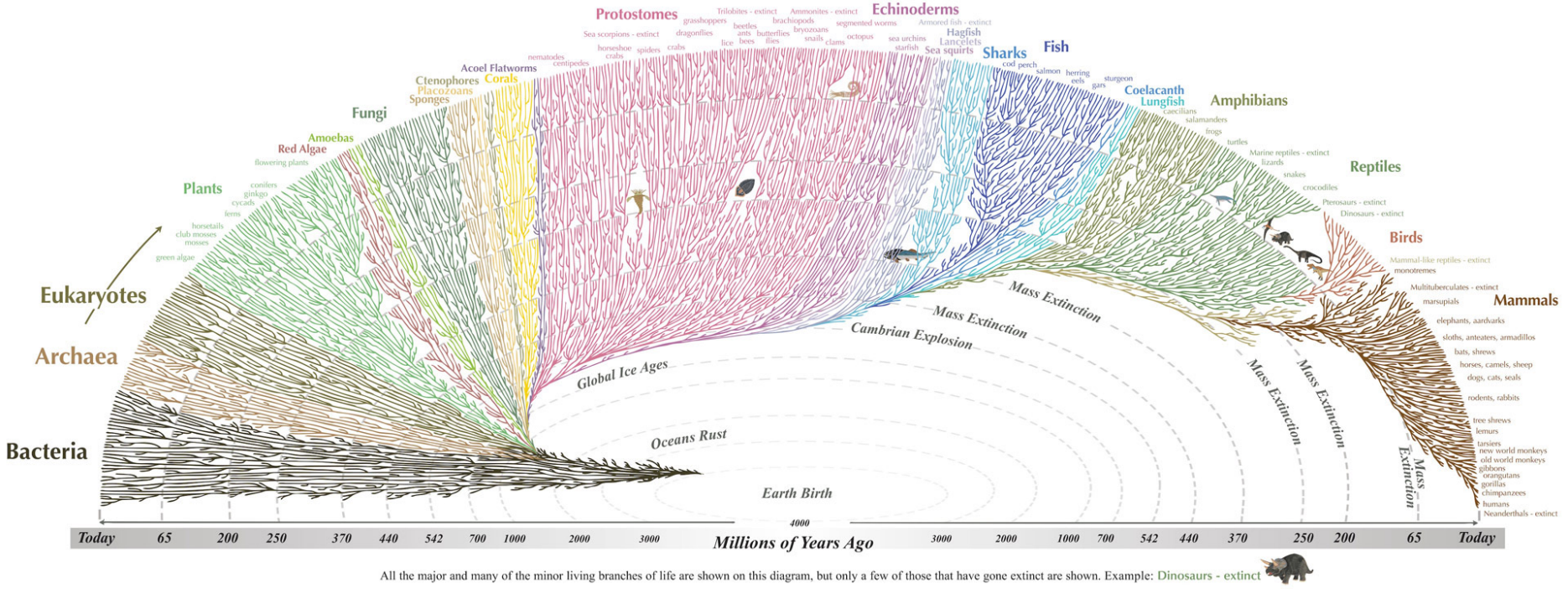
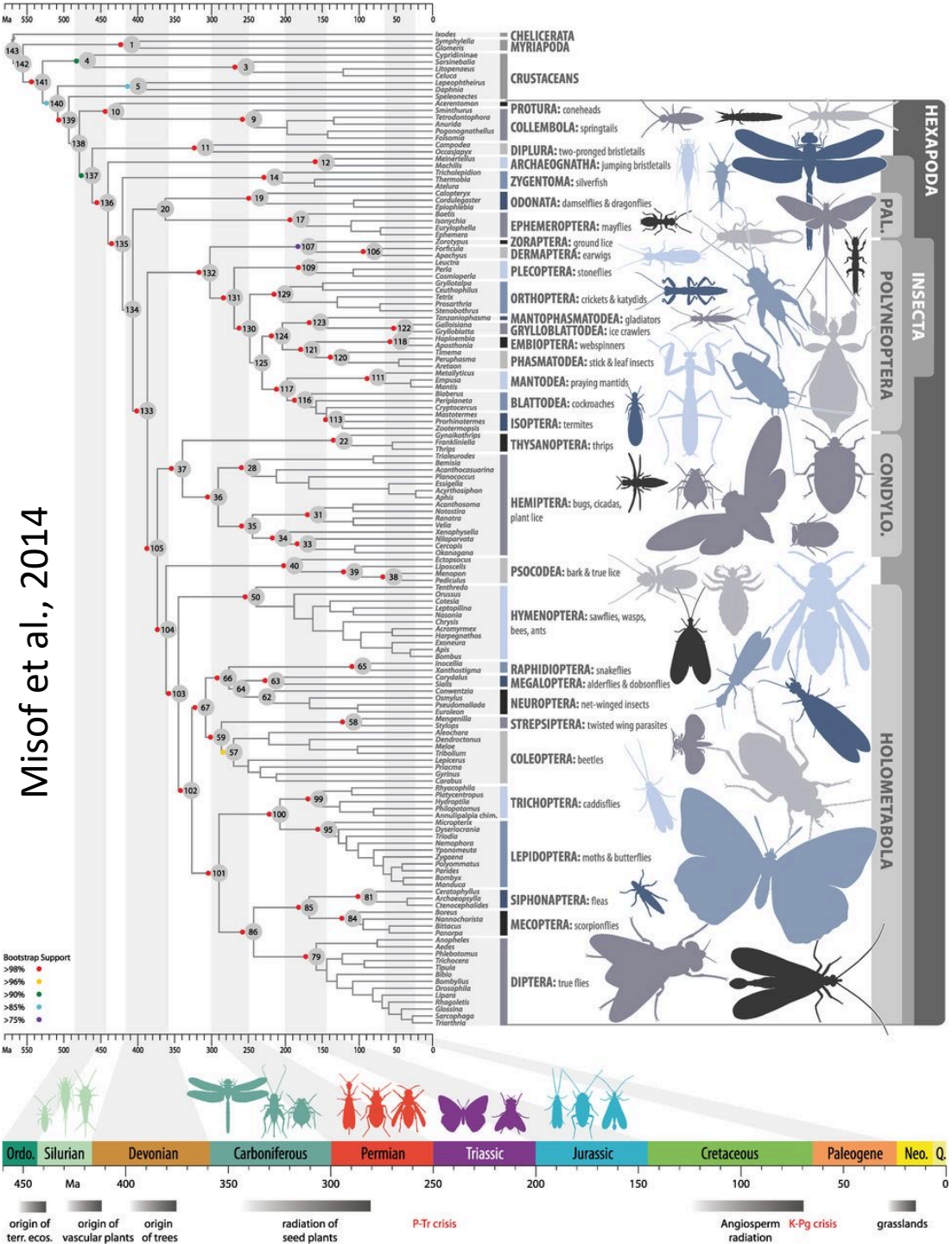
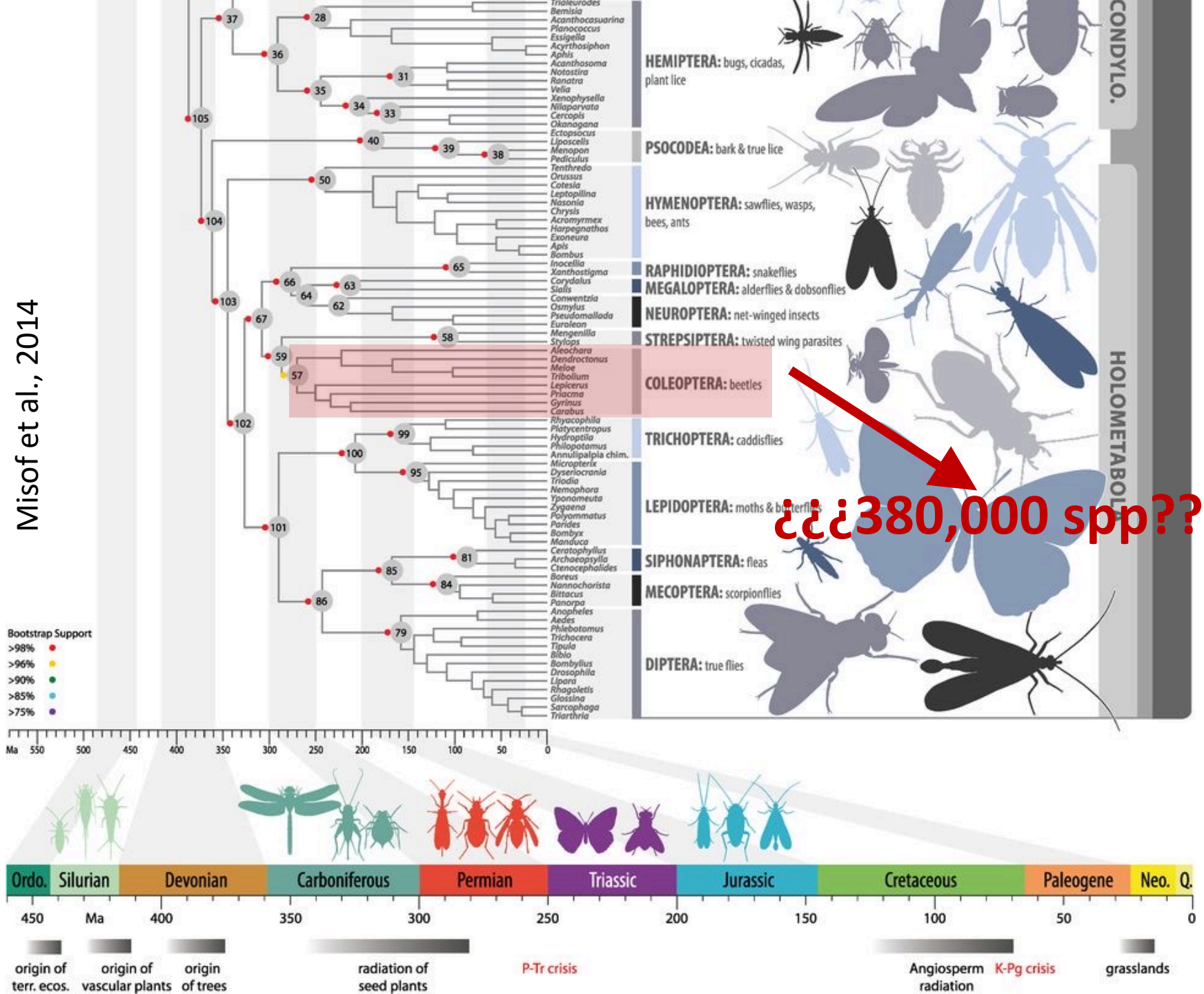
La diversidad actual no es producto de un único mecanismo evolutivo, ni es gradual ni silenciosa (Gould, 1989; Foote, 1997)

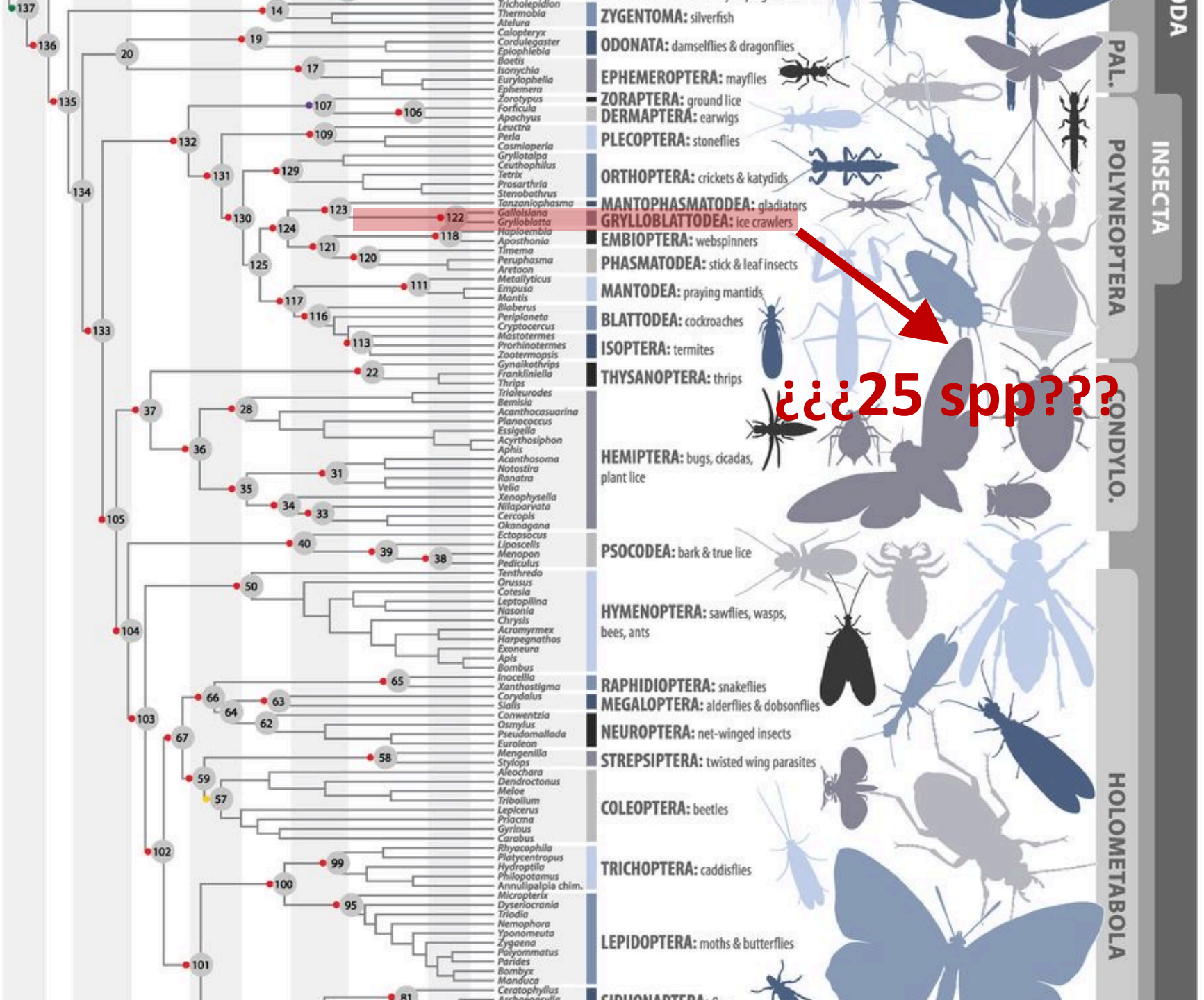


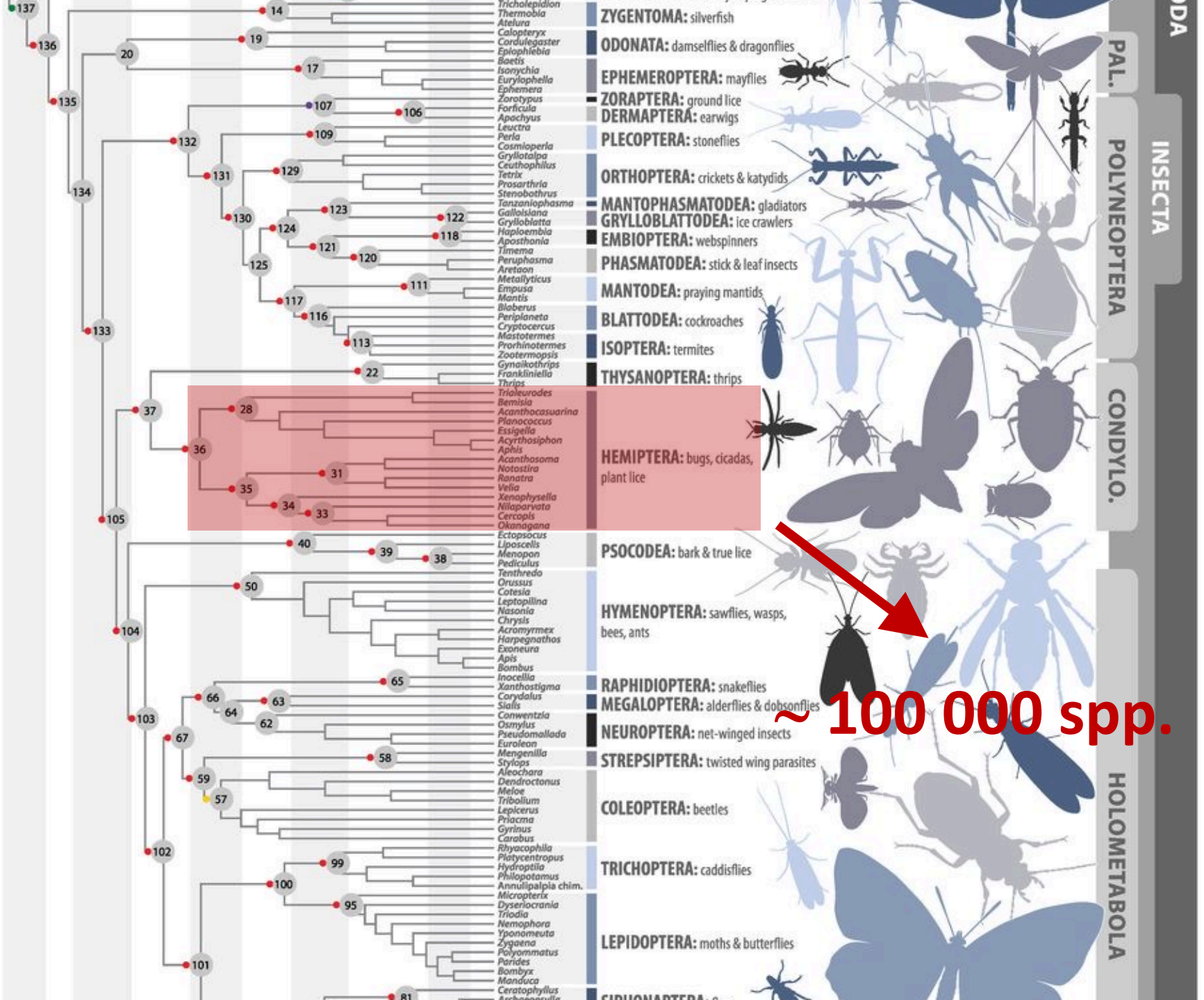
