

# Catostomus ardens ND2

POPULATION SIZE, MIGRATION, DIVERGENCE, ASSIGNMENT, HISTORY

Bayesian inference using the structured coalescent

Migrate-n version 4.4.4(git:v4-series-26-ge85c6ff) [June-1-2019]

Compiled for a SYMMETRIC multiprocessors (Grandcentral)

Program started at Thu May 20 03:37:34 2021

Program finished at Thu May 20 06:19:43 2021 [Runtime:0000:02:42:09]



## Options

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) 2839446262

Start parameters:

Theta values were generated RANDOM start value from the prior

M values were generated RANDOM start value from the prior

Connection matrix:

m = average (average over a group of Thetas or M,

s = symmetric migration M, S = symmetric 4Nm,

0 = zero, and not estimated,

\* = migration free to vary, Thetas are on diagonal

d = row population split off column population, D = split and then migration

Population	1	2
1 Great_Salt_Lake	*	0
2 Sevier_Desert	d	*

Order of parameters:

1	$\Theta_1$	<displayed>
2	$\Theta_2$	<displayed>
3	$\Delta_{1 \rightarrow 2}$	<displayed>

4  $\sigma_{1 \rightarrow 2}$  <displayed>

Mutation rate among loci: Mutation rate is constant

Analysis strategy: Bayesian inference

-Population size estimation: Exponential Distribution

-Geneflow estimation: Exponential Distribution

-Divergence time estimation: Normal Distribution Shortcut (mean and standard dev.)

Proposal distributions for parameter

Parameter	Proposal
Theta	Metropolis sampling
M	Metropolis sampling
Divergence	Metropolis sampling
Divergence Spread	Metropolis sampling
Genealogy	Metropolis-Hastings

Prior distribution for parameter

Parameter	Prior	Minimum	Mean	Maximum	Delta	Bins	UpdateFreq
1 Theta **	Uniform	0.000000	0.050	0.100	0.010	1500	0.12500
2 Theta **	Uniform	0.000000	0.050	0.100	0.010	1500	0.12500
3 Splittime mean **	Uniform	0.000000	0.250	0.500	0.050	1500	0.12500
4 Splittime std **	Uniform	0.000000	0.250	0.500	0.050	1500	0.12500

[\* \* means priors were set globally]

Markov chain settings: Long chain

Number of chains	1
Recorded steps [a]	10000
Increment (record every x step [b])	1000
Number of concurrent chains (replicates) [c]	2
Visited (sampled) parameter values [a*b*c]	20000000
Number of discard trees per chain (burn-in)	1000

Multiple Markov chains:

Static heating scheme	4 chains with temperatures
1000000.00	3.00 1.50 1.00
	Swapping interval is 1

Print options:

Data file:	infile
Haplotyping is turned on:	NO
Output file:	outfile
Log file:	logfile

Posterior distribution raw histogram file:	bayesfile
Raw data from the MCMC run:	bayesallfile.gz
Print data:	No
Print genealogies [only some for some data type]:	None

## *Data summary*

Data file: infile  
 Datatype: Haplotype data  
 Number of loci: 1

### Mutationmodel:

Locus	Sublocus	Mutationmodel	Mutationmodel parameters
1	1	Kimura	[Basefreq: =0.25, kappa=3.7400]

### Sites per locus

Locus	Sites
1	400

### Site rate variation and probabilities:

Locus	Sublocus	Region type	Rate of change	Probability	Patch size
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1	1	1	1.000	1.000	1.000
Population				Locus	Gene copies data (missing)
1 Great_Salt_Lake				1	81
2 Sevier_Desert				1	19
Total of all populations				1	100 (0)

