Preliminary migrate analysis of M. californianus

MIGRATION RATE AND POPULATION SIZE ESTIMATION
using the coalescent and maximum likelihood or Bayesian inference
Migrate-n version 3.7.2 [April-12-18]
Program started at   Tue Jun 1 13:45:41 2021
Program finished at   Tue Jun 1 14:15:29 2021

Options

Datatype:	DNA sequence data

Inheritance scalers in use for Thetas:
All loci use an inheritance scaler of 1.0
[The locus with a scaler of 1.0 used as reference]

Random number seed:	(with internal timer)	401882010

Start parameters:

Theta values were generated	from guessed values

   Theta = 0.01000

M values were generated	from guessed values

  M-matrix:
  100000.00 [all are the same]
Connection type matrix:
 where m = average (average over a group of Thetas or M,
 s = symmetric M, S = symmetric 4Nm, 0 = zero, and not estimated,
 * = free to vary, Thetas are on diagonal

Population	1	2	3	4	5	6	7	8	9	10	11	12
1 ElfinCo	*	0	0	0	0	0	0	0	0	0	0	0
2 Bamfiel	*	*	0	0	0	0	0	0	0	0	0	0
3 PortRen	0	*	*	0	0	0	0	0	0	0	0	0
4 WalkOnB	0	0	*	*	0	0	0	0	0	0	0	0
5 BodegaH	0	0	0	*	*	0	0	0	0	0	0	0
6 Davenpo	0	0	0	0	*	*	0	0	0	0	0	0
7 VistaDe	0	0	0	0	0	*	*	0	0	0	0	0
8 HazardR	0	0	0	0	0	0	*	*	0	0	0	0
9 Refugio	0	0	0	0	0	0	0	*	*	0	0	0
10 Carpint	0	0	0	0	0	0	0	0	*	*	0	0

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11 WhitePo        0   0   0   0   0   0   0   0   0   *   *   0
12 LaJolla        0   0   0   0   0   0   0   0   0   0   *   *
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Order of parameters:

1	Θ_1	\<displayed\>
2	Θ_2	\<displayed\>
3	Θ_3	\<displayed\>
4	Θ_4	\<displayed\>
5	Θ_5	\<displayed\>
6	Θ_6	\<displayed\>
7	Θ_7	\<displayed\>
8	Θ_8	\<displayed\>
9	Θ_9	\<displayed\>
10	Θ_{10}	\<displayed\>
11	Θ_{11}	\<displayed\>
12	Θ_{12}	\<displayed\>
24	$M_{1\rightarrow2}$	\<displayed\>
36	$M_{2\rightarrow3}$	\<displayed\>
48	$M_{3\rightarrow4}$	\<displayed\>
60	$M_{4\rightarrow5}$	\<displayed\>
72	$M_{5\rightarrow6}$	\<displayed\>
84	$M_{6\rightarrow7}$	\<displayed\>
96	$M_{7\rightarrow8}$	\<displayed\>
108	$M_{8\rightarrow9}$	\<displayed\>
120	$M_{9\rightarrow10}$	\<displayed\>
132	$M_{10\rightarrow11}$	\<displayed\>
144	$M_{11\rightarrow12}$	\<displayed\>

Mutation rate among loci: Mutation rate is constant

Analysis strategy: Bayesian inference

Proposal distributions for parameter

Parameter	Proposal
Theta	Metropolis sampling
M	Slice sampling

Prior distribution for parameter

Parameter	Prior	Minimum	Mean*	Maximum	Delta	Bins
Theta	Exp window	0.000010	0.010000	10.000000	1.000000	500
M	Exp window	0.000100	100000.000000	1000000.000000	100000.000000	500

Markov chain settings: Long chain
Number of chains   1
   Recorded steps [a]   1000
   Increment (record every x step [b]   100
   Number of concurrent chains (replicates) [c]   3
   Visited (sampled) parameter values [a*b*c]   300000
   Number of discard trees per chain (burn-in)   1000

Multiple Markov chains:
   Static heating scheme   4 chains with temperatures
                           100000.00   3.00   1.50   1.00
                                   Swapping interval is 1

Print options:
   Data file: ../../mcalifornianus_210528.mig
   Output file: outfile.txt
   Posterior distribution raw histogram file: bayesfile
   Print data: No
   Print genealogies [only some for some data type]:   None

