**Supplementary Tables**

**Table S1 (pp.2-5)**

List of origins of viviparity reconstructed in the focal BEAST random local clock analysis

**Table S2 (pp.6-13)**

Details of split clades and parameter estimates for all split BiSSE models

**Table S3 (p.14)**

Two additional models, showing that root state assumptions and problems with extinction rate estimation do not affect the outcome of the BiSSE analyses

**Table S4 (p.15)**

Estimates of asymmetry for all models in the simulations

**Table S5 (p.16)**

Simulation results for ace (APE function)

**Table S1 – list of origins of viviparity in the focal analysis**

List of origins of viviparity reconstructed in the consensus tree of the focal analysis. In general an origin will be sampled on a particular branch with a probability of greater than 0.5. However, due to the nature of a Bayesian analysis, in groups where the evolution of parity mode has been complex the origin of viviparity that is the relevant one for a particular group can be spread across a number of branches, such that support on any given branch is low. Thus, accepting only those origins with a probability of >0.5 on a particular branch will leave some viviparous squamates without an origin of viviparity! This is most notably the case in pit vipers, where the origins of viviparity are sampled on every branch from the base of the subfamily to the branch leading to North American Crotalines. Thus what is represented here is a best estimate of the total origins of viviparity in Squamates taken together. In some cases the exact location of these origins can be ascertained, in other cases this is less certain. An example is in the Aniloidea clade. The long branches that separate Aniliidae from Tropidophiidae mean that the analysis cannot distinguish between separate origins in the two groups and a single origin. The Bayesian analysis shows that this uncertainty exists and that, provided the tree does not substantially change, current data is not sufficient to solve this uncertainty.

The table summarises the 115 inferred origins of viviparity. It also gives key statistics - the number of species, minimum age of the origin of viviparity, posterior probability of the change to viviparity occurring on the particular branch leading to the clade. The uncertainty column is filled when the latter is low. "1" means that the posterior probability is low because the analysis sometimes splits the inferred single origin of viviparity into more than one origin, ie sampling convergent origins on more recent branches. "2"means the analysis sometimes combines two separate inferred origins by sampling an origin on an older branch. This reduces the number of origins and often causes reversals to be sampled as well.