All the major and many of the minor living branches of life are shown on this diagram, but only a few of those that have gone extinct are shown. Example: Dinosaurs - extinct


Misof et al., 2014
CHELICERATA
MYRIAPODA
CRUSTACEANS
HEXAPODA
INSECTA
PAL.
POLYNEOPTERA
CONDYLO.
HOLOMETABOLA
PROTURA: coneheads
COLLEMBOLA: springtails
DIPLURA: two-pronged bristletails
ARCHAEOGNATHA: jumping bristletails
ZYGENTOMA: silverfish
ODONATA: damselflies & dragonflies
EPHEMEROPTERA: mayflies
ZORAPTERA: ground lice
DERMAPTERA: earwigs
PLECOPTERA: stoneflies
ORTHOPTERA: crickets & katydids
MANTOPHASMATODEA: gladiators
GRYLLOBLATTODEA: ice crawlers
EMBIOPTERA: webspinners
PHASMATODEA: stick & leaf insects
MANTODEA: praying mantids
BLATTODEA: cockroaches
ISOPTERA: termites
THYSANOPTERA: thrips
HEMIPTERA: bugs, cicadas, plant lice
PSOCODEA: bark & true lice
HYMENOPTERA: sawflies, wasps, bees, ants
RAPHIDIOPTERA: snakeflies
MEGALOPTERA: alderflies & dobsonflies
NEUROPTERA: net-winged insects
STREPSIPTERA: twisted wing parasites
COLEOPTERA: beetles
TRICHOPTERA: caddisflies
LEPIDOPTERA: moths & butterflies
SIPHONAPTERA: fleas
MECOPTERA: scorpionflies
DIPTERA: true flies
Bootstrap Support
>98%
>96%
>90%
>85%
>75%
Ma 550 500 450 400 350 300 250 200 150 100 50 0
Ordo. Silurian Devonian Carboniferous Permian Triassic Jurassic Cretaceous Paleogene Neo. Q.
450 Ma 400 350 300 250 200 150 100 50 0
origin of terr. ecos.