Data summary

Datatype: Sequence data
Number of loci: 1

Population	Locus	Gene copies
1 ElfinCo	1	19
2 Bamfiel	1	23
3 PortRen	1	15
4 WalkOnB	1	16
5 BodegaH	1	7
6 Davenpo	1	17
7 VistaDe	1	19
8 HazardR	1	23
9 Refugio	1	16
10 Carpint	1	19
11 WhitePo	1	11
12 LaJolla	1	8
Total of all populations	1	193

Bayesian Analysis: Posterior distribution table

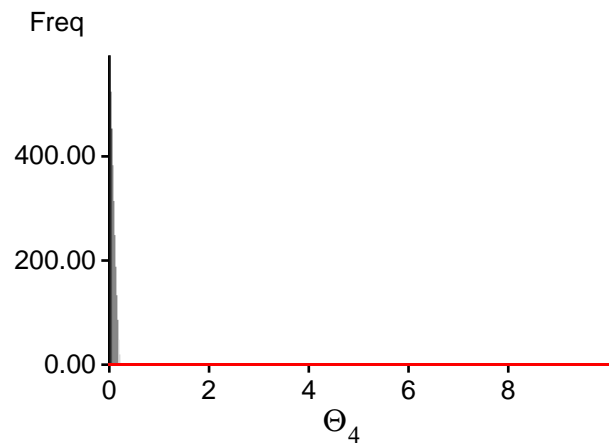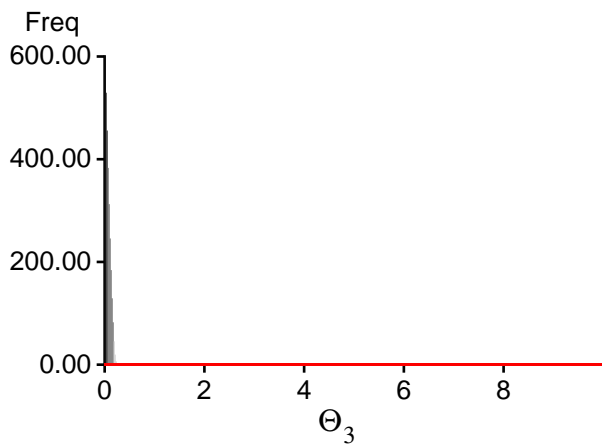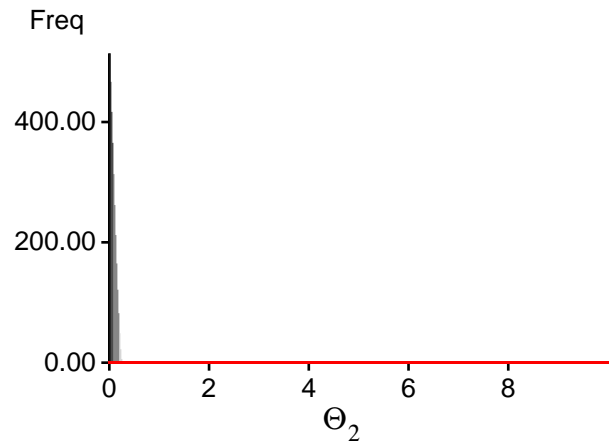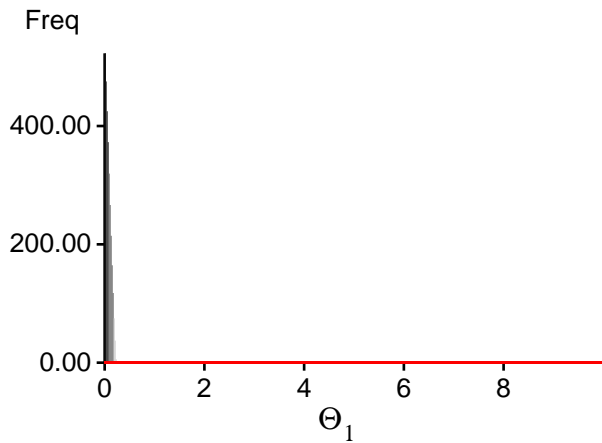| Locus	Parameter	2.5%	25.0%	Mode	75.0%	97.5%	Median	Mean
1	Θ_1	0.00001	0.00001	0.01001	0.08001	0.18001	0.09001	0.02794
1	Θ_2	0.00001	0.00001	0.01001	0.08001	0.20001	0.09001	0.03651
1	Θ_3	0.00001	0.00001	0.01001	0.06001	0.18001	0.07001	0.02395
1	Θ_4	0.00001	0.00001	0.01001	0.06001	0.18001	0.07001	0.02367
1	Θ_5	0.00001	0.00001	0.01001	0.06001	0.16001	0.07001	0.01897
1	Θ_6	0.00001	0.00001	0.01001	0.08001	0.18001	0.09001	0.03080
1	Θ_7	0.00001	0.00001	0.01001	0.08001	0.18001	0.09001	0.02875
1	Θ_8	0.00001	0.00001	0.01001	0.06001	0.16001	0.07001	0.01197
1	Θ_9	0.00001	0.00001	0.01001	0.06001	0.16001	0.07001	0.01948
1	Θ_{10}	0.00001	0.00001	0.01001	0.06001	0.16001	0.07001	0.01885
1	Θ_{11}	0.00001	0.00001	0.01001	0.06001	0.16001	0.07001	0.01296
1	Θ_{12}	0.00001	0.00001	0.01001	0.06001	0.16001	0.07001	0.00719
1	$M_{1->2}$	0.0	0.0	1000.0	10000.0	46000.0	11000.0	15442.8
1	$M_{2->3}$	0.0	6000.0	15000.0	22000.0	34000.0	19000.0	14758.1
1	$M_{3->4}$	0.0	4000.0	13000.0	20000.0	34000.0	17000.0	12815.6
1	$M_{4->5}$	0.0	0.0	13000.0	26000.0	40000.0	25000.0	40319.8
1	$M_{5->6}$	0.0	0.0	5000.0	18000.0	24000.0	19000.0	33527.6
1	$M_{6->7}$	0.0	0.0	1000.0	12000.0	30000.0	13000.0	10774.2
1	$M_{7->8}$	0.0	10000.0	27000.0	54000.0	114000.0	47000.0	51121.6
1	$M_{8->9}$	0.0	22000.0	37000.0	48000.0	58000.0	33000.0	26072.6
1	$M_{9->10}$	0.0	10000.0	21000.0	28000.0	44000.0	23000.0	21473.4
1	$M_{10->11}$	0.0	0.0	11000.0	32000.0	80000.0	33000.0	233830.4
1	$M_{11->12}$	0.0	0.0	9000.0	32000.0	738000.0	183000.0	228209.9