Note that this list does not include origins of viviparity within reproductively bimodal species (e.g. *Zootoca vivipara*).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | ­Number of species | Age of MRCA | Posterior probability | Uncertainty type |
| **Gekkota (2)** |  |  |  |  |
| *Rhacodactylus trachyrhynchus* | 1 | 0 | 1 |  |
| *Nautilinus + Hoplodactylus* | 18 | 27.8 | 0.999 |  |
|  |  |  |  |  |
| **Scincoidea (39)** |  |  |  |  |
| *Xantusiidae (Cricosaura + Xantusia + Lepidophyma)* | 26 | 103.3 | 0.7437 | 1 |
| *Cordylus + Chamaesaura* | 35 | 47.6 | 0.9487 |  |
| *Typhlosaurus + Microacontias + Acontiaphiops + Acontias* | 16 | 49.6 | 0.9654 |  |
| *Ophiomorus* | 2 | 48.93 | 0.7667 | 2 |
| *Brachymeles* | 13 | 59.1339 | 0.7407 | 2 |
| *Plestiodon copei + P. ochopterenae* | 5 | 15.336 | 0.996 |  |
| *Scincus mitranus* | 1 | 0 | 0.9777 |  |
| *Chalcides* | 21 | 30.1 | 0.7437 | 2 |
| *Sepsina + Typhlocontias + Melanoseps + Feylinia + Proscelotes + Scelotes* | 19 | 60.8 | 0.5583 | 1,2 |
| *Amphiglossus macrocercus* | 1 | 0 | 0.986 |  |
| *Asymblepharus alaicus* | 1 | 0 | 0.9434 |  |
| *Tropidophorus berdmorei + T. hainanus* | 10 | 47.4 | 0.8868 |  |
| *Tropidomorphus misaminius + T. cocincinensis* | 8 | 49.3 | 0.8369 |  |
| *Isopachys anguinoides* | 1 | 0 | 0.9704 |  |
| *Sphenomorphus cocinnatus* | 1 | 0 | 1 |  |
| *Sphenomorphus leptofasciatus* | 1 | 0 | 0.9797 |  |
| *Sphenomorphus indicus* | 1 | 0 | 1 |  |
| *Lipinia noctua* | 1 | 0 | 0.9967 |  |
| *Eulamprus frerei* | 1 | 0 | 0.9214 |  |
| *Nangura spinosa* | 1 | 0 | 0.9218 |  |
| *Gnypetoscincus queenslandiae + Eulamprus amplus + E. sokosoma* | 7 | 24.7 | 0.8302 |  |
| *Eulamprus luteilateralis + E. tryoni* | 3 | 21.2 | 0.7786 | 1 |
| *Anomalopus swansoni* | 1 | 0 | 0.997 |  |
| *Eulamprus leuraensis + E. neatwolei* | 5 | 12.5 | 0.9943 |  |
| *Glaphyromorphus gracilipes + G. hemiergis* | 6 | 20.9 | 0.9893 |  |
| *Lerista microtis* | 1 | 0 | 0.9874 |  |
| *Tribolonotus schmidtii* | 1 | 0 | 0.9993 |  |
| *Corucia zebrata + Bellatorius + Cyclodomorphus + Egernia + Tiliqua* | 30 | 48.6 | 0.9381 |  |
| *Eutropis multifasciata* | 1 | 0 | 0.9923 |  |
| *Trachylepis vittata + aurata* | 2 | 29.1 | 0.4943 | 1,2 |
| *Eumecia + Chioninia + Macroscincus + Mabuya* | 27 | 42.5 | 0.4334 | 1,2 |
| *Trachylepis brevicollis* | 1 | 0 | 0.6764 | 2 |
| *Trachylepis varia* | 1 | 0 | 0.8778 |  |
| *Trachylepis striata + T. variegata* | 3 | 17.0 | 0.6877 | 1,2 |
| *Pseudomoia pagenstecheri* | 1 | 0 | 0.8898 |  |
| *Pseudooia entrecasteauxii* | 1 | 0 | 0.8845 |  |
| *Oligosoma (- suteri) + Cyclodina* | 31 | 15.6 | 0.9081 |  |
| *Marmorosphax tricolor* | 1 | 0 | 0.9764 |  |
| *Niveoscincus* | 4 | 22.6 | 0.9744 |  |
|  |  |  |  |  |
| **Lacertoidea (3)** |  |  |  |  |
| *Trogonophis wiegmanni* | 1 | 0 | 0.998 |  |
| *Monopeltis capensis* | 1 | 0 | 1 |  |
| *Eremias multiocellata + E. przewalskii* | 2 | 3.0 | 1 |  |
|  |  |  |  |  |
| **Anguimorpha (8)** |  |  |  |  |
| *Xenosaurus* | 2 | 16.7 | 0.983 |  |
| *Anniella* | 2 | 26.0292 | 0.8938 |  |
| *Celestes enneagrammus* | 1 | 0 | 0.7287 | 2 |
| *Celestes (-enneagrammus) + Ophiodes striatus + Diploglossus pleii* | 4 | 41.9514 | 0.5406 |  |
| *Anguis fragilis* | 1 | 0 | 0.9897 |  |
| *Elgaria coerulea* | 1 | 0 | 0.9817 |  |
| *Abronia + Barisia + Mesaspis* | 18 | 26.4706 | 0.9377 |  |
| *Shinisaurus crocodilurus* | 1 | 0 | 1 |  |
|  |  |  |  |  |
| **Iguania (26)** |  |  |  |  |
| *Bradypodion* | 15 | 14.841 | 0.999 |  |
| *Chamaeleo affinis* | 1 | 0 | 1 |  |
| *Chamaeleo tempeli + C. rudis* | 10 | 22.2862 | 0.995 |  |