origin of vascular plants
origin of trees
radiation of seed plants
P-Tr crisis
Angiosperm radiation
K-Pg crisis
grasslands

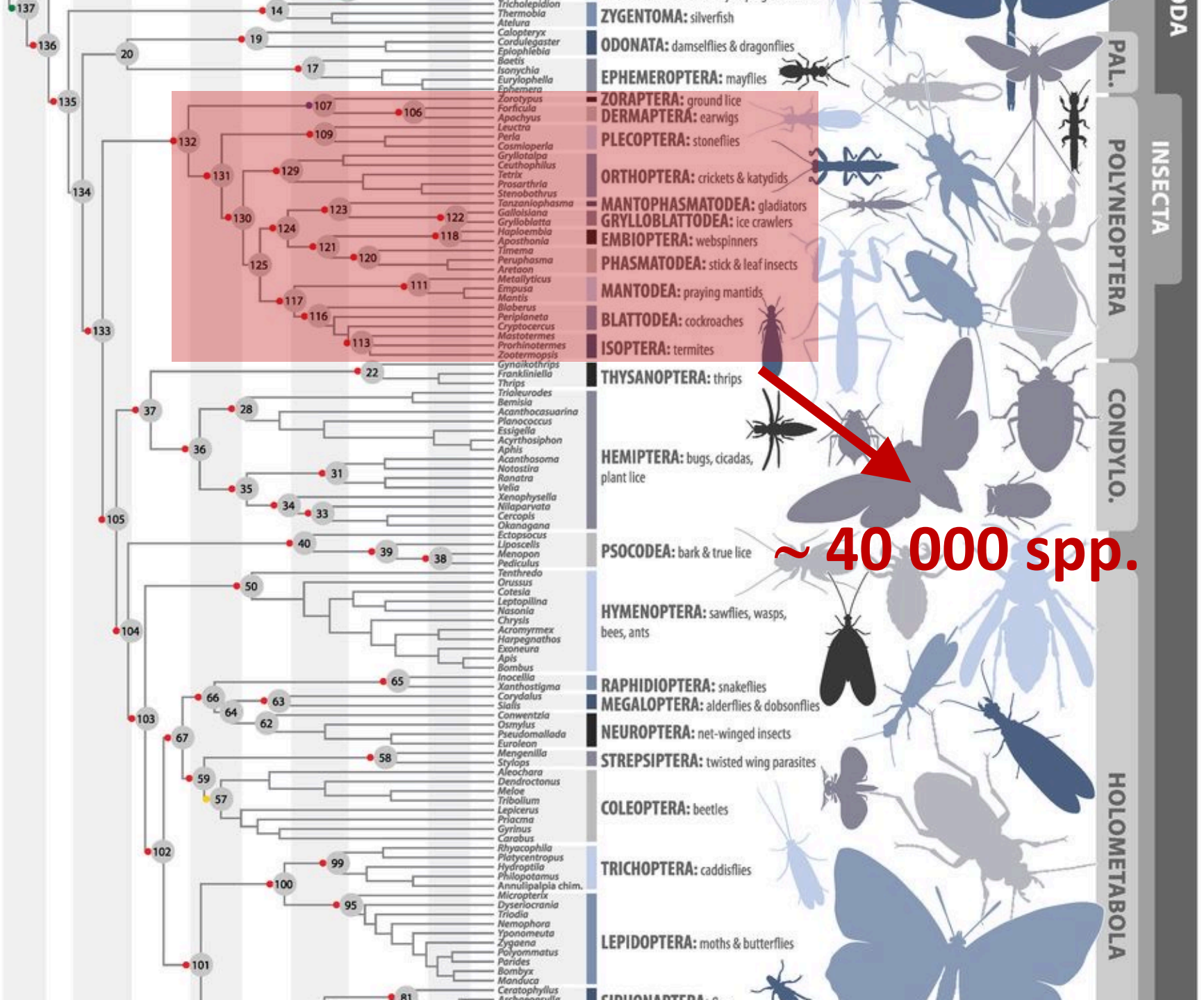

Misof et al., 2014
HEMIPTERA: bugs, cicadas, plant lice
PSOCODEA: bark & true lice
HYMENOPTERA: sawflies, wasps, bees, ants
RAPHIDIOPTERA: snakeflies
MEGALOPTERA: alderflies & dobsonflies
NEUROPTERA: net-winged insects
STREPSIPTERA: twisted wing parasites
COLEOPTERA: beetles
TRICHOPTERA: caddisflies
LEPIDOPTERA: moths & butterflies
SIPHONAPTERA: fleas
MECOPTERA: scorpionflies
DIPTERA: true flies
CONDYLO.
HOLOMETABOLA
¿¿¿380,000 spp???
Bootstrap Support
>98%
>96%
>90%
>85%
>75%
Ma 550 500 450 400 350 300 250 200 150 100 50 0
Ordo. Silurian Devonian Carboniferous Permian Triassic Jurassic Cretaceous Paleogene Neo. Q.