Citation suggestions:

Beerli P., 2006. Comparison of Bayesian and maximum-likelihood inference of population genetic parameters.
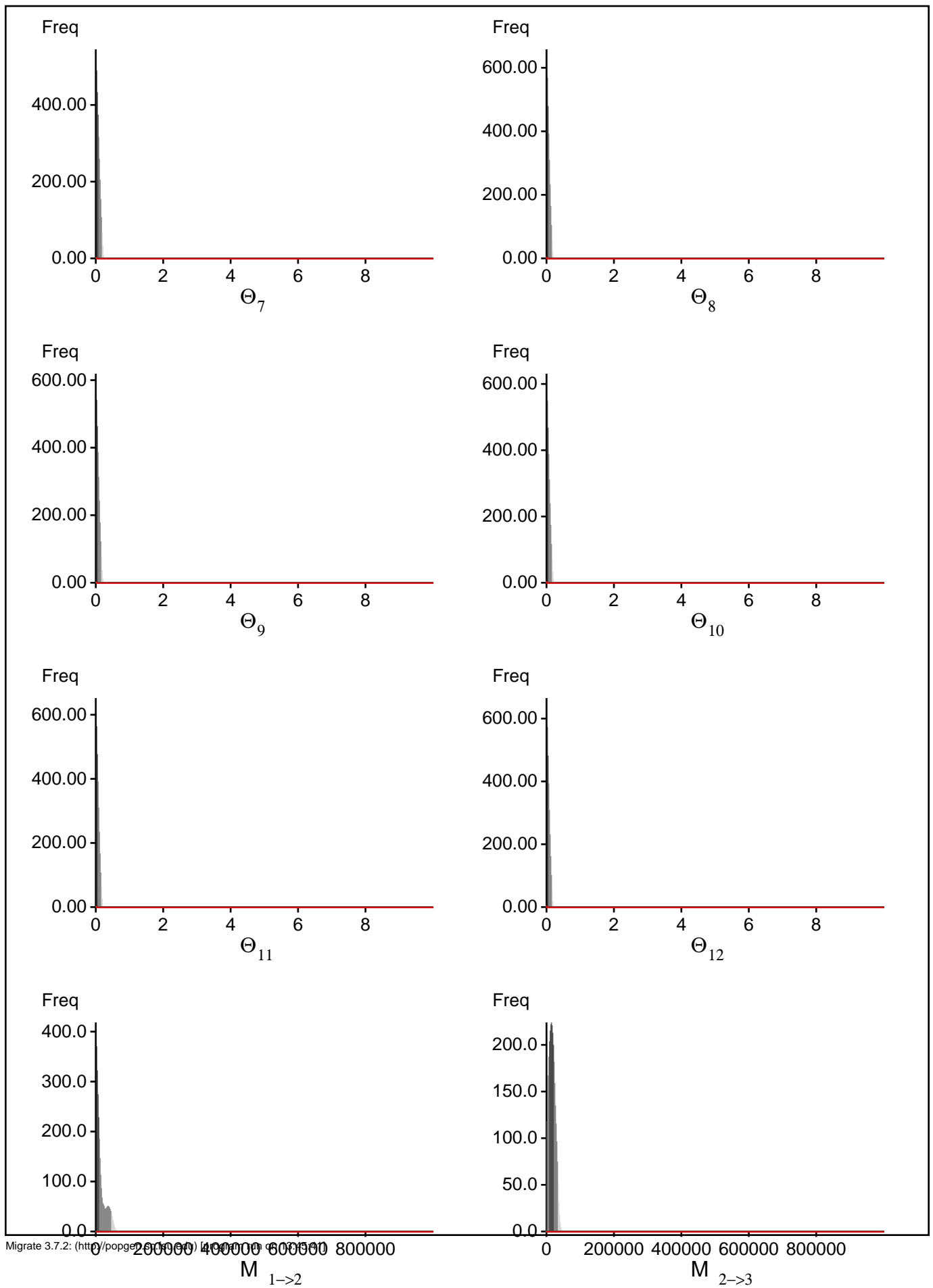   Bioinformatics 22:341-345