| *Phrynocephalus forsythia + P. vlangalii* | 4 | 12.6181 | 0.998 |  |
| *Cophotis* | 2 | 4.349 | 0.9977 |  |
| *Phrynosoma Taurus + P. braconnieri* | 2 | 15.7238 | 0.8888 | 1 |
| *Phrynosoma orbiculare + P. douglassii* | 4 | 16.3671 | 0.8958 | 1 |
| *Sceloporus grammicus + S. palaciosi* | 3 | 11.5036 | 0.7959 | 1 |
| *Sceloporus bicanthalis* | 1 | 0 | 0.9621 |  |
| *Sceloporus goldmani* | 1 | 0 | 0.965 |  |
| *Sceloporus megalepidurus + S. serrifer* | 12 | 16.3955 | 0.7034 | 1 |
| *Sceloporus malachiticus* | 1 | 0 | 0.5409 | 2 |
| *Sceloporus smaragdinus* | 1 | 0 | 0.536 | 2 |
| *Sceloporus formosus + S. stejnegeri* | 3 | 4.63 | 0.5303 | 2 |
| *Phymaturus* | 8 | 30.7284 | 0.7963 | 1 |
| *Liolaemus nigroviridis* | 1 | 0 | 0.9794 |  |
| *Liolaemus paulinae* | 1 | 0 | 0.9611 |  |
| *Liolaemus austromendocinus + L. kriegii* | 10 | 11.7848 | 0.9614 |  |
| *Liolaemus bellii + L. pictus* | 6 | 9.77 | 0.6102 |  |
| *Liolaemus pagaburoi* | 1 | 0 | 0.9983 |  |
| *Liolaemus walker + L. puna* | 2 | 0.59 | 0.9844 |  |
| *Liolaemus hatcheri + L archeforus* | 16 | 13.97 | 0.9447 |  |
| *Liolaemus orientalis + L. audituvelatus* | 11 | 10.75 | 0.7074 | 2 |
| *Liolaemus espinozai* | 1 | 0 | 0.98 |  |
| *Liolaemus crepuscularis + L. ornatus* | 6 | 5.04 | 0.8698 | 1 |
| *Corytophanes percarinatus* | 1 | 0 | 0.9947 |  |
|  |  |  |  |  |
| **Serpentes (37)** |  |  |  |  |
| *Anilius scytale* | 1 | 0 | 0.5819 | 2 |
| *Trachyboa + Tropidophis* | 8 | 33.53 | 0.5636 | 2 |
| *Sanzinia + Acrantophis* | 3 | 25.51 | 0.475 | 2 |
| *Ungaliophiinae + Candoiinae + Erycinae +Boinae* | 30 | 57.30 | 0.4734 | 2 |
| *Anomochilidae + Cylindrophiidae + Uropeltidae* | 17 | 53.45 | 0.5613 | 1 |
| *Acrochordus* | 3 | 27.21 | 0.9634 |  |
| *Vipera xanthina + V. abbizona* | 5 | 6.71 | 0.971 |  |
| *Daboia russelii* | 1 | 0 | 0.996 |  |
| *Vipera ammodytes + V. renardi* | 13 | 15.38 | 0.9587 |  |
| *Proatheris supercilliaris* | 1 | 0 | 0.9724 |  |
| *Cerastes vipera* | 1 | 0 | 0.9617 |  |
| *Bitis + Atheris* | 17 | 28.96 | 0.8762 | 1 |
| *Tropidolaemus wagleri* | 1 | 0 | 0.8985 | 2 |
| *Hypnale* | 3 | 14.97 | 0.8063 | 2 |
| *Trimeresurus puniceus* | 1 | 0 | 0.5839 | 2 |
| *Trimeresurus malabaricus + T. gramineus* | 3 | 0 | 0.5416 | 2 |
| *Himalayophis + Popeia + Viridovipera + Cryptelytrops* | 18 | 18.34 | 0.5626 | 1,2 |
| *Trimeresurus gracilis + Ovophis + Gloydius + New World Crotalines* | 102 | 25.58 | 0.1974 | 1,2 |
| *Homalopsidae* | 20 | 26.36 | 0.9983 |  |
| *Pseudaspis cana* | 1 | 0 | 0.9883 |  |
| *Psammodynastes pulverulentus* | 1 | 0 | 1 |  |
| *Amplorhinus + Duberria* | 3 | 27.78 | 0.7397 | 1 |
| *Stenophis citrinus* | 1 | 0 | 0.9587 |  |
| *Lycodryas sanctijohannis* | 1 | 0 | 0.9594 |  |
| *Stenophis pseudogranuliceps* | 1 | 0 | 0.973 |  |
| *Liopholidophis sexlineatus* | 1 | 0 | 0.9913 |  |
| *Hemachatus haemachatus* | 1 | 0 | 1 |  |
| *Acanthophis* | 2 | 3.76 | 0.9937 |  |
| *Pseudechis porphyriacus* | 1 | 0 | 0.9977 |  |
| *Elapognathus + Rhinoplocephalus + Suta* | 7 | 20.57 | 0.9737 |  |
| *Echiopsis + Drysdalia + Austrelaps + Tropidechis + Notechis + Hoplocephalus + Hemiaspis + Sea Snakes (Hydrophiini)* | 31 | 20.91 | 0.992 |  |
| *Ahaetulla* | 3 | 15.43 | 0.995 |  |
| *Conopsis* | 2 | 8.03 | 0.9927 |  |
| *Elaphe rufodorsata + Coronella austriaca* | 2 | 14.92 | 0.9437 |  |
| *Sinonatrix annularis* | 1 | 0 | 1 |  |
| *New World Natricines* | 44 | 13.93 | 0.998 |  |
| *Pseudoeryx + Hydrops + Helicops + Gomesophis + Calamodontophis + Tachymenis + Pseudotomodon + Ptychophis + Tomodon + Thamnodynastes* | 17 | 29.27 | 0.9571 |  |

