区，事後確率= 0.4469，p値= 0.439


事後予測分布（北区）
Frequency
0
2000
4000
6000
0
200
400
600
800
得票数
11：北区，事後確率= 0.3639，p値= 0.355

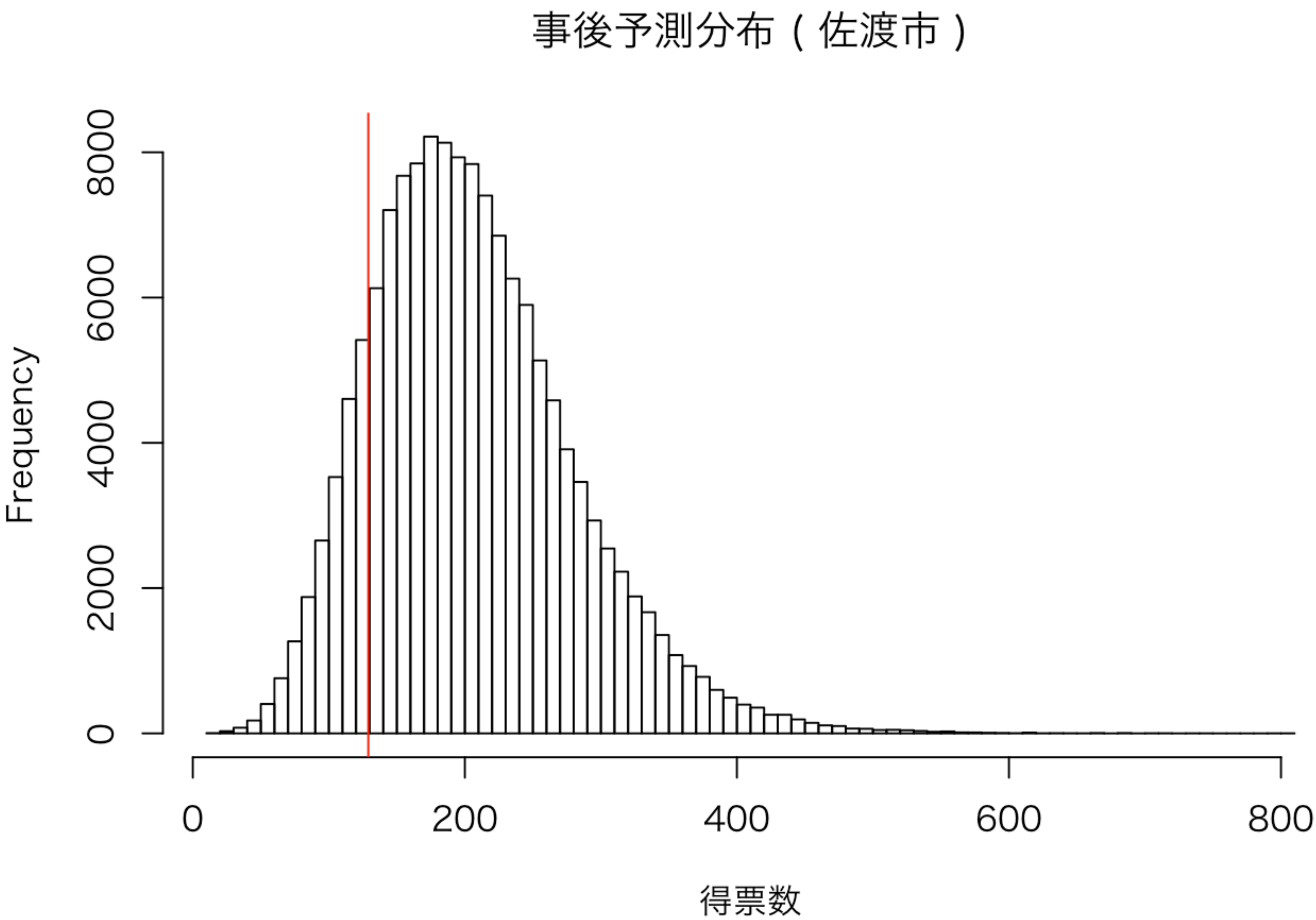

事後予測分布（村上市）
Frequency
0
2000
4000
6000
8000
0
200
400
600
800
得票数
12：村上市，事後確率= 0.8117，p値= 0.8041