Beerli P., 2007. Estimation of the population scaled mutation rate from microsatellite data,
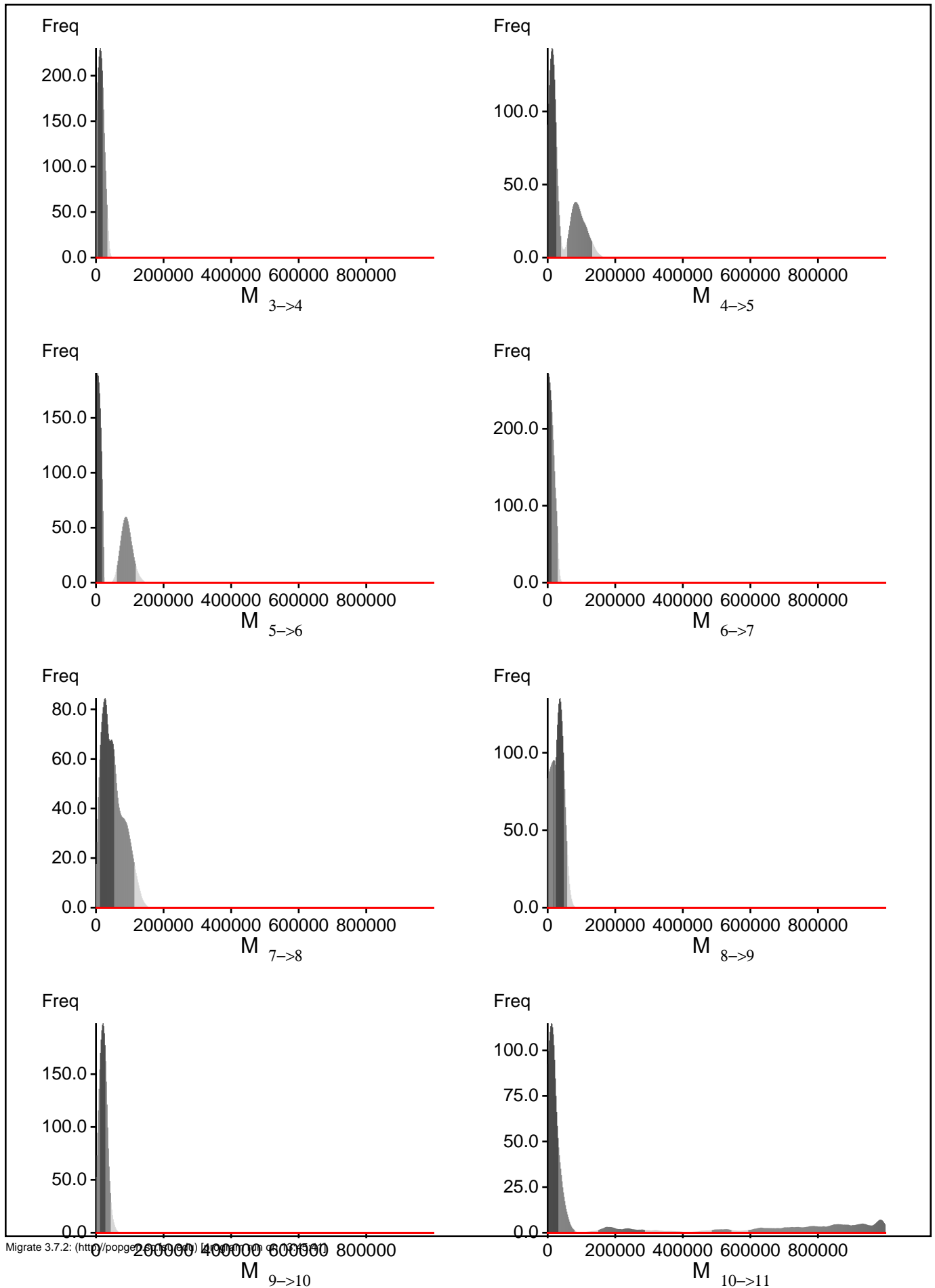   Genetics, 177:1967-1968.