**Table S2 (on following pages)**

Details of the clades used, and parameter estimates for the split BiSSE models used.

**clade definitions**: (species used to obtain the node number of the clade in the phylogenetic tree from the ape package in R, in other words the common ancestor of the two species listed is the common ancestor of the clade)

**Gekkota***: Phyllurus kabikabi, Phelsuma kely*

**Scincoidea***: Cricosaura typica, Carlia vivax*

**Scincidae***: Typhlosaurus braini, Carlia viva*

**Anguimorpha***: Xenosaurus platyceps, Varanus baritji*

***Sceloporus*****subclade***: Sceloporus grammicus, Sceloporus adleri*

**Liolaemidae***: Phymaturus indistinctus, Liolaemus lavillai*

**Scolecophidia***: Leptotyphlops nigricans, Austrotyphlops pilbarensis*

**Alethinophidia***: Anilius scytale, Pseudoboa coronata*

"**Henophidia**"*: Casarea dussumieri, Antaresia childreni*

**Viperidae***: Eristicophis macmahoni, Crotalus adamanteus*

**Colubridae***: Pseudorabdion oxycephalon, Pseudoboa coronata*

In the following tables,

q01.x refers to the rate of O⇒V forward transitions in taxon x (background or split clade)

q10.x refers to the rate of V⇒O reversals in taxon x (background or split clade)

ΔAIC refers to the AIC difference compared to optimal model (Table 2).

λ0 and λ1refer to speciation rate in oviparous and viviparous taxa respectively.