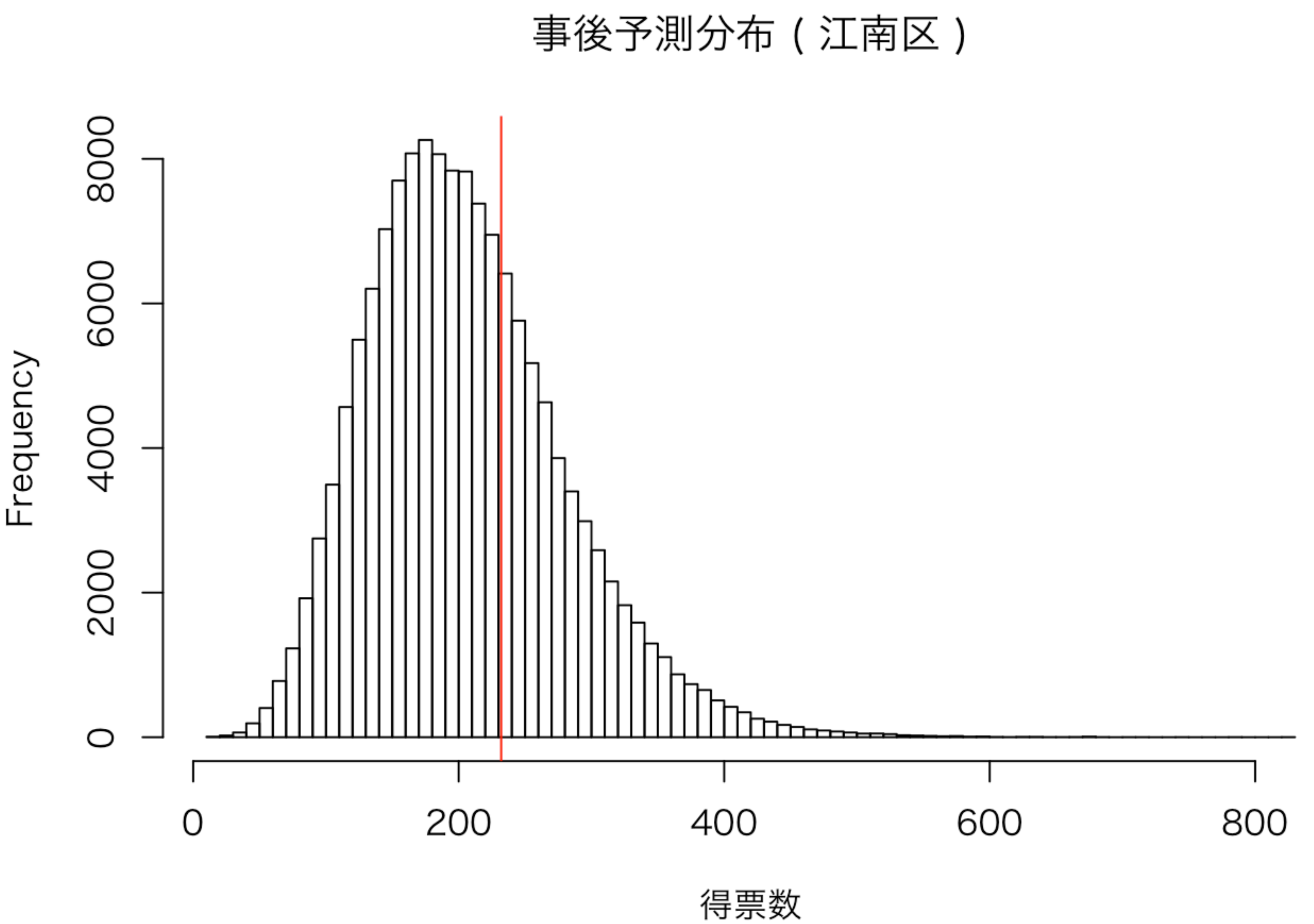
13 : 南魚沼市 , 事後確率= 0.8299 , p値= 0.8288



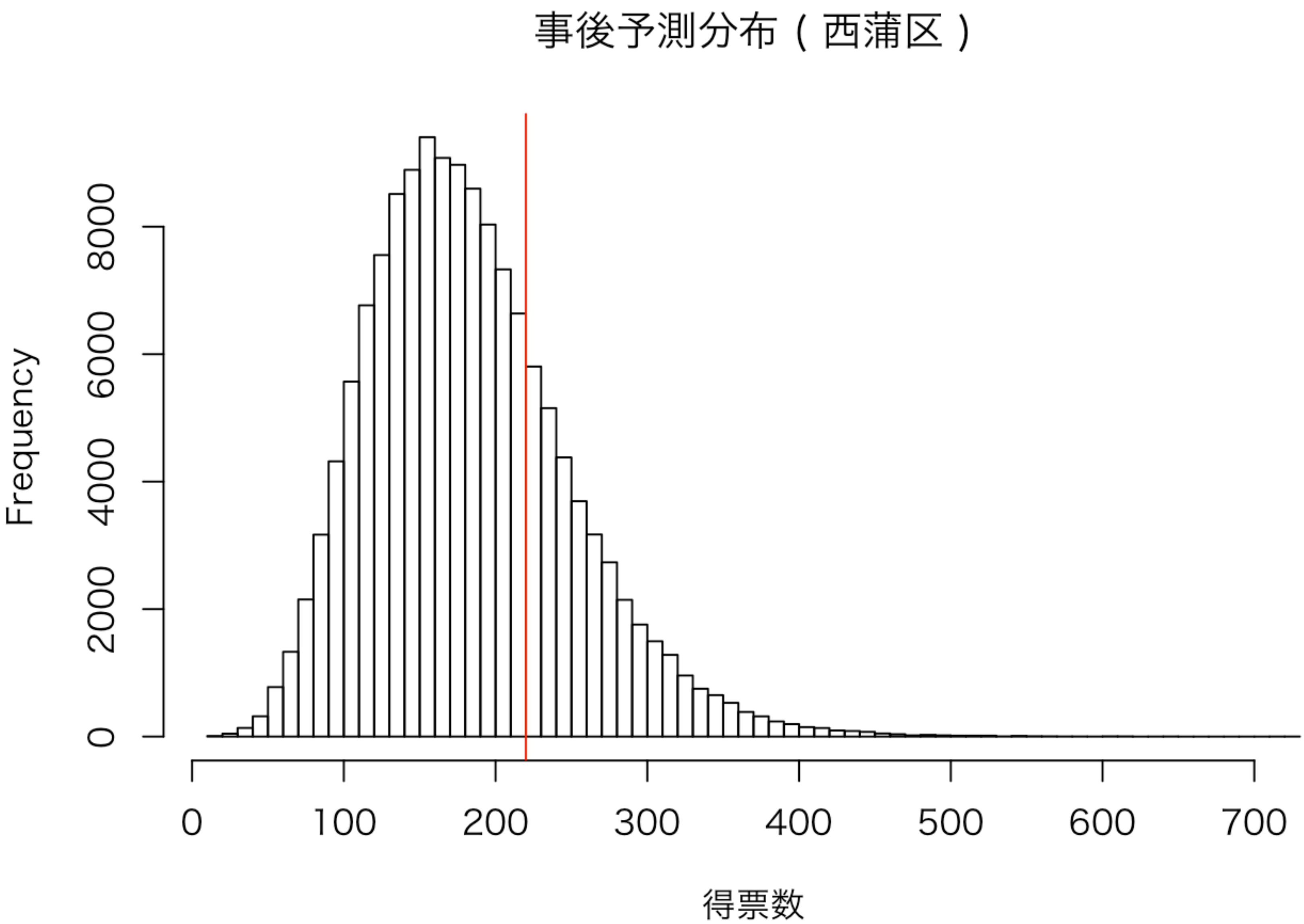
14 : 十日町市 , 事後確率= 0.6861 , p値= 0.6726



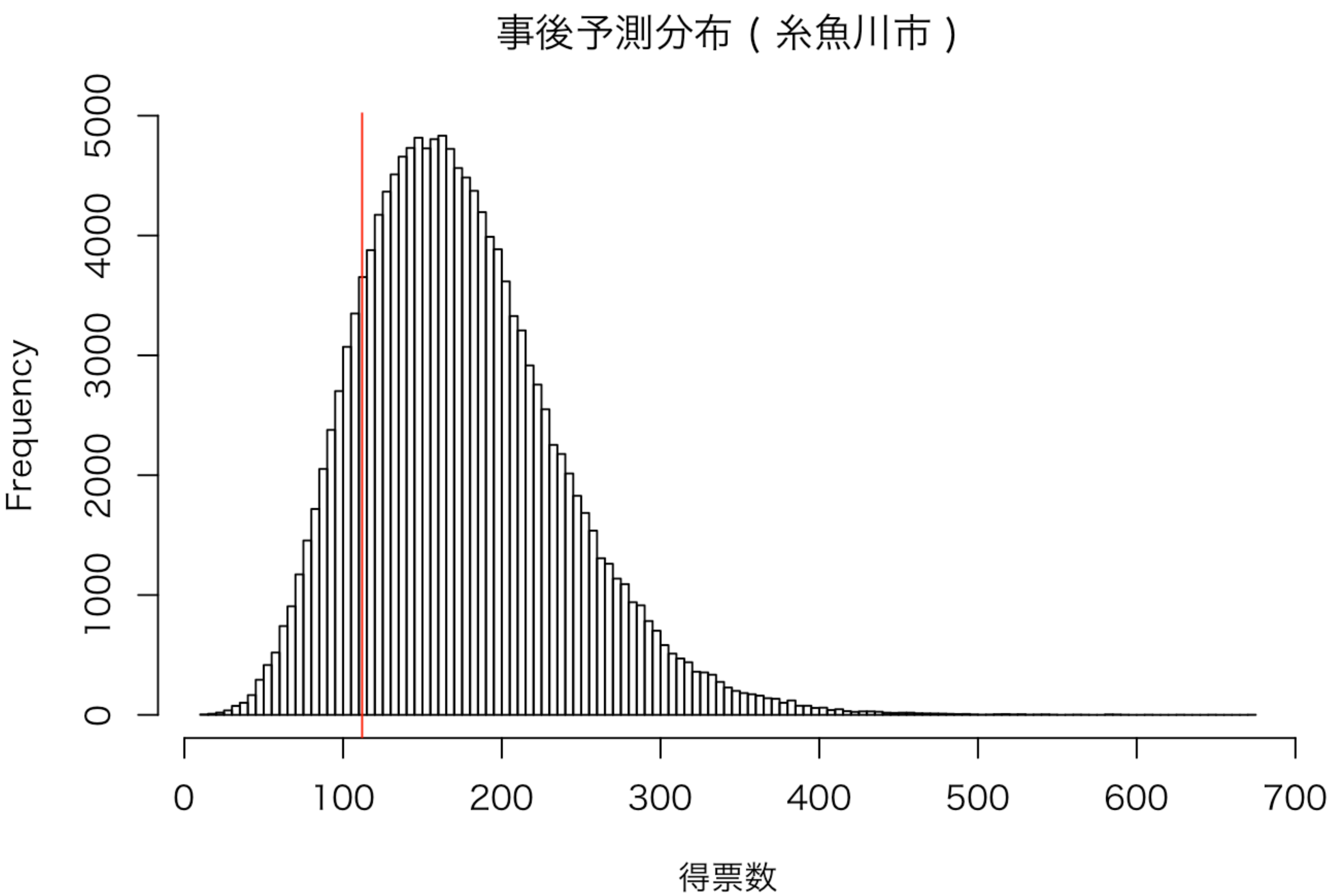
15：佐渡市，事後確率= 0.2807，p値= 0.2621



16：江南区，事後確率= 0.6447，p値= 0.6393

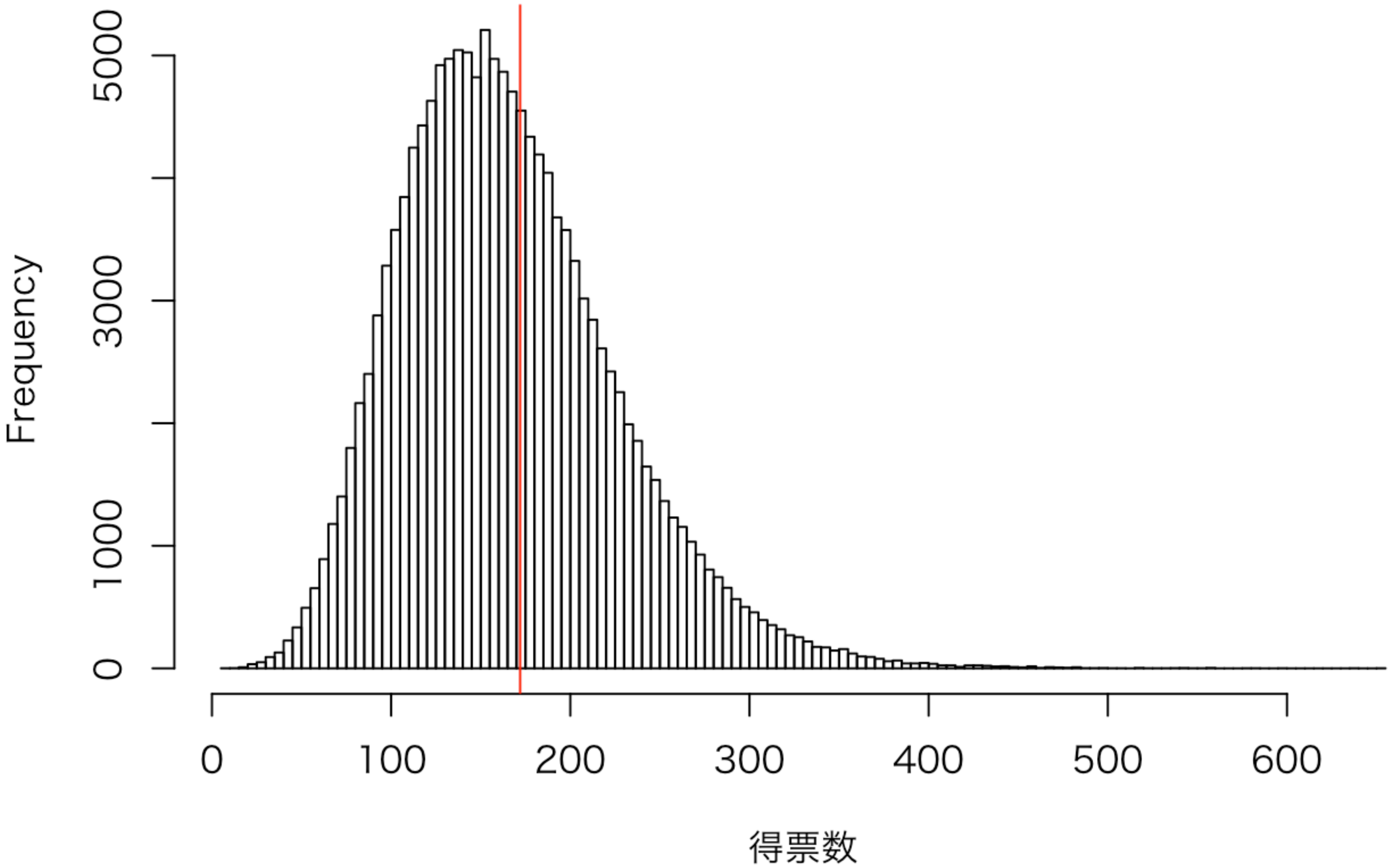


17 : 西蒲区 , 事後確率= 0.5056 , p値= 0.4975