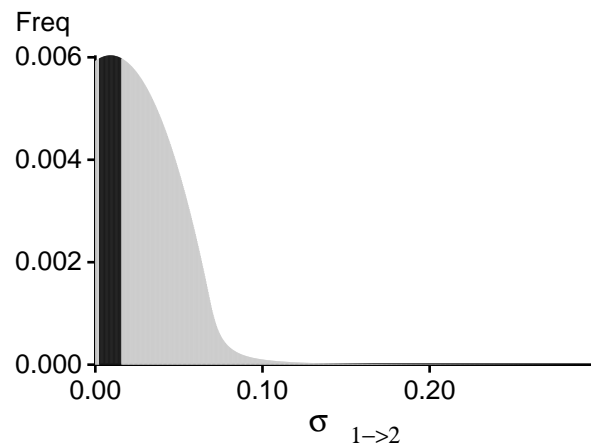
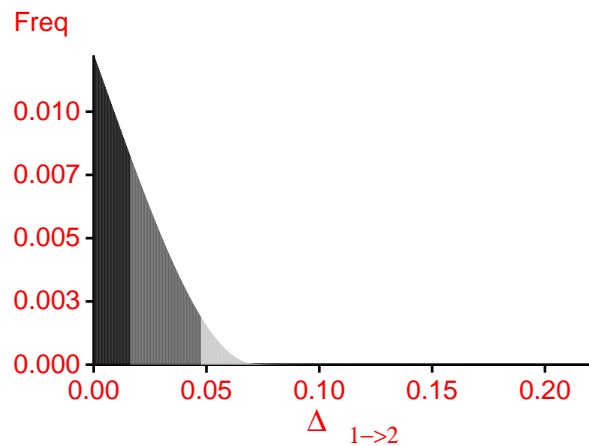
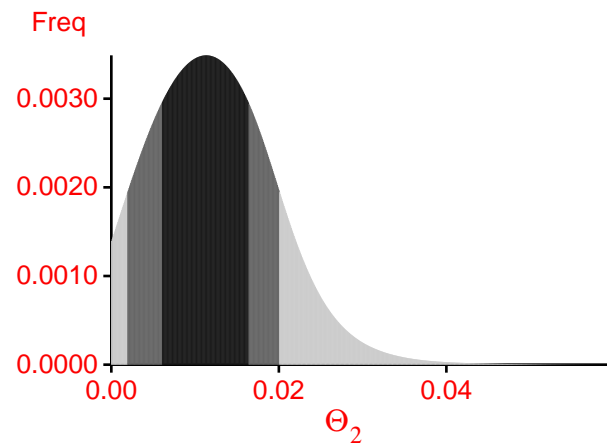
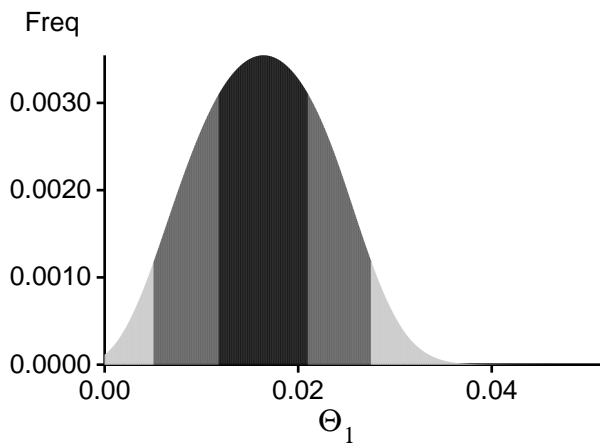
## *Bayesian Analysis: Posterior distribution table*

Locus	Parameter	2.5%	25.0%	Mode	75.0%	97.5%	Median	Mean
1	$\Theta_1$	0.00500	0.01173	0.01643	0.02100	0.02753	0.01650	0.01643
1	$\Theta_2$	0.00187	0.00600	0.01130	0.01640	0.02007	0.01210	0.01177
1	$D_{1 \rightarrow 2}$	0.00000	0.00000	0.00017	0.01633	0.04767	0.01650	0.00390
1	$S_{1 \rightarrow 2}$	0.00200	0.00200	0.00917	0.01567	0.01567	0.02850	0.01125

### Citation suggestions:

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

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 for locus 1*

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

Use this value for Bayes factor calculations:

$BF = \text{Exp}[\ln(\text{Prob}(D \mid \text{thisModel}) - \ln(\text{Prob}(D \mid \text{otherModel}))]$

or as  $LBF = 2 (\ln(\text{Prob}(D \mid \text{thisModel}) - \ln(\text{Prob}(D \mid \text{otherModel})))$

shows the support for thisModel]

Method	$\ln(\text{Prob}(D \mid \text{Model}))$	Notes
Thermodynamic integration	-1553.036420	(1a)
	-1016.962706	(1b)
Harmonic mean	-887.630613	(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
$\Theta_1$	1410830/2499332	0.56448
$\Theta_2$	962954/2499827	0.38521
$\Delta_{1 \rightarrow 2}$	948224/2502898	0.37885
$\sigma_{1 \rightarrow 2}$	834369/2501358	0.33357
Genealogies	3029793/9996585	0.30308



## *MCMC-Autocorrelation and Effective MCMC Sample Size*

Parameter	Autocorrelation	Effective Sampe Size
$\Theta_1$	0.70969	4061.92
$\Theta_2$	0.30856	10566.98
$\Delta_{1 \rightarrow 2}$	0.28365	12403.99
$\sigma_{1 \rightarrow 2}$	0.45092	9912.50
Genealogies	0.45092	9912.50

## *Potential Problems*

This section reports potential problems with your run, but such reporting is often not very accurate. With 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 whether 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