μ0 and μ1refer to extinction rate in oviparous and viviparous taxa respectively.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Split Clades :  Gekkota, Scincidae, Lacertoidea, Iguania, Sceloporus\*, Liolaemidae, Typhlopidae+Leptotyphlopidae, Viperidae, Colubridae, | | Split Clades :  Scincidae, Sceloporus\*, Liolaemidae, Viperidae | |
| no. of params | | 24 |  | 14 |
| q01.1/q10.1 | | 11.69104804 |  | 0.157921942 |
| Log(q01.1/q10.1) | | 1.067853445 |  | -0.801557525 |
| -logL |  | 16487.91 |  | 16513.99 |
| AIC |  | 33023.82 |  | 33055.98 |
| ΔAIC |  | 7.36 |  | 39.52 |
| λ0 |  | 0.06218313 |  | 0.06241382 |
| λ1 |  | 0.0737658 |  | 0.07199333 |
| μ0 |  | 4.78555E-07 |  | 1.61691E-07 |
| μ1 |  | 2.20443E-06 |  | 9.76972E-07 |
| q01.1 | **Background** | 0.003894799 | **Background** | 0.000491552 |
| q10.1 |  | 0.000333144 |  | 0.003112627 |
| q01.2 | **Gekkota** | 8.95533E-05 | **Scincidae** | 0.005212156 |
| q01.2 |  | 7.41258E-08 |  | 1.27936E-07 |
| q01.3 | **Scincidae** | 0.001778815 | **Sceloporus** | 0.03972411 |
| q10.3 |  | 4.82178E-08 |  | 0.002943425 |
| q01.4 | **Lacertoidea** | 0.000265735 | **Liolaemidae** | 0.01808885 |
| q10.4 |  | 1.70699E-05 |  | 0.01038419 |
| q01.5 | **Iguania** | 0.000387237 | **Viperidae** | 0.01569024 |
| q10.5 |  | 1.56582E-07 |  | 0.001113897 |
| q01.6 | **Sceloporus** | 0.03417061 |  |  |
| q10.6 |  | 0.004874848 |  |  |
| q01.7 | **Liolaemidae** | 0.01802687 |  |  |
| q10.7 |  | 0.01058196 |  |  |
| q01.8 | **Scolecophidia** | 5.14374E-08 |  |  |
| q10.8 |  | 121962.3 |  |  |
| q01.9 | **Viperidae** | 0.01561563 |  |  |
| q10.9 |  | 0.001133048 |  |  |
| q01.10 | **Colubridae** | 0.000656969 |  |  |
| q10.10 |  | 3.40116E-08 |  |  |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Split Clades :  Scincidae, Anguimorpha, Sceloporus\*, Liolaemidae, Alethinophidia | | Split Clades :  Scincidae, Sceloporus, Liolaemidae, "Henophidea", Viperidae | |
| no. of params | | 16 |  | 16 |
| q01.1/q10.1 |  | 2808.056872 |  | 0.279347826 |
| Log(q01.1/q10.1) | | 3.448405899 |  | -0.553854704 |
| -logL |  | 16497.15 |  | 16512.75 |
| AIC |  | 33026.3 |  | 33057.5 |
| ΔAIC |  | 9.84 |  | 41.04 |
| λ0 |  | 0.0621 |  | 0.0623 |
| λ1 |  | 0.0737 |  | 0.0726 |
| μ0 |  | 0.000000248 |  | 0.0000183 |
| μ1 |  | 0.0000236 |  | 0.00000406 |
| q01.1 | **Background** | 0.000237 | **Background** | 0.000514 |
| q10.1 |  | 8.44E-08 |  | 0.00184 |
| q01.2 | **Scincidae** | 0.00521 | **Scincidae** | 0.0052 |
| q01.2 |  | 4.61E-09 |  | 0.00000934 |
| q01.3 | **Anguimorpha** | 0.00433 | **Sceloporus** | 0.0396 |
| q10.3 |  | 0.00000498 |  | 0.00311 |
| q01.4 | **Sceloporus\*** | 0.0394 | **Liolaemidae** | 0.018 |
| q10.4 |  | 0.00354 |  | 0.0104 |
| q01.5 | **Liolaemidae** | 0.018 | **"Henophidea"** | 0.00334 |
| q10.5 |  | 0.0106 |  | 0.00248 |
| q01.6 | **Alethinophidia** | 0.00128 | **Viperidae** | 0.0157 |
| q10.6 |  | 0.00589 |  | 0.0011 |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Split Clades :  Scincidae, Anguimorpha, Sceloporus, Liolaemidae, "Henophidea", Viperidae | | Split Clades :  Scincidae, Anguimorpha, Sceloporus, Liolaemidae, Alethinophidea, "Henophidea", Viperidae | |
| no. of params | | 18 |  | 20 |
| q01.1/q10.1 |  | 122636.8159 |  | 1475.903614 |
| Log(q01.1/q10.1) | | 5.088620866 |  | 3.169057996 |
| -logL |  | 16502.77 |  | 16488.23 |
| AIC |  | 33041.54 |  | 33016.46 |
| ΔAIC |  | 25.08 |  | 0 |
| λ0 |  | 0.0622 |  | 0.0622 |
| λ1 |  | 0.0731 |  | 0.0733 |
| μ0 |  | 5.01E-08 |  | 0.00000024 |
| μ1 |  | 0.000000195 |  | 0.0000018 |
| q01.1 | **Background** | 0.000493 | **Background** | 0.000245 |
| q10.1 |  | 4.02E-09 |  | 0.000000166 |
| q01.2 | **Scincidae** | 0.00518 | **Scincidae** | 0.00524 |
| q01.2 |  | 1.22E-08 |  | 0.00000426 |
| q01.3 | **Anguimorpha** | 0.00434 | **Anguimorpha** | 0.00431 |
| q10.3 |  | 0.00000293 |  | 0.00000573 |
| q01.4 | **Sceloporus** | 0.0395 | **Sceloporus** | 0.0396 |
| q10.4 |  | 0.00335 |  | 0.00284 |
| q01.5 | **Liolaemidae** | 0.018 | **Liolaemidae** | 0.018 |
| q10.5 |  | 0.0105 |  | 0.0105 |
| q01.6 | **"Henophidea"** | 0.00342 | **Alethinophidia** | 0.0015 |
| q10.6 |  | 0.00245 |  | 0.000000419 |
| q01.7 | **Viperidae** | 0.0156 | **"Henophidea"** | 0.00342 |
| q10.7 |  | 0.0112 |  | 0.00244 |
| q01.8 |  |  | **Viperidae** | 0.0155 |
| q10.8 |  |  |  | 0.00112 |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Split Clades :  Anguimorpha, Sceloporus, Lioleamidae, Alethinophidea | | Split Clades :  Scincidae, Sceloporus, Liolaemidae, Alethinophidia | |