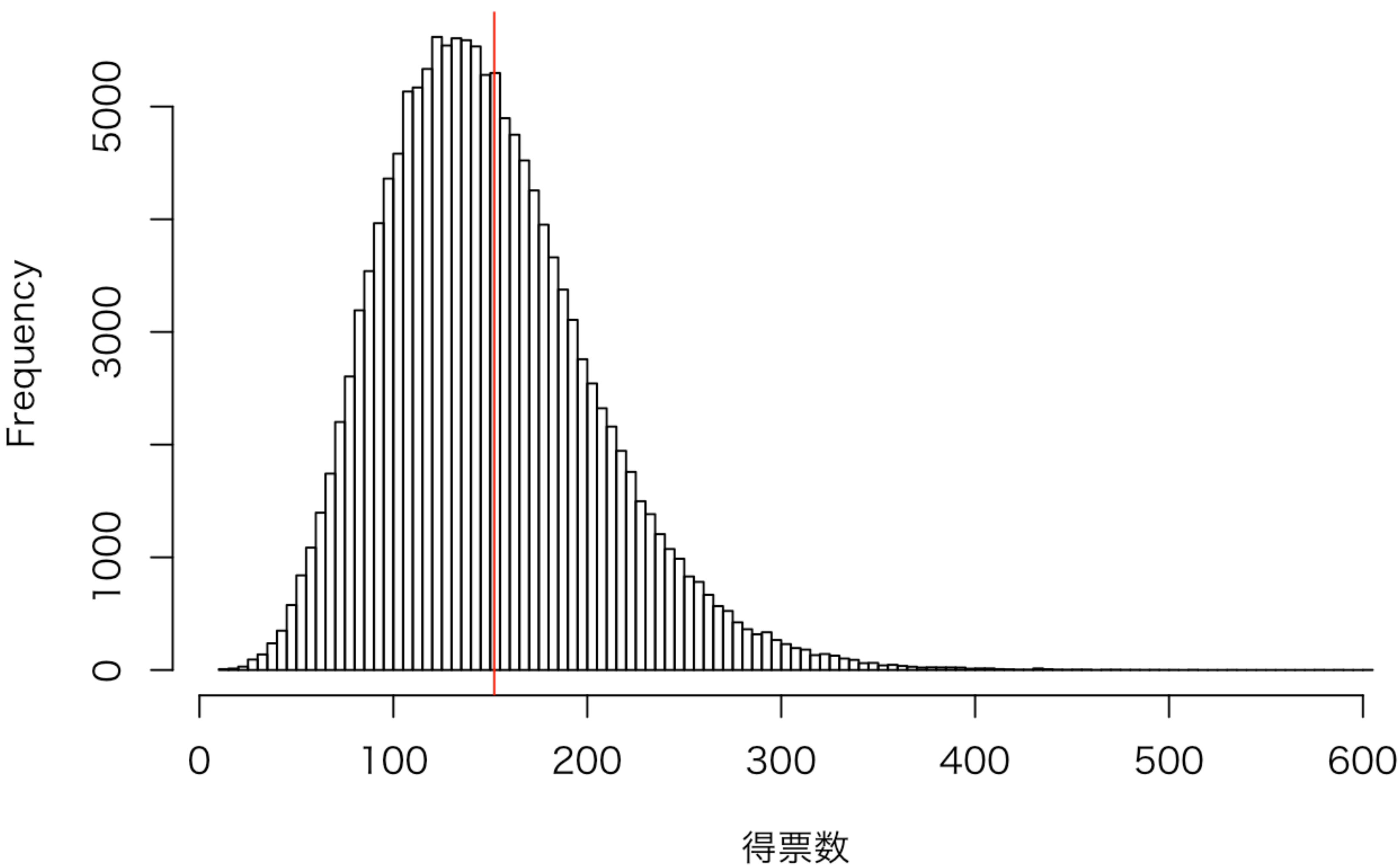
18 : 糸魚川市 , 事後確率= 0.314 , p値= 0.2953

事後予測分布（五泉市）



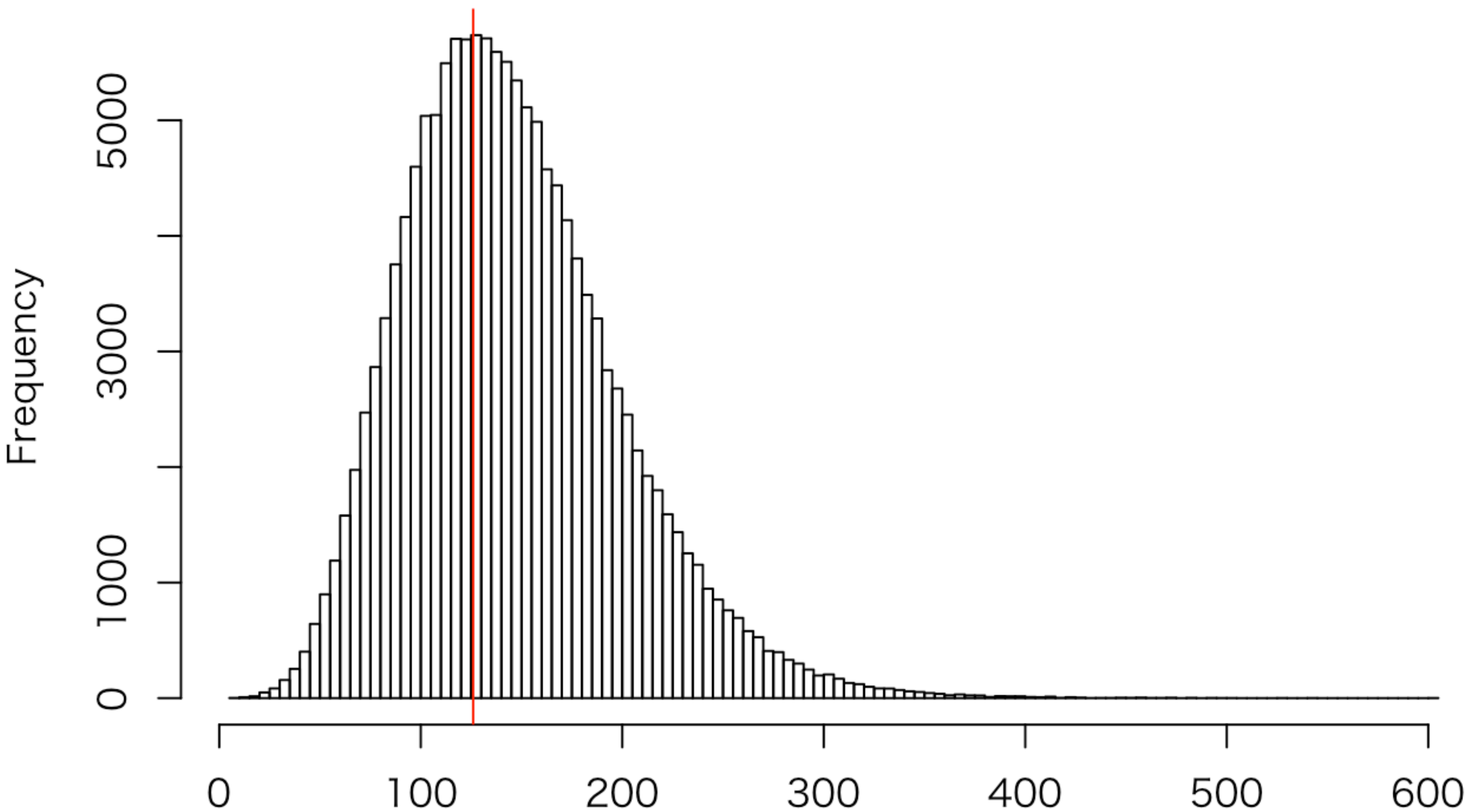
19：五泉市，事後確率= 0.8176，p値= 0.8164

事後予測分布（阿賀野市）



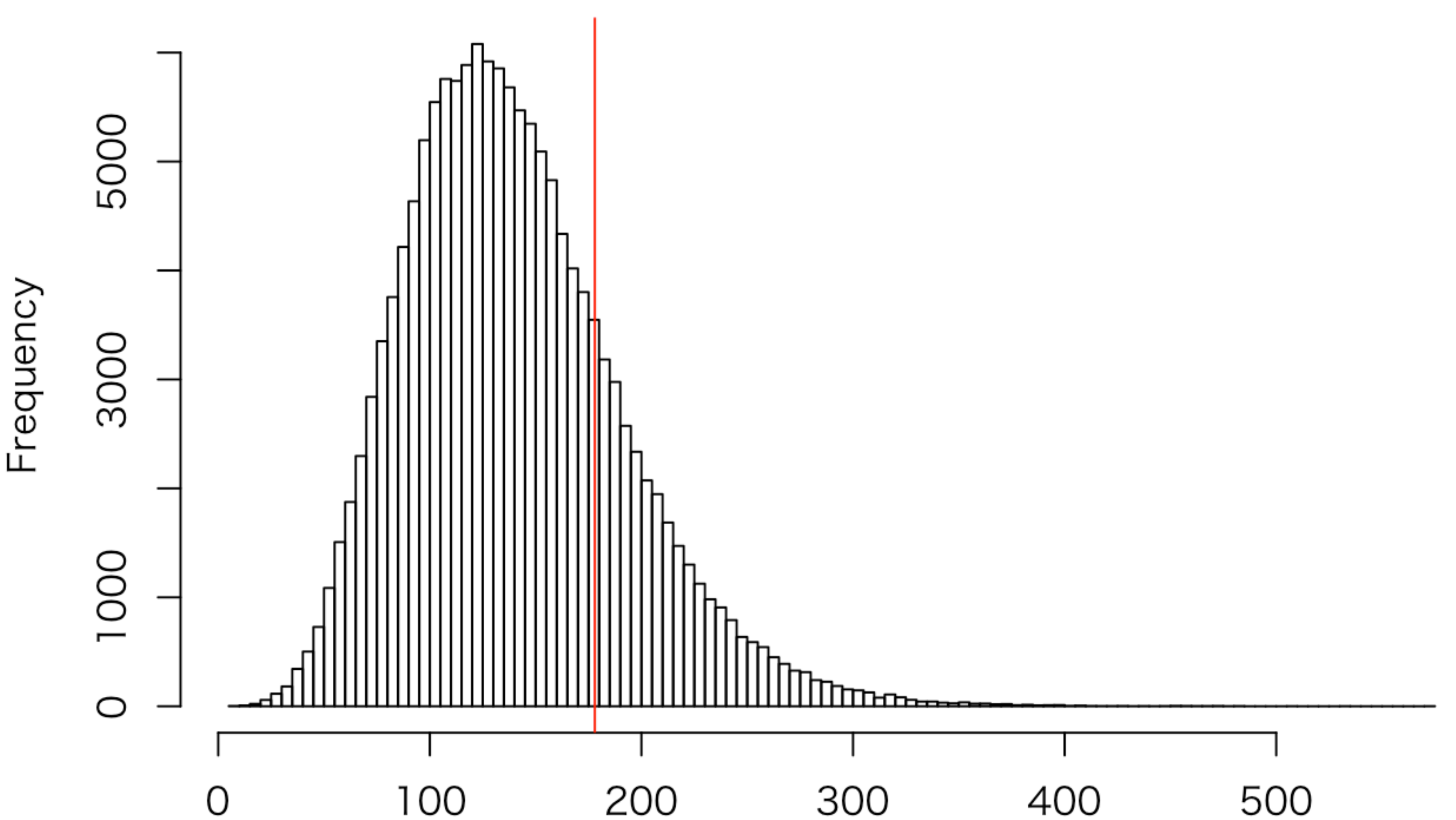
20：阿賀野市，事後確率= 0.8613，p値= 0.8612

事後予測分布 (魚沼市)



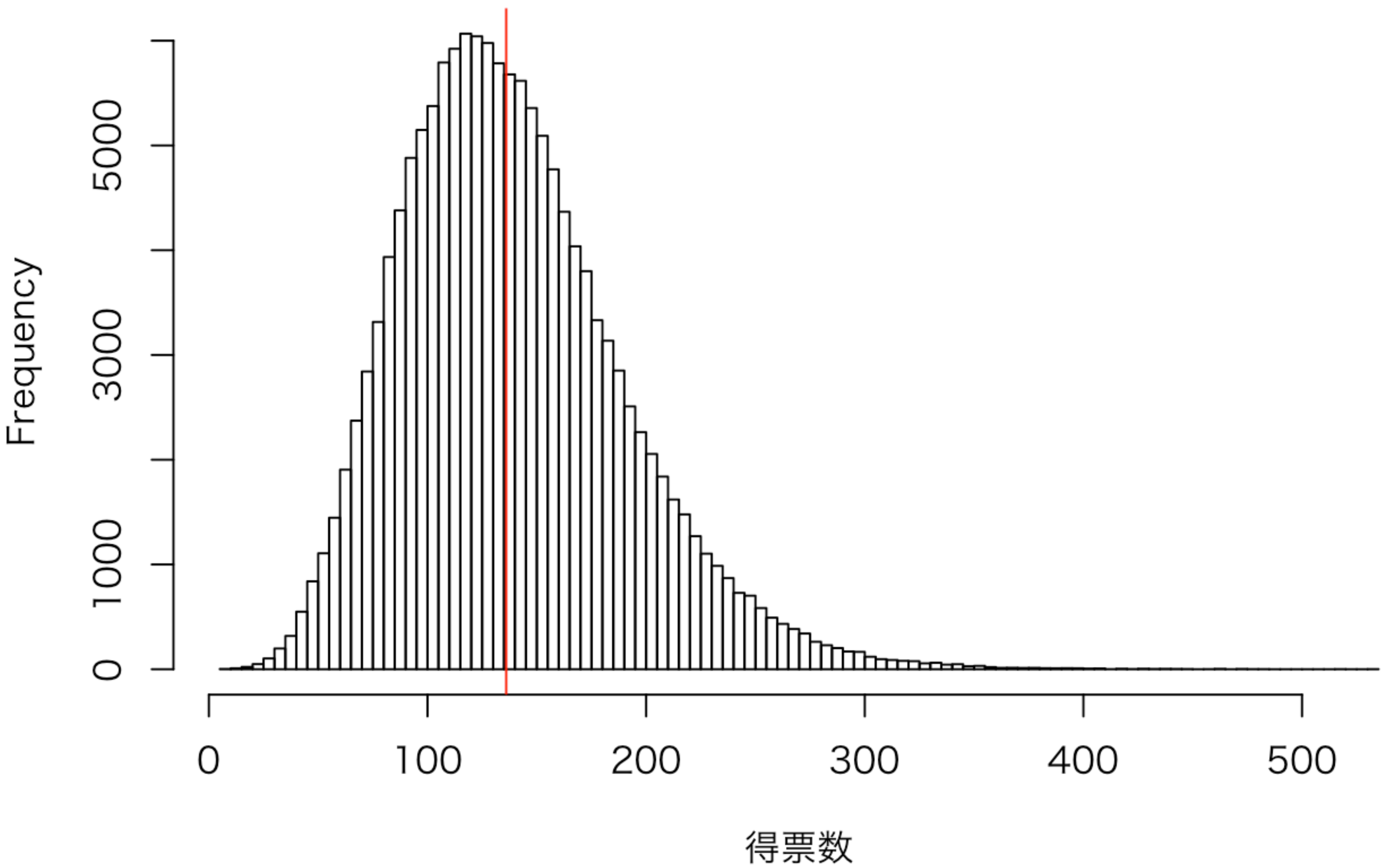
得票数
21 : 魚沼市 , 事後確率= 0.7848 , p値= 0.7755