Beerli P., 2009. How to use MIGRATE or why are Markov chain Monte Carlo programs difficult to use?
   In Population Genetics for Animal Conservation, G. Bertorelle, M. W. Bruford, H. C. Hauffe, A. Rizzoli,
   and C. Vernesi, eds., vol. 17 of Conservation Biology, Cambridge University Press, Cambridge UK, pp. 42-79.

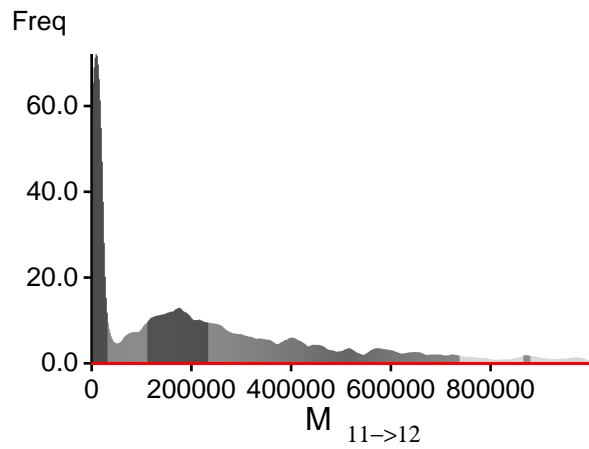# *Bayesian Analysis: Posterior distribution over all loci*

Freq

400.00

200.00

0.00

Θ_1

Freq

400.00

200.00

0.00

Θ_2

Freq

600.00

400.00

200.00

0.00

Θ_3

Freq

400.00

200.00

0.00

Θ_4

Freq

600.00

400.00

200.00

0.00

Θ_5

Freq

400.00

200.00

0.00

Θ_6

Freq

200.0

150.0

100.0

50.0

0.0

0   200000 400000 600000 800000

M $_{3->4}$

Freq

100.0

50.0

0.0

0   200000 400000 600000 800000

M $_{4->5}$

Freq

150.0

100.0

50.0

0.0

0   200000 400000 600000 800000

M $_{5->6}$

Freq

200.0

100.0

0.0

0   200000 400000 600000 800000

M $_{6->7}$

Freq

80.0

60.0

40.0

20.0

0.0

0   200000 400000 600000 800000

M $_{7->8}$

Freq

100.0

50.0

0.0

0   200000 400000 600000 800000

M $_{8->9}$

Freq

150.0

100.0

50.0

0.0

0   200000 400000 600000 800000

M $_{9->10}$

Freq

100.0

75.0

50.0

25.0

0.0

0   200000 400000 600000 800000

M $_{10->11}$

Freq

$M_{11->12}$

Log-Probability of the data given the model (marginal likelihood)

Use this value for Bayes factor calculations:

BF = Exp[ln(Prob(D | thisModel) - ln(Prob(D | otherModel)

or as LBF = 2 (ln(Prob(D | thisModel) - ln(Prob(D | otherModel))

shows the support for thisModel]

Method	ln(Prob(D|Model))	Notes
Thermodynamic integration	-2199.924827	(1a)
	-2127.121224	(1b)
Harmonic mean	-1890.414831	(2)

(1a, 1b and 2) are approximations to the marginal likelihood, make sure that the program run long enough!