| no. of params | | 14 |  | 14 |
| q01.1/q10.1 |  | 0.096136364 |  | 0.112350598 |
| Log(q01.1/q10.1) | | -1.017112309 |  | -0.949424613 |
| -logL |  | 16536.36 |  | 16508.36 |
| AIC |  | 33100.72 |  | 33044.72 |
| ΔAIC |  | 84.26 |  | 28.26 |
| λ0 |  | 0.0623 |  | 0.00623 |
| λ1 |  | 0.0758 |  | 0.0725 |
| μ0 |  | 8.83E-08 |  | 0.000000186 |
| μ1 |  | 0.00777 |  | 6.55E-08 |
| q01.1 | **Background** | 0.000423 | **Background** | 0.000282 |
| q10.1 |  | 0.0044 |  | 0.00251 |
| q01.2 | **Anguimorpha** | 0.00467 | **Scincidae** | 0.00521 |
| q01.2 |  | 7.65E-08 |  | 1.02E-08 |
| q01.3 | **Sceloporus** | 0.04 | **Sceloporus** | 0.0396 |
| q10.3 |  | 0.00316 |  | 0.00313 |
| q01.4 | **Liolaemidae** | 0.0185 | **Liolaemidae** | 0.0181 |
| q10.4 |  | 0.0102 |  | 0.0104 |
| q01.5 | **Alethinophidia** | 0.0013 | **Alethinophidia** | 0.00129 |
| q10.5 |  | 0.00571 |  | 0.00589 |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Split Clades :  Scincidae, Anguimorpha, Liolaemidae, Alethinophidia | | Split Clades :  Scincidae, Anguimorpha, Sceloporus, Alethinophidia | |
| no. of params | | 14 |  | 14 |
| q01.1/q10.1 |  | 0.07295082 |  | 0.067976424 |
| Log(q01.1/q10.1) | | -1.136969824 |  | -1.167641684 |
| -logL |  | 16516.06 |  | 16531.09 |
| AIC |  | 33060.12 |  | 33090.18 |
| ΔAIC |  | 43.66 |  | 73.72 |
| λ0 |  | 0.0619 |  | 0.062 |
| λ1 |  | 0.0746 |  | 0.0741 |
| μ0 |  | 0.000000121 |  | 0.000000341 |
| μ1 |  | 0.000000151 |  | 0.0000151 |
| q01.1 | **Background** | 0.000267 | **Background** | 0.000346 |
| q10.1 |  | 0.00366 |  | 0.00509 |
| q01.2 | **Scincidae** | 0.0052 | **Scincidae** | 0.0052 |
| q01.2 |  | 4.71E-09 |  | 0.00000361 |
| q01.3 | **Anguimorpha** | 0.00433 | **Anguimorpha** | 0.00433 |
| q10.3 |  | 0.000000235 |  | 0.00000489 |
| q01.4 | **Liolaemidae** | 0.018 | **Sceloporus** | 0.0393 |
| q10.4 |  | 0.0107 |  | 0.00374 |
| q01.5 | **Alethinophidia** | 0.00128 | **Alethinophidia** | 0.00126 |
| q10.5 |  | 0.00594 |  | 0.00601 |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Split Clades :  Scincidae, Anguimorpha, Sceloporus, Liolaemus | | Split Clades :  Scincidae, Anguimorpha, Sceloporus, Liolaemidae, "Henophidea" | |
| no. of params | | 14 |  | 16 |
| q01.1/q10.1 |  | 0.08003876 |  | 0.076146789 |
| Log(q01.1/q10.1) | | -1.09669965 |  | -1.118348406 |
| -logL |  | 16513.75 |  | 16513.38 |
| AIC |  | 33055.5 |  | 33058.76 |
| dAIC |  | 39.04 |  | 42.3 |
| λ0 |  | 0.0621 |  | 0.0621 |
| λ1 |  | 0.0739 |  | 0.0739 |
| μ0 |  | 1.6E-10 |  | 4.21E-09 |
| μ1 |  | 0.00000661 |  | 0.000000186 |
| q01.1 | **Background** | 0.000413 | **Background** | 0.000415 |
| q10.1 |  | 0.00516 |  | 0.00545 |
| q01.2 | **Scincidae** | 0.0052 | **Scincidae** | 0.0052 |
| q01.2 |  | 8.18E-08 |  | 0.000000736 |
| q01.3 | **Anguimorpha** | 0.00437 | **Anguimorpha** | 0.00433 |
| q10.3 |  | 7.84E-08 |  | 7.19E-08 |
| q01.4 | **Sceloporus** | 0.0393 | **Sceloporus** | 0.0393 |
| q10.4 |  | 0.00362 |  | 0.00364 |
| q01.5 | **Liolaemus** | 0.018 | **Liolaemus** | 0.018 |
| q10.5 |  | 0.0107 |  | 0.0106 |
| q01.6 |  |  | **"Henophidea"** | 0.00000944 |
| q10.6 |  |  |  | 0.00429 |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Split Clades :  Scincoidea, Anguimorpha, Sceloporus, Liolaemidae, Alethinophidia | | Split Clades :  Gekkota, Anguimorpha, Sceloporus, Liolaemidae, Alethinophidia, "Henophidia", Viperidae | |
| no. of params | | 16 |  | 20 |
| q01.1/q10.1 |  | 4117.647059 |  | 0.222712934 |
| Log(q01.1/q10.1) | | 3.614649119 |  | -0.652254561 |
| -logL |  | 16497.61 |  | 16540.85 |
| AIC |  | 33027.22 |  | 33121.7 |
| ΔAIC |  | 10.76 |  | 105.24 |
| λ0 |  | 0.0621 |  | 0.0624 |
| λ1 |  | 0.074 |  | 0.0717 |
| μ0 |  | 0.000000838 |  | 0.000000368 |
| μ1 |  | 5.6E-09 |  | 0.00000371 |
| q01.1 | **Background** | 0.000217 | **Background** | 0.000706 |
| q10.1 |  | 5.27E-08 |  | 0.00317 |
| q01.2 | **Scincoidea** | 0.00454 | **Gekkota** | 0.0000965 |
| q01.2 |  | 2.73E-08 |  | 0.0000257 |
| q01.3 | **Anguimorpha** | 0.00433 | **Anguimorpha** | 0.00435 |
| q10.3 |  | 0.00000444 |  | 0.000000391 |
| q01.4 | **Sceloporus** | 0.0393 | **Sceloporus** | 0.0398 |
| q10.4 |  | 0.00364 |  | 0.00281 |
| q01.5 | **Liolaemus** | 0.018 | **Liolaemidae** | 0.0181 |
| q10.5 |  | 0.0106 |  | 0.0103 |
| q01.6 | **Alethinophidia** | 0.00128 | **Alethinophidia** | 0.00151 |
| q10.6 |  | 0.00586 |  | 0.000000433 |
| q01.7 |  |  | **"Henophidia"** | 0.00338 |
| q10.7 |  |  |  | 0.00247 |
| q01.8 |  |  | **Viperidae** | 0.0157 |
| q10.8 |  |  |  | 0.00112 |