事後予測分布 (見附市)



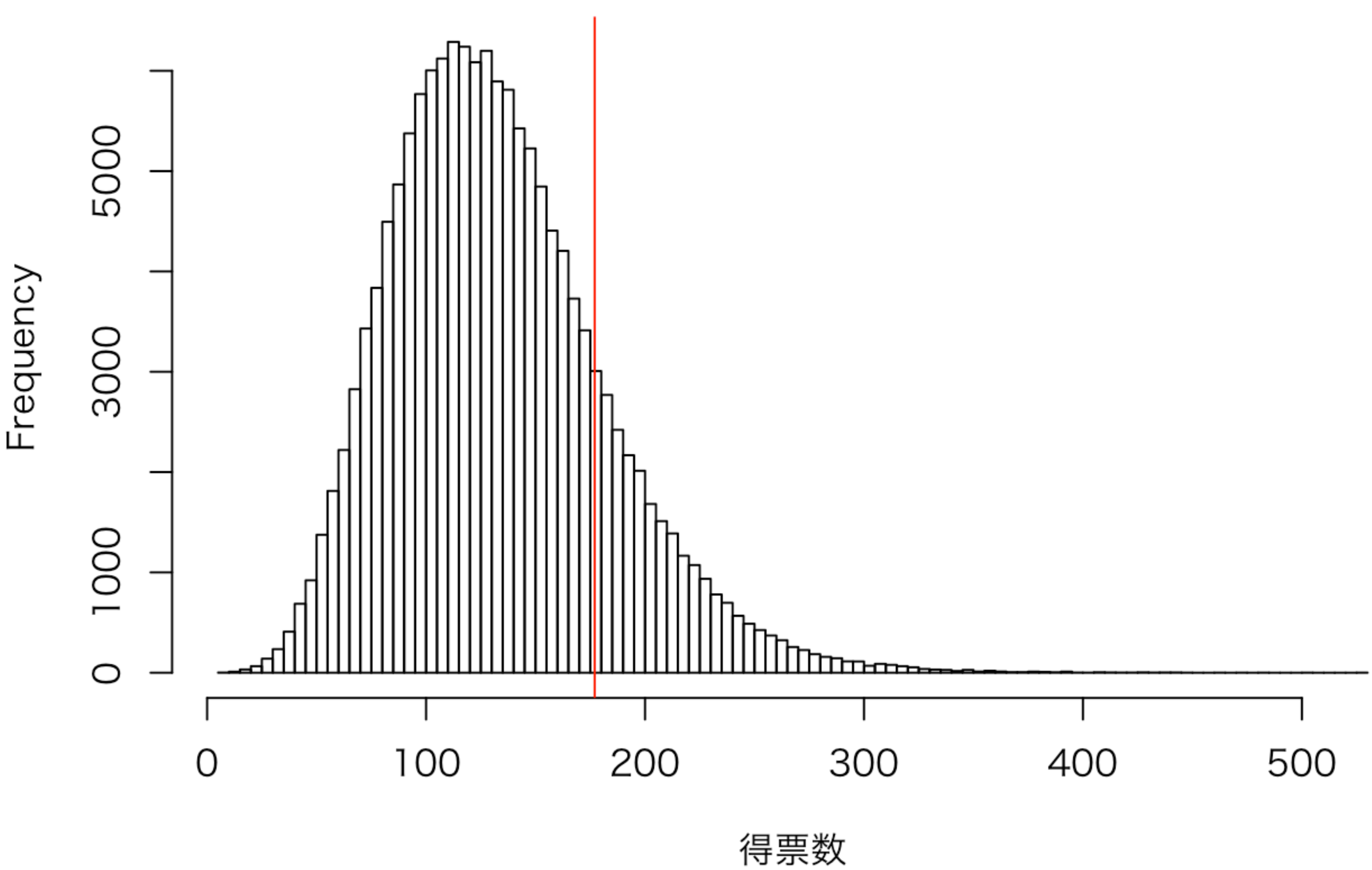
得票数
22 : 見附市 , 事後確率= 0.4129 , p値= 0.4027