(1a, 1b) and (2) should give similar results, in principle.

But (2) is overestimating the likelihood, it is presented for historical reasons and should not be used

(1a, 1b) needs heating with chains that span a temperature range of 1.0 to at least 100,000.

(1b) is using a Bezier-curve to get better approximations for runs with low number of heated chains

Citation suggestions:

Beerli P. and M. Palczewski, 2010. Unified framework to evaluate panmixia and migration direction among
   multiple sampling locations, Genetics, 185: 313-326.

Acceptance ratios for all parameters and the genealogies

Parameter	Accepted changes	Ratio
Θ_1	360/6517	0.05524
Θ_2	1126/6506	0.17307
Θ_3	1913/6560	0.29162
Θ_4	1567/6523	0.24023
Θ_5	2746/6545	0.41956
Θ_6	1757/6514	0.26973
Θ_7	1115/6556	0.17007
Θ_8	3455/6572	0.52572
Θ_9	2712/6598	0.41103
Θ_{10}	2883/6438	0.44781
Θ_{11}	4512/6422	0.70258
Θ_{12}	4566/6665	0.68507
$M_{1->2}$	6474/6474	1.00000
$M_{2->3}$	6587/6587	1.00000
$M_{3->4}$	6377/6377	1.00000
$M_{4->5}$	6567/6567	1.00000
$M_{5->6}$	6509/6509	1.00000
$M_{6->7}$	6685/6685	1.00000
$M_{7->8}$	6349/6349	1.00000
$M_{8->9}$	6381/6381	1.00000
$M_{9->10}$	6539/6539	1.00000
$M_{10->11}$	6527/6527	1.00000
$M_{11->12}$	6530/6530	1.00000
Genealogies	40061/150059	0.26697

MCMC-Autocorrelation and Effective MCMC Sample Size

Parameter	Autocorrelation	Effective Sampe Size
Θ_1	0.97851	32.74
Θ_2	0.86074	242.90
Θ_3	0.76666	415.02
Θ_4	0.81436	310.49
Θ_5	0.59161	861.58
Θ_6	0.72162	583.26
Θ_7	0.88425	188.13
Θ_8	0.49021	1033.41
Θ_9	0.58077	810.64
Θ_{10}	0.59967	756.36
Θ_{11}	0.34247	1542.56
Θ_{12}	0.23855	1902.07
$M_{1\rightarrow2}$	0.70935	511.41
$M_{2\rightarrow3}$	0.76919	393.54
$M_{3\rightarrow4}$	0.79916	338.18
$M_{4\rightarrow5}$	0.85090	241.90
$M_{5\rightarrow6}$	0.71933	489.94
$M_{6\rightarrow7}$	0.79143	349.34
$M_{7\rightarrow8}$	0.73270	463.06
$M_{8\rightarrow9}$	0.64176	669.27
$M_{9\rightarrow10}$	0.76059	408.00
$M_{10\rightarrow11}$	0.82141	294.16
$M_{11\rightarrow12}$	0.68056	594.82
Ln[Prob(D|G)]	0.98346	25.00

Potential Problems

This section reports potential problems with your run, but such reporting is often not very accurate. Whith many parameters in a multilocus analysis, it is very common that some parameters for some loci will not be very informative, triggering suggestions (for example to increase the prior range) that are not sensible. This suggestion tool will improve with time, therefore do not blindly follow its suggestions. If some parameters are flagged, inspect the tables carefully and judge wether an action is required. For example, if you run a Bayesian inference with sequence data, for macroscopic species there is rarely the need to increase the prior for Theta beyond 0.1; but if you use microsatellites it is rather common that your prior distribution for Theta should have a range from 0.0 to 100 or more. With many populations (>3) it is also very common that some migration routes are estimated poorly because the data contains little or no information for that route. Increasing the range will not help in such situations, reducing number of parameters may help in such situations.

No warning was recorded during the run