|  |  |  |
| --- | --- | --- |
|  | **Best fit model with root state assumption changed to equal weighting for the two character states** | **Best fit model with extinction set to 0** |
| No. of params | 20 | 18 |
| -logL | 16489.02 | 16488.22 |
| AIC | 33018.04 | 33012.44 |
| λ0 | 6.23e-2 | 6.23e-2 |
| λ1 | 7.33e-2 | 7.33e-2 |
| μ0 | 8.28e-9 | 0 |
| μ1 | 7.32e-5 | 0 |
| q01.1 | 2.44e-4 | 2.46e-4 |
| q10.1 | 7.16e-9 | 4.93e-10 |
| q01.2 | 5.21e-3 | 5.22e-3 |
| q10.2 | 4.36e-8 | 5.18e-8 |
| q01.3 | 4.34e-3 | 4.33e-3 |
| q10.3 | 1.07e-5 | 2.80e-7 |
| q01.4 | 3.95e-2 | 3.95e-2 |
| q10.4 | 3.36e-3 | 3.38e-3 |
| q01.5 | 1.80e-2 | 1.80e-2 |
| q10.5 | 1.05e-2 | 1.05e-2 |
| q01.6 | 1.51e-3 | 1.51e-3 |
| q10.6 | 9.36e-6 | 1.74e-6 |
| q01.7 | 3.42e-3 | 3.41e-3 |
| q10.7 | 2.45e-3 | 2.46e-3 |
| q01.8 | 1.56e-2 | 1.57e-2 |
| q10.8 | 1.12e-3 | 1.12e-3 |