事後予測分布（小千谷市）



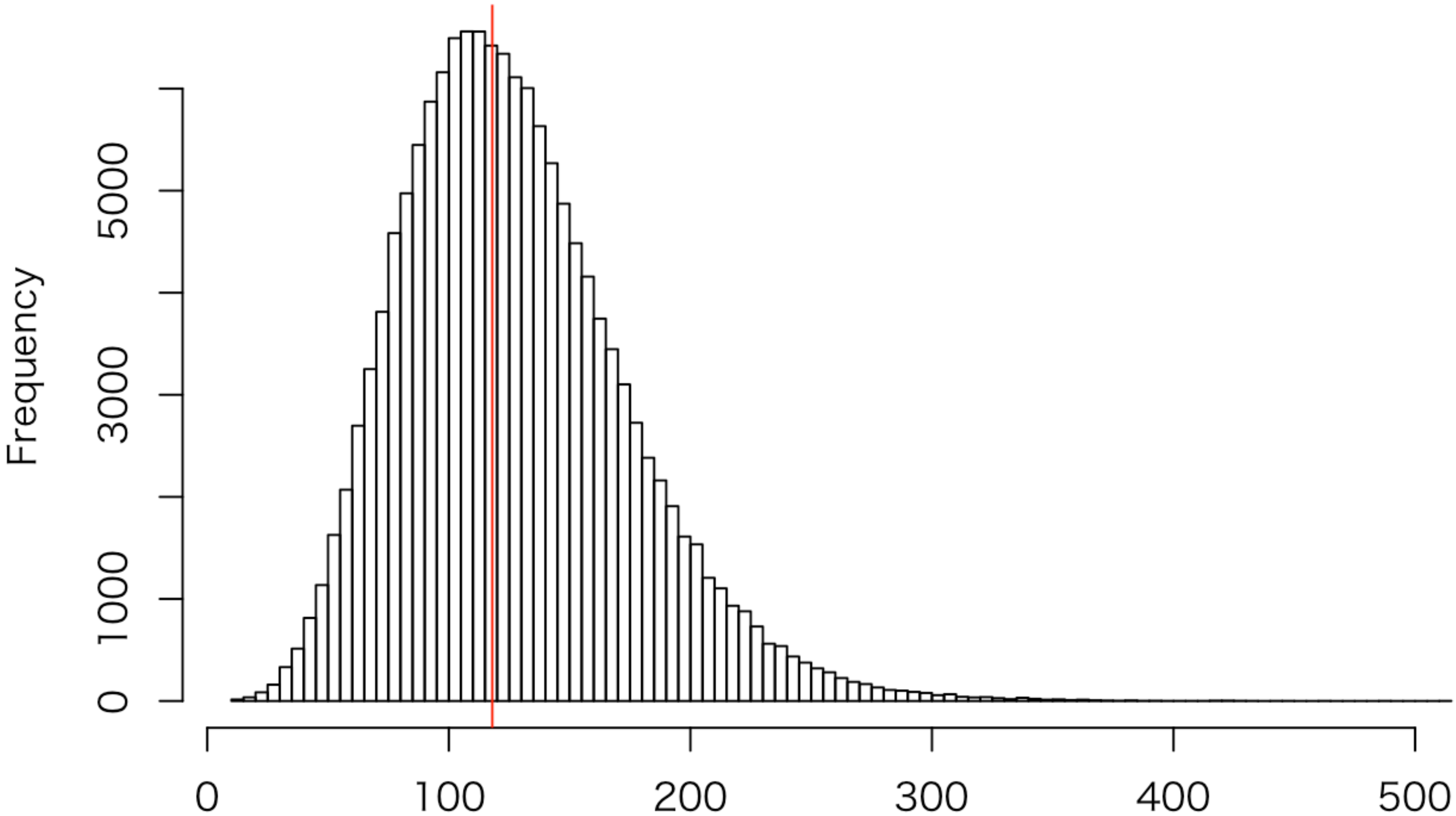
23：小千谷市，事後確率= 0.9501，p値= 0.9521

事後予測分布（南区）



24：南区，事後確率= 0.3383，p値= 0.3286

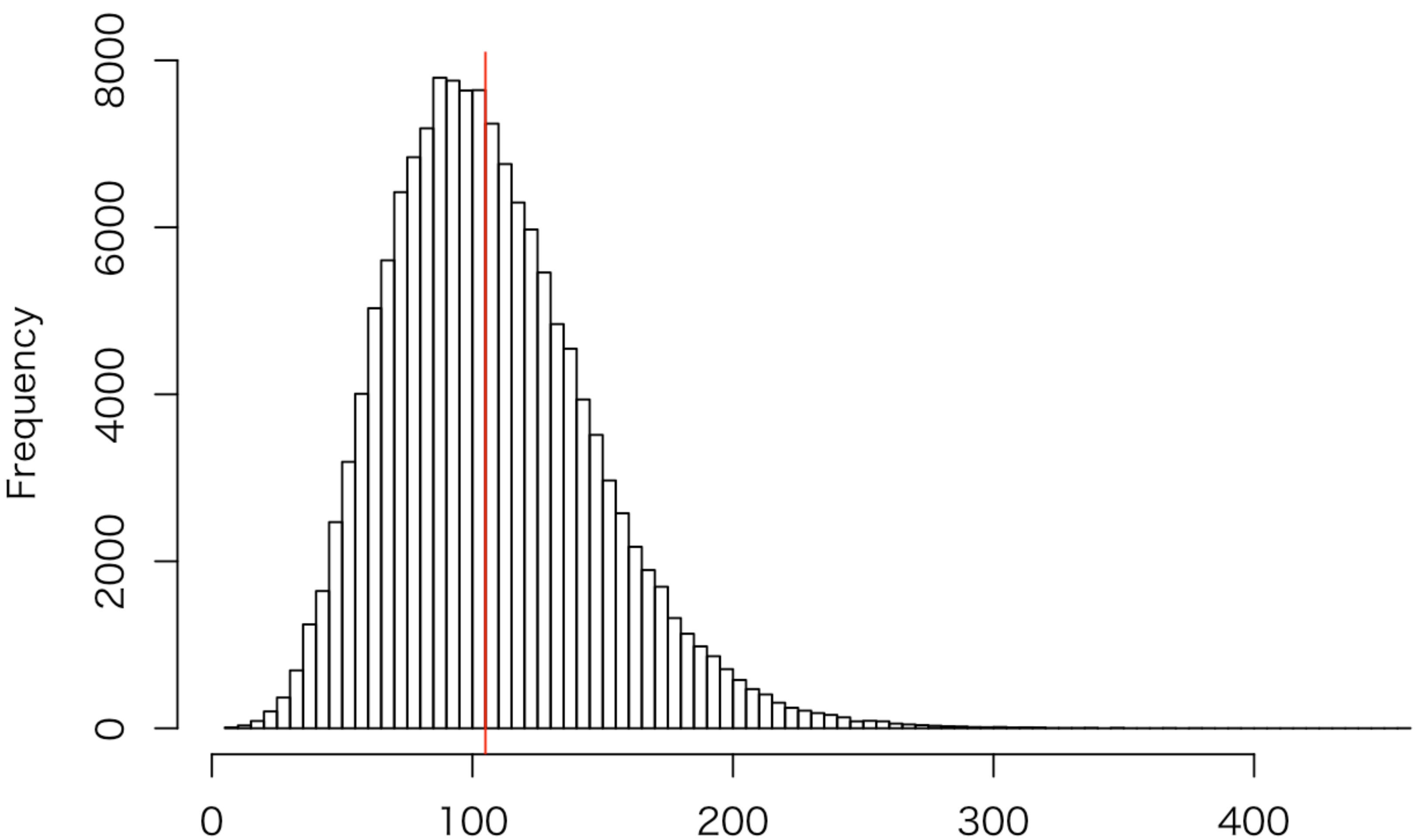
事後予測分布（妙高市）



得票数

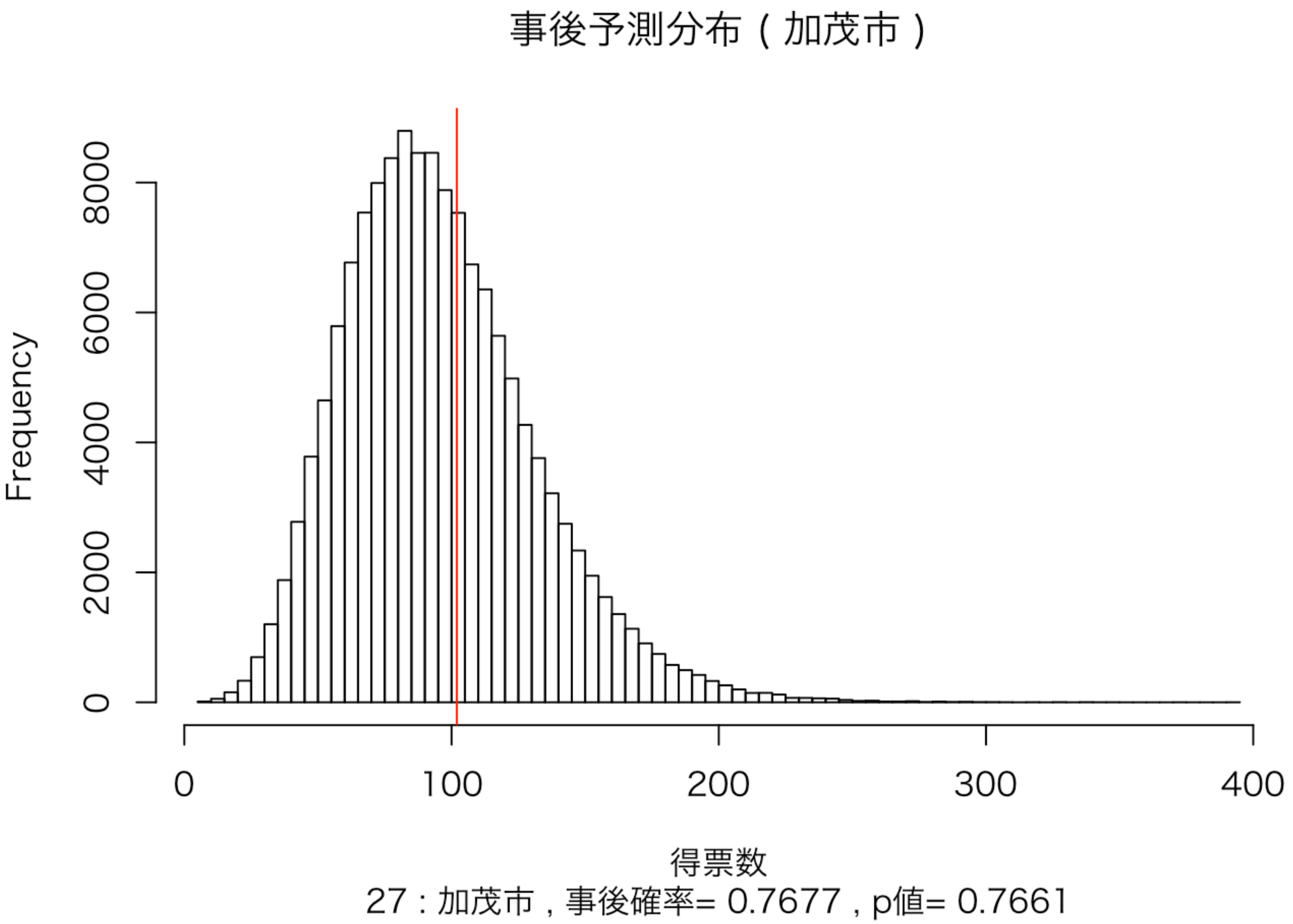
25：妙高市，事後確率= 0.9319，p値= 0.9254

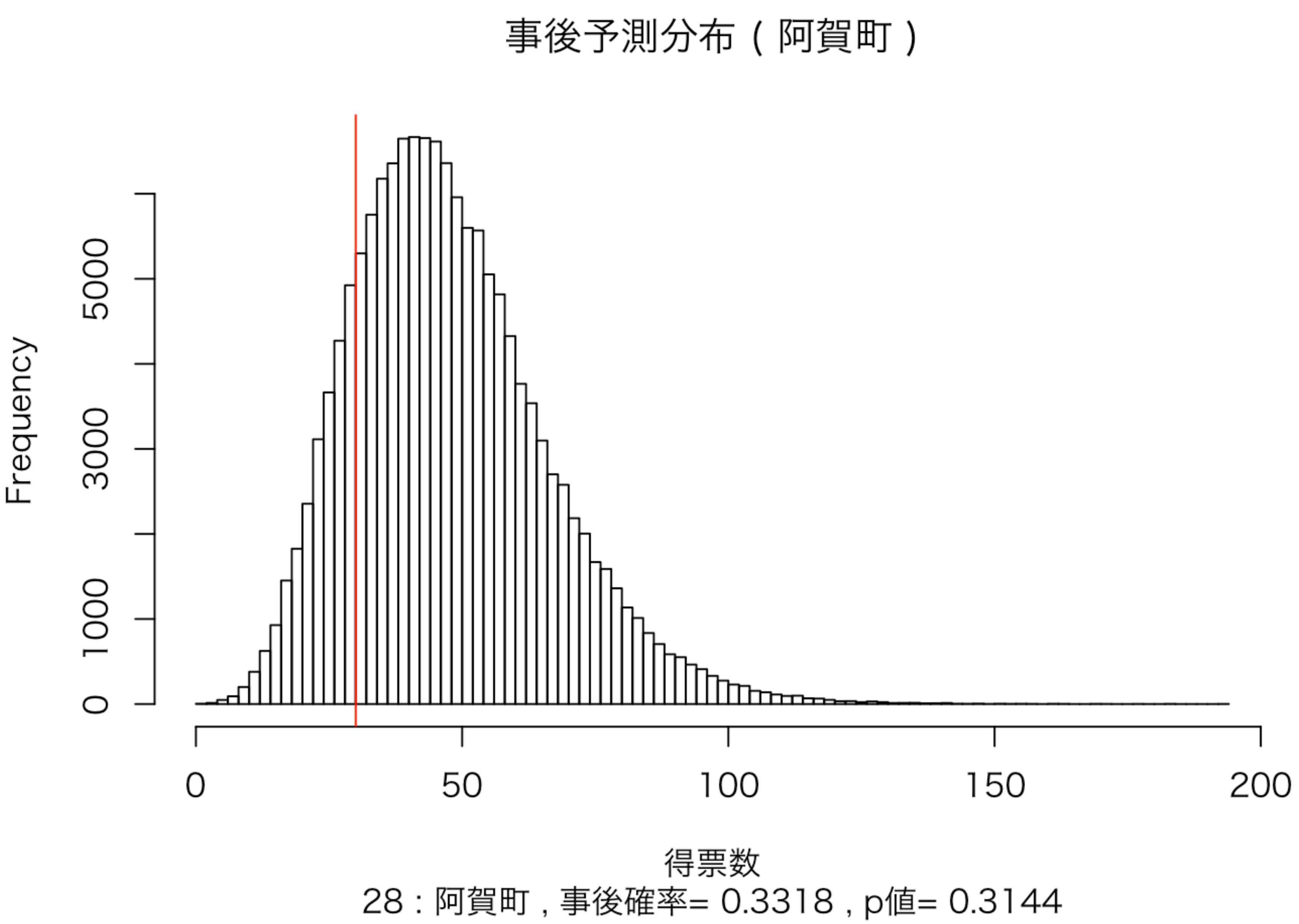
事後予測分布（胎内市）