450 Ma 400 350 300 250 200 150 100 50 0
origin of terr. ecos.
origin of vascular plants
origin of trees
radiation of seed plants
P-Tr crisis
Angiosperm radiation
K-Pg crisis
grasslands

Misof et al., 2014

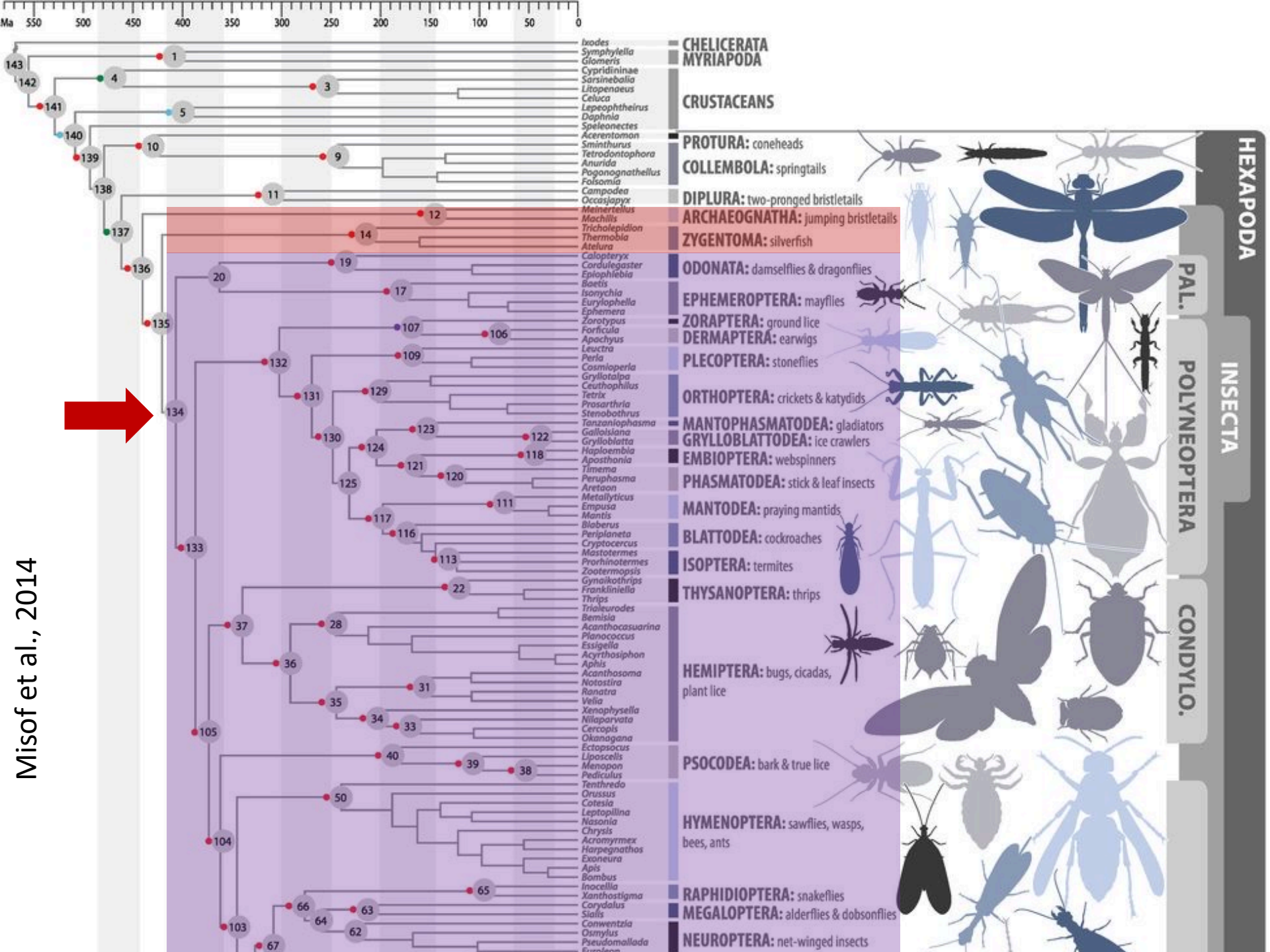