**Table S3**

Parameter estimates for two analyses explore the effect of 1) root state assumptions and 2) extinction rate estimation. Setting the root assumption to equal weights does not affect the outcome. Forcing extinction to be 0, such that speciation becomes net diversification, also does not affect the results. This model has better support than the 20 parameter version however (δAIC=-4.02 relative to 20 parameter model).

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Simulation | Model (Simulation) | Simulated Bias | ace Mk1 | ace mk2 | BEAST SC Mk1 | BEAST SC Mk2 | BEAST RLC Mk1 | BEAST RLC Mk2 |
| 1 | Asymm | 20 | [1] | 30.72 | [1] | 18.42 | [1] | 17.86 |
| 2 | Asymm | 20 | [1] | 14.43 | [1] | 4.09 | [1] | 3.95 |
| 3 | Asymm | 20 | [1] | 11.89 | [1] | 9.56 | [1] | 0.84 |
| 4 | Asymm | 20 | [1] | 28.64 | [1] | 17.18 | [1] | 17.01 |
| 5 | Asymm | 20 | [1] | 24.84 | [1] | 16.7 | [1] | 16.54 |
| 6 | Heterotach | 1 | [1] | 0.03 | [1] | 0.07 | [1] | 0.84 |
| 7 | Heterotach | 1 | [1] | 0.05 | [1] | 0.44 | [1] | 2.04 |
| 8 | Heterotach | 1 | [1] | 0.02 | [1] | 0.04 | [1] | 0.54 |
| 9 | Heterotach | 1 | [1] | 0.05 | [1] | 0.08 | [1] | 0.25 |
| 10 | Heterotach | 1 | [1] | 0.09 | [1] | 1.38 | [1] | 2.02 |
| 11 | Asy+Het | 20 | [1] | 0.00 | [1] | 0.21 | [1] | 6.07 |
| 12 | Asy+Het | 20 | [1] | 0.16 | [1] | 1.83 | [1] | 7.93 |
| 13 | Asy+Het | 20 | [1] | 6.46 | [1] | 4.09 | [1] | 14.15 |
| 14 | Asy+Het | 20 | [1] | 0.69 | [1] | 0.72 | [1] | 0.72 |
| 15 | Asy+Het | 20 | [1] | 0.13 | [1] | 0.18 | [1] | 10.11 |
| 16 | AsyVar+Het | 5, 20 | [1] | 1.76 | [1] | 1.94 | [1] | 6.22 |
| 17 | AsyVar+Het | 5, 20 | [1] | 0.07 | [1] | 0.17 | [1] | 10.11 |
| 18 | AsyVar+Het | 5, 20 | [1] | 0.35 | [1] | 1.16 | [1] | 12.25 |
| 19 | AsyVar+Het | 5, 20 | [1] | 0.71 | [1] | 0.73 | [1] | 21.02 |
| 20 | AsyVar+Het | 5, 20 | [1] | 0.30 | [1] | 0.18 | [1] | 5.17 |

**Table S4.** Estimates of asymmetry (bias) for each model for every simulation. Numbers are forward rate ÷ reverse rate: numbers above 1 indicate a bias toward forward rates and vice versa.

|  |  |  |
| --- | --- | --- |
| **Simulation** | **ace Mk1** | **ace Mk2** |
| **1** Asymmetry only | 146.39 | **126** |
| **2** | 114.96 | **105.12** |
| **3** | 194.1 | **189.18** |
| **4** | 135.18 | **110.34** |
| **5** | 155.27 | **131.81** |
| **6** Heterotachy only | 144.69 | **126.87** |
| **7** | 140.42 | **131.26** |
| **8** | 157.18 | **126.52** |
| **9** | 141.21 | **117.88** |
| **10** | 161.2 | **152.71** |
| **11** Asymmetry + heterotachy | 112.28 | **103.99** |
| **12** | **102.04** | 100.88 |
| **13** | **90.47** | **88.37** |
| **14** | **40.79** | 40.66 |
| **15** | 109.88 | **100.03** |
| **16** Asymmetry + heterotachy (uneven) | **133.88** | 133.49 |
| **17** | 66.44 | **61.48** |
| **18** | **121.46** | 120.28 |
| **19** | **126.62** | 126.35 |
| **20** | 142.59 | **140.14** |

**Table S5.** Results for simulations, analysed in APE using the ace function. Models that produced accurate ancestral reconstructions are designated by shaded cells. Numbers are negative log likelhoods. Model(s) with best support in bold. Note that when the simulation has heterotachy, but the analyses only allows asymmetry, Mk2 always produces inaccurate reconstructions despite strong support over Mk1.