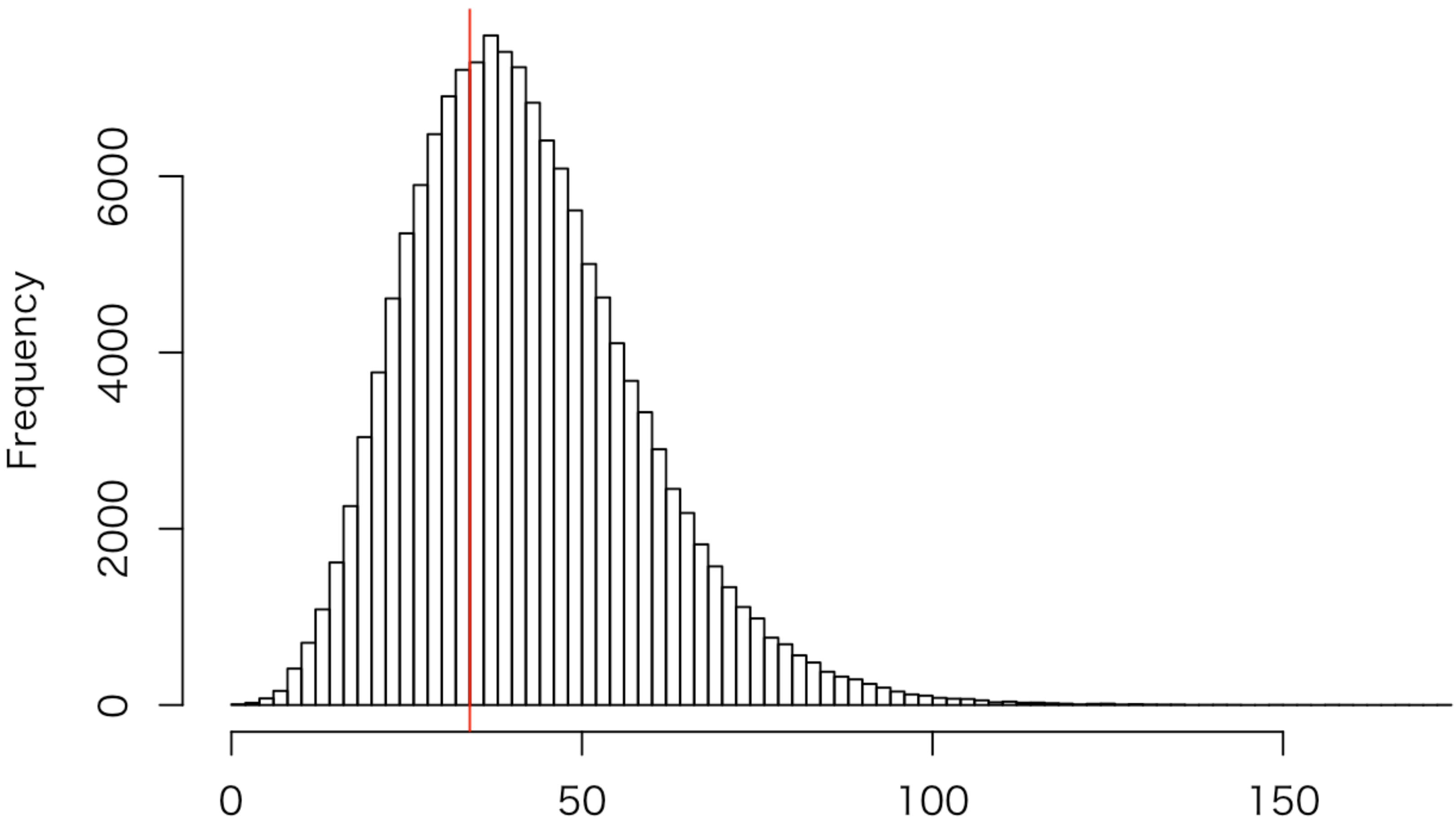
得票数

26：胎内市，事後確率= 0.9464，p値= 0.9498


事後予測分布（加茂市）
Frequency
0
2000
4000
6000
8000
0
100
200
300
400
得票数
27 : 加茂市 , 事後確率= 0.7677 , p値= 0.7661

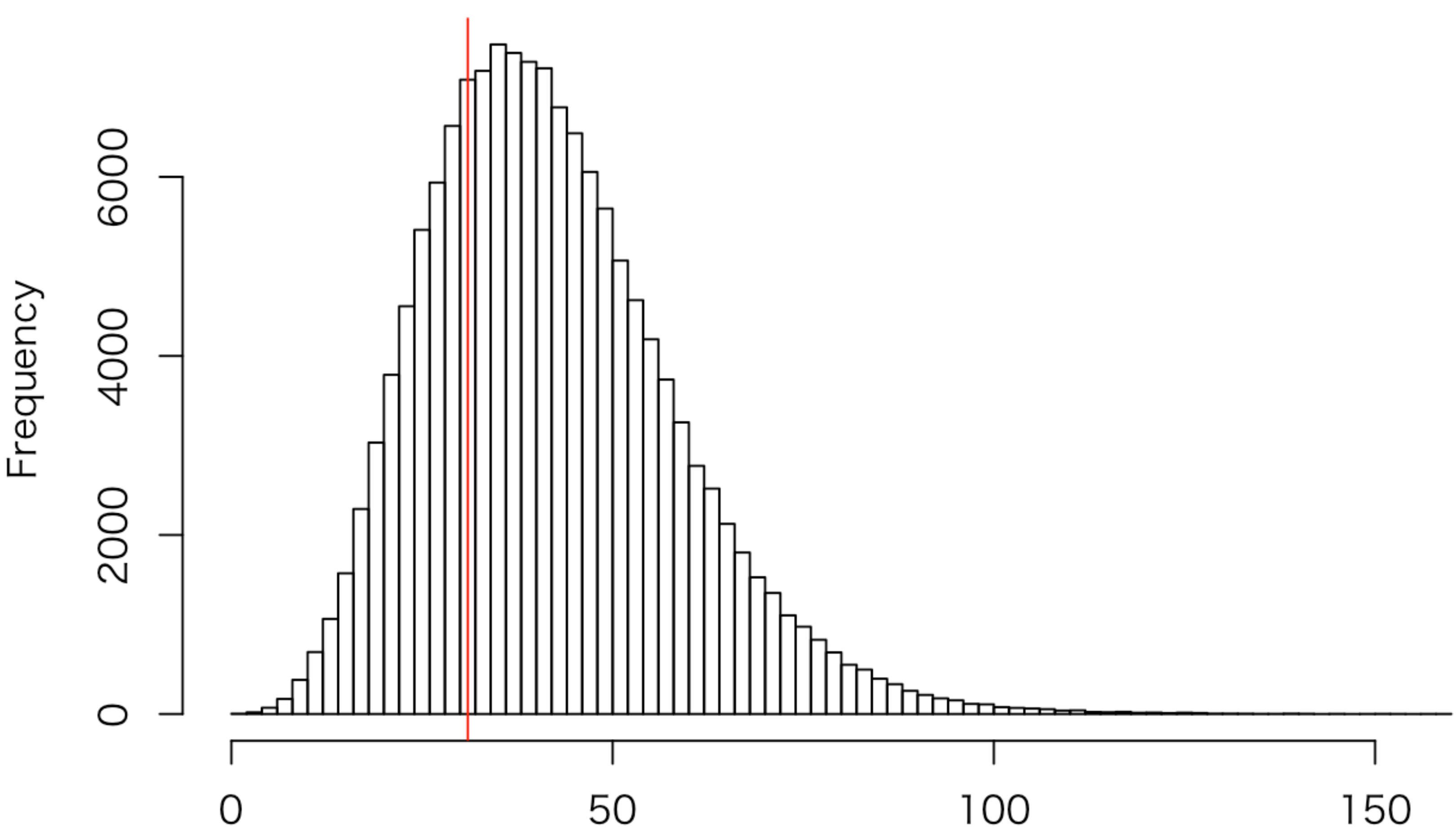

事後予測分布（阿賀町）
Frequency
0
1000
3000
5000
0
50
100
150
200
得票数
28 : 阿賀町 , 事後確率= 0.3318 , p値= 0.3144

事後予測分布（聖籠町）

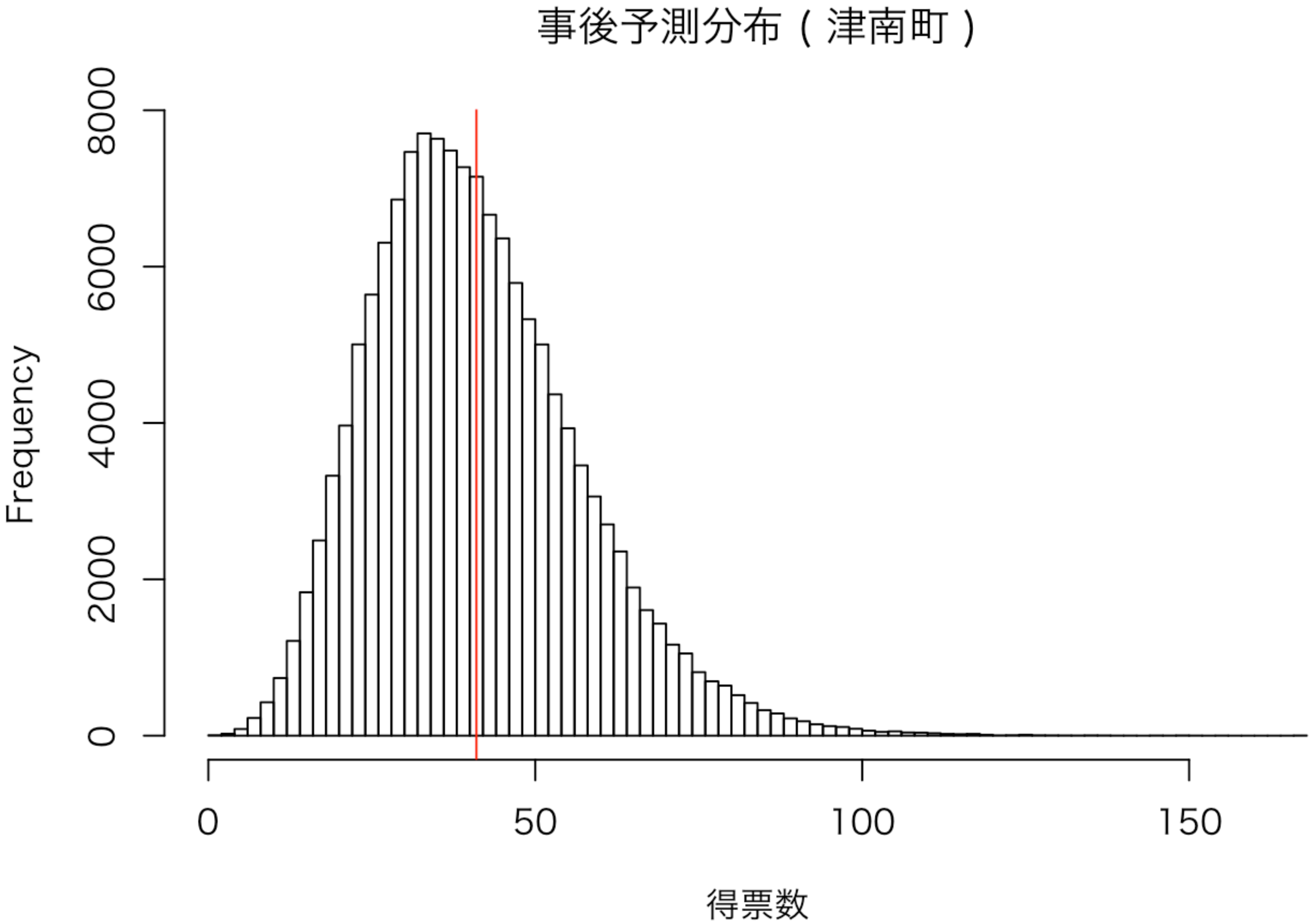


得票数
29：聖籠町，事後確率= 0.6891，p値= 0.6787

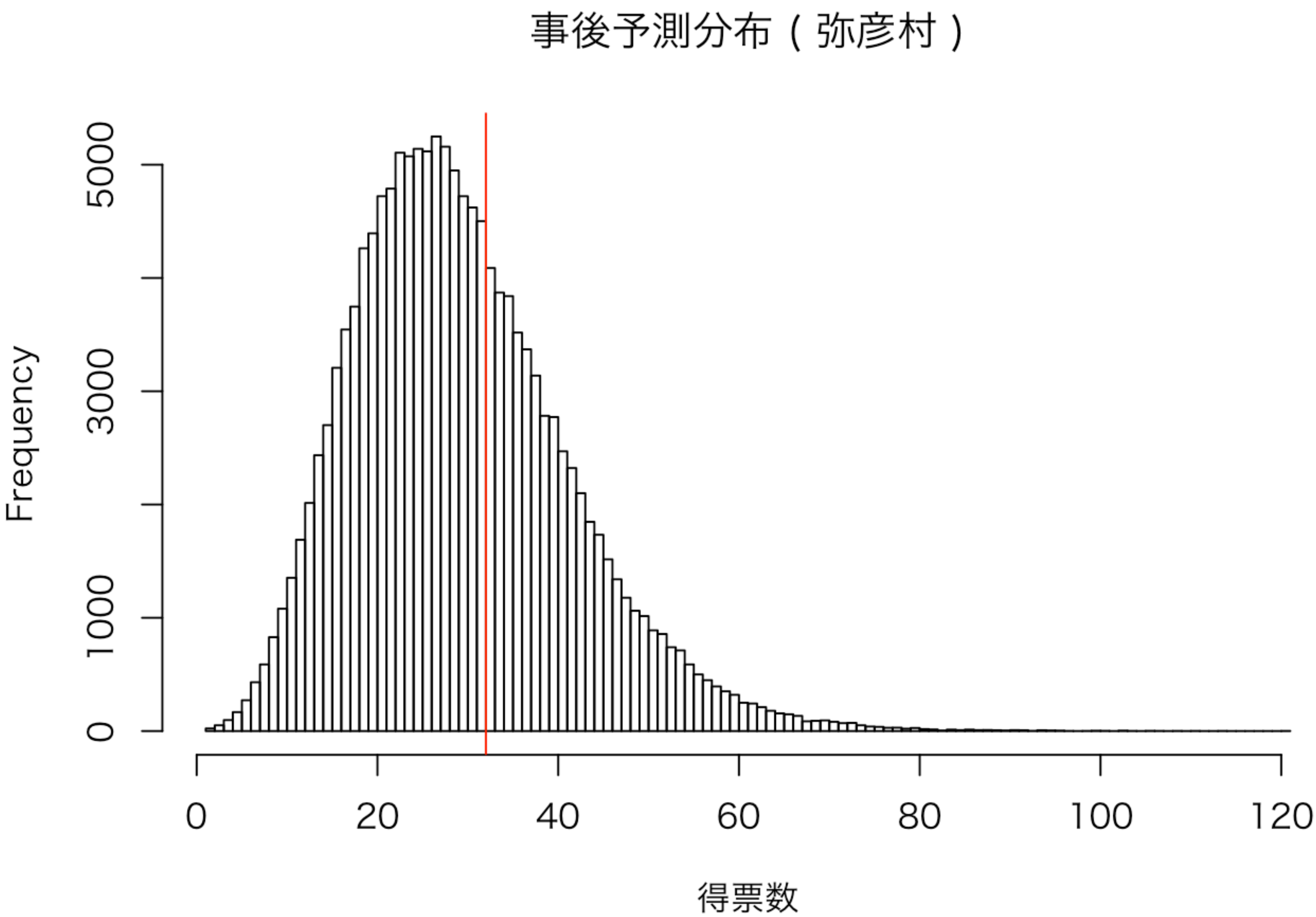
事後予測分布（田上町）



得票数
30：田上町，事後確率= 0.5432，p値= 0.5279

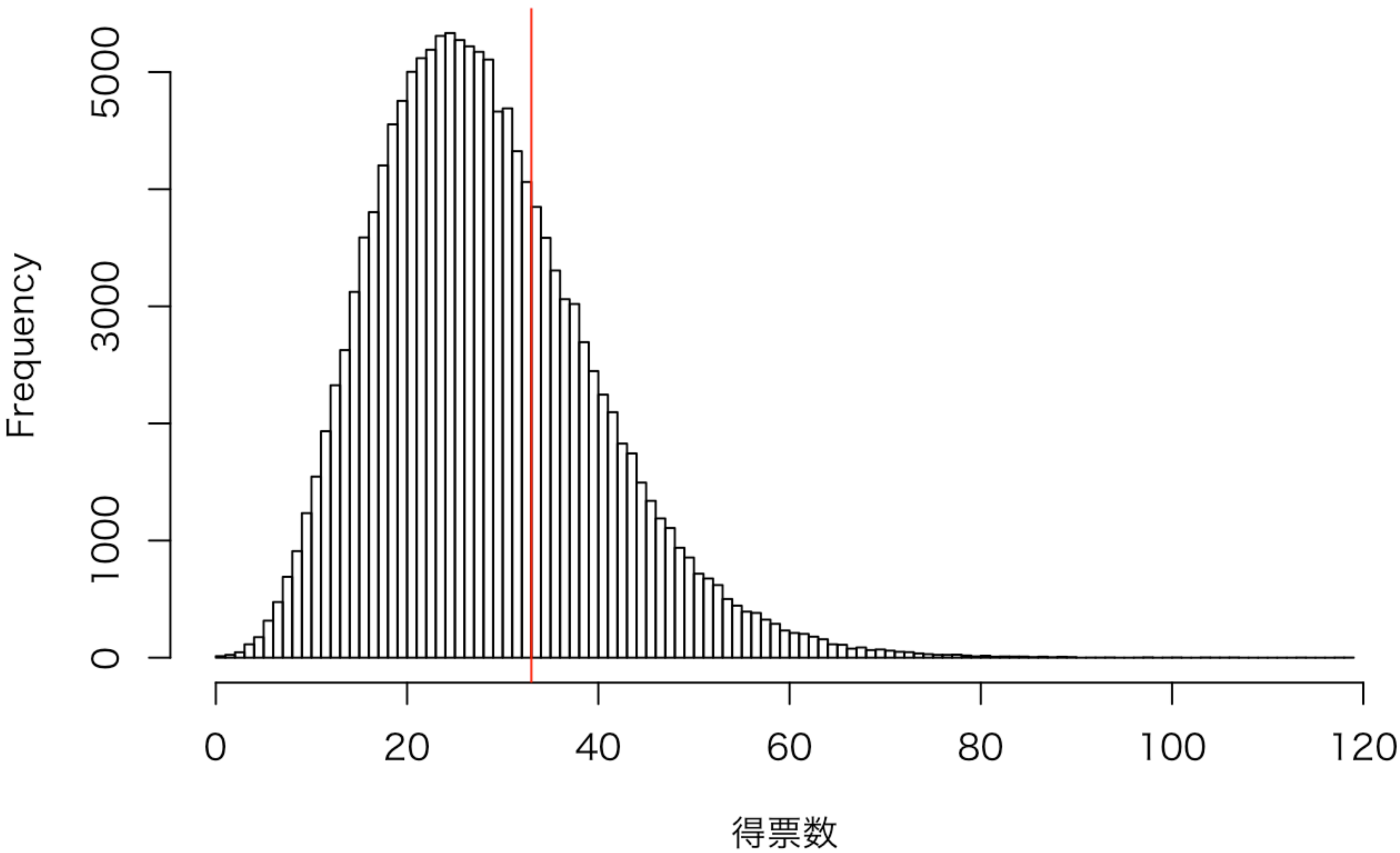


31 : 津南町 , 事後確率= 0.8987 , p値= 0.9003



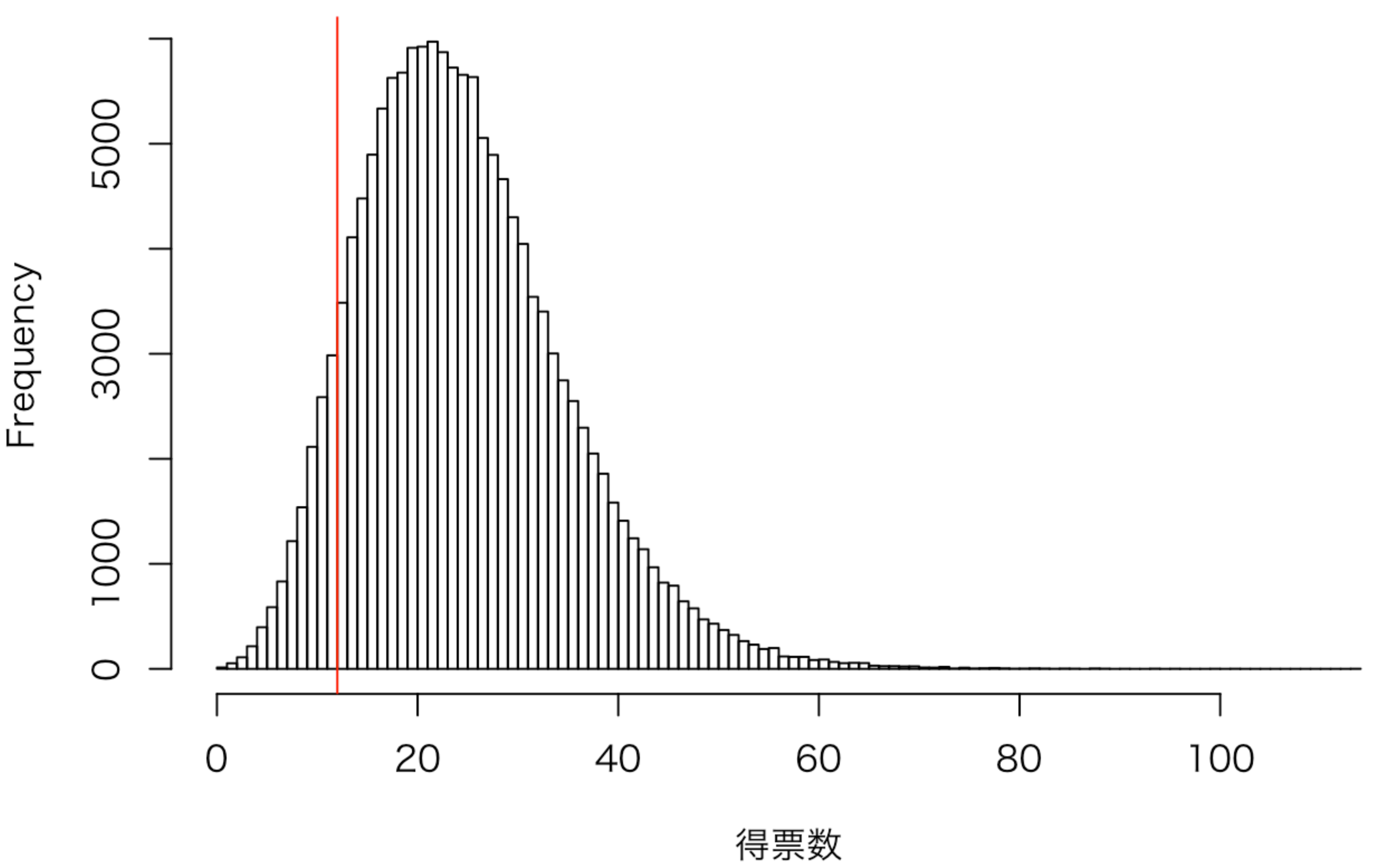
32 : 弥彦村 , 事後確率= 0.7217 , p値= 0.7218

事後予測分布（湯沢町）



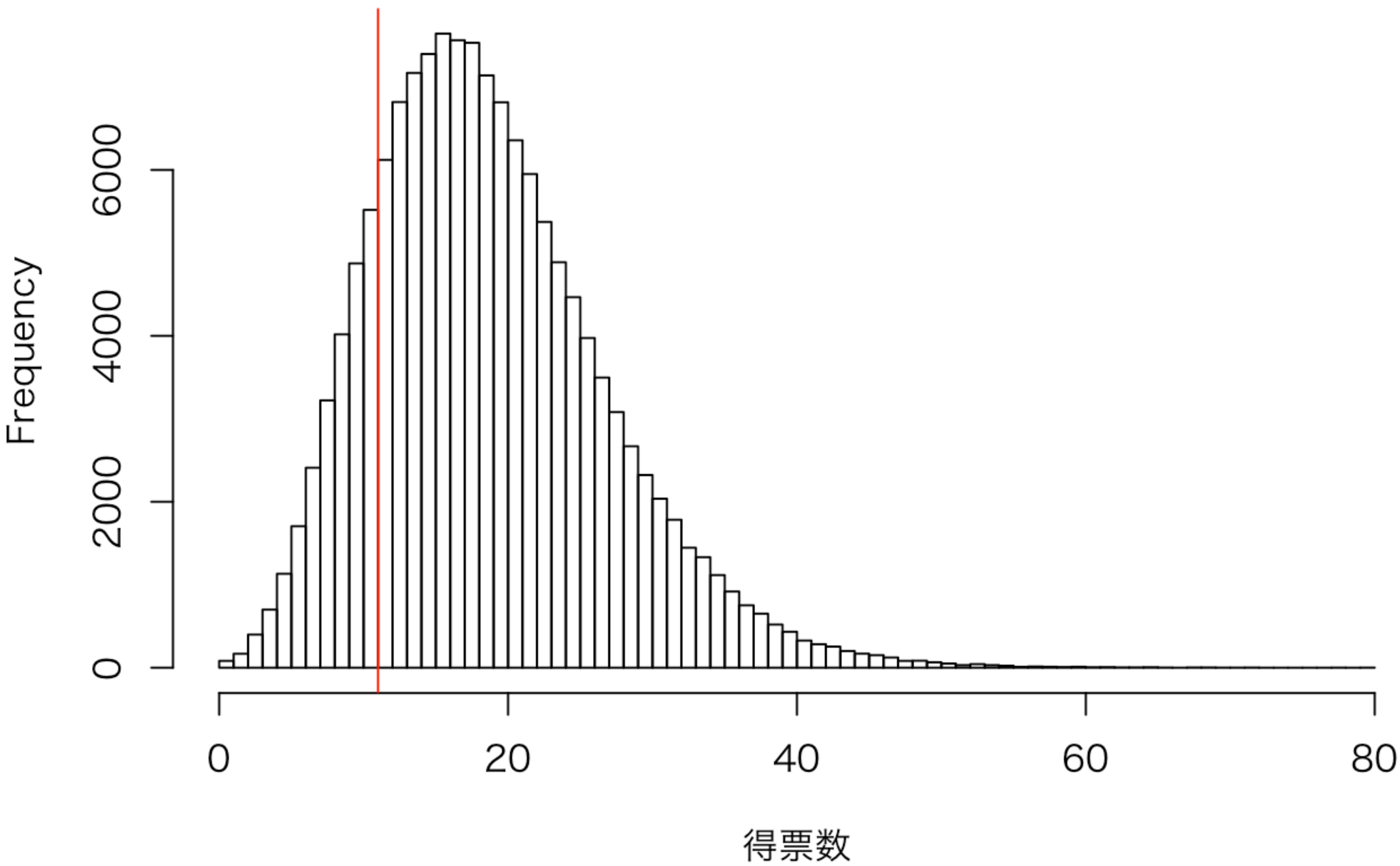
33 : 湯沢町 , 事後確率= 0.5983 , p値= 0.5927

事後予測分布（関川村）



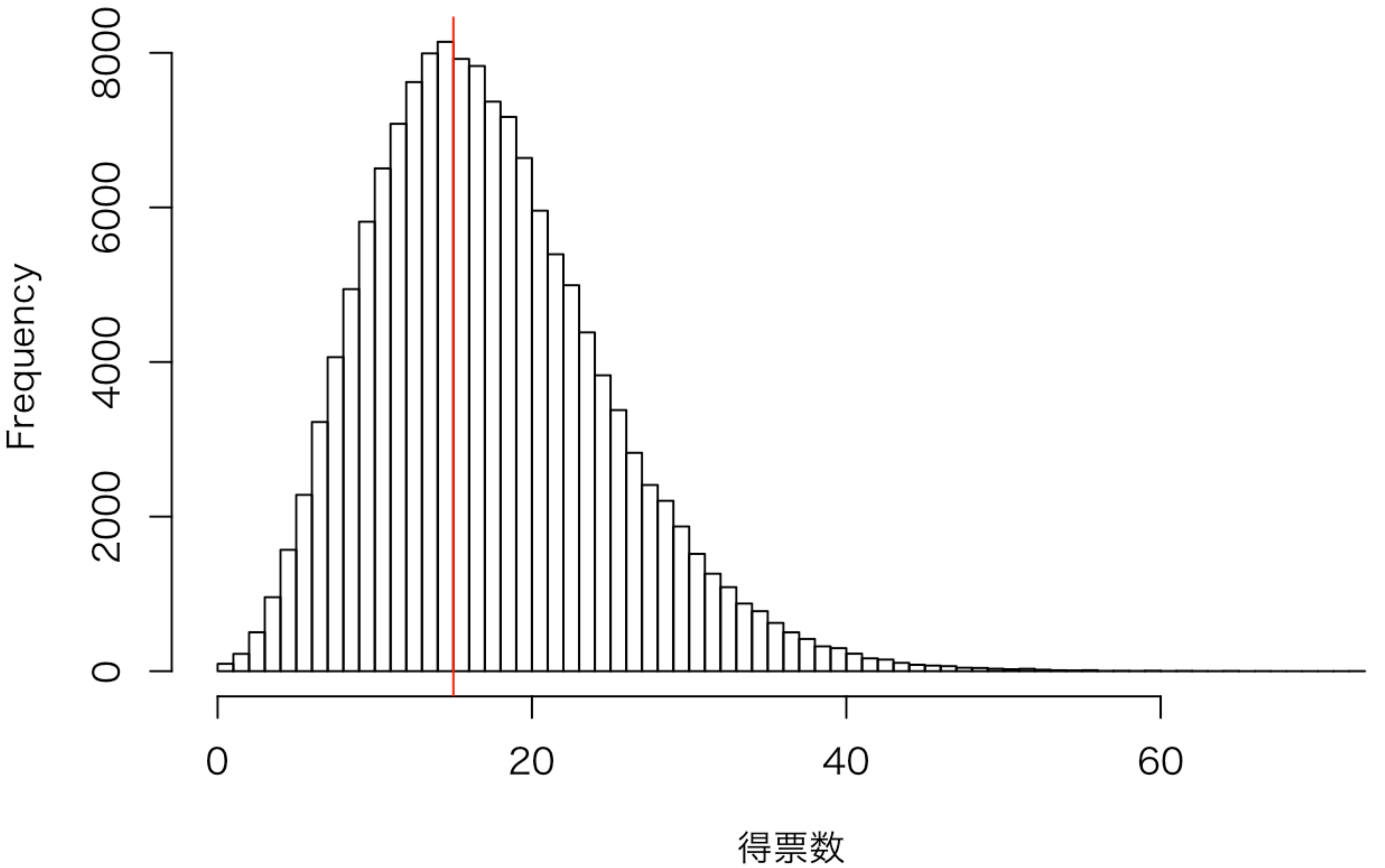
34 : 関川村 , 事後確率= 0.1756 , p値= 0.1614

事後予測分布（刈羽村）

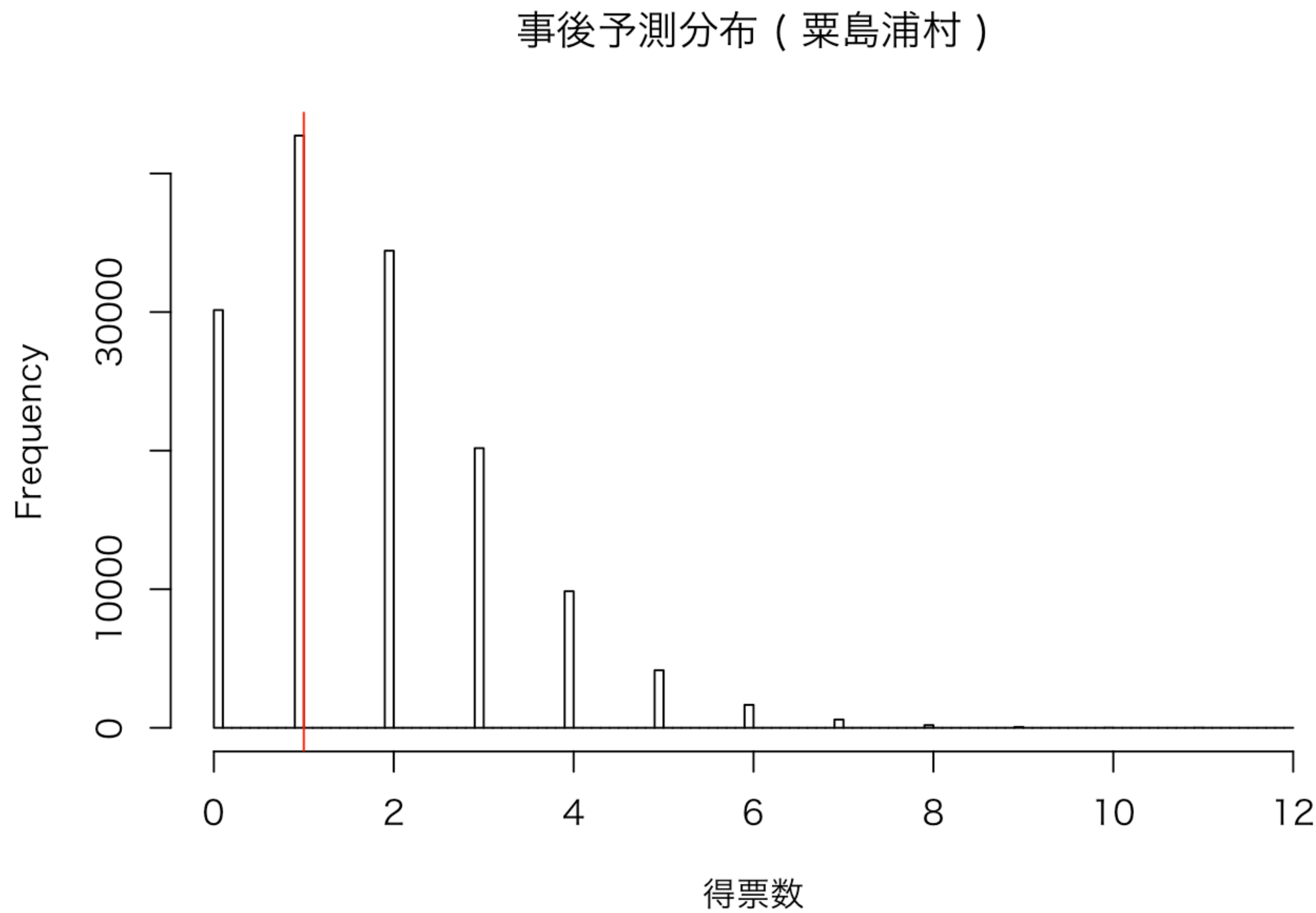


35：刈羽村，事後確率= 0.3365，p値= 0.3219

事後予測分布（出雲崎町）



36：出雲崎町，事後確率= 0.8475，p値= 0.8392



37 : 粟島浦村 , 事後確率= 0.9878 , p値= 0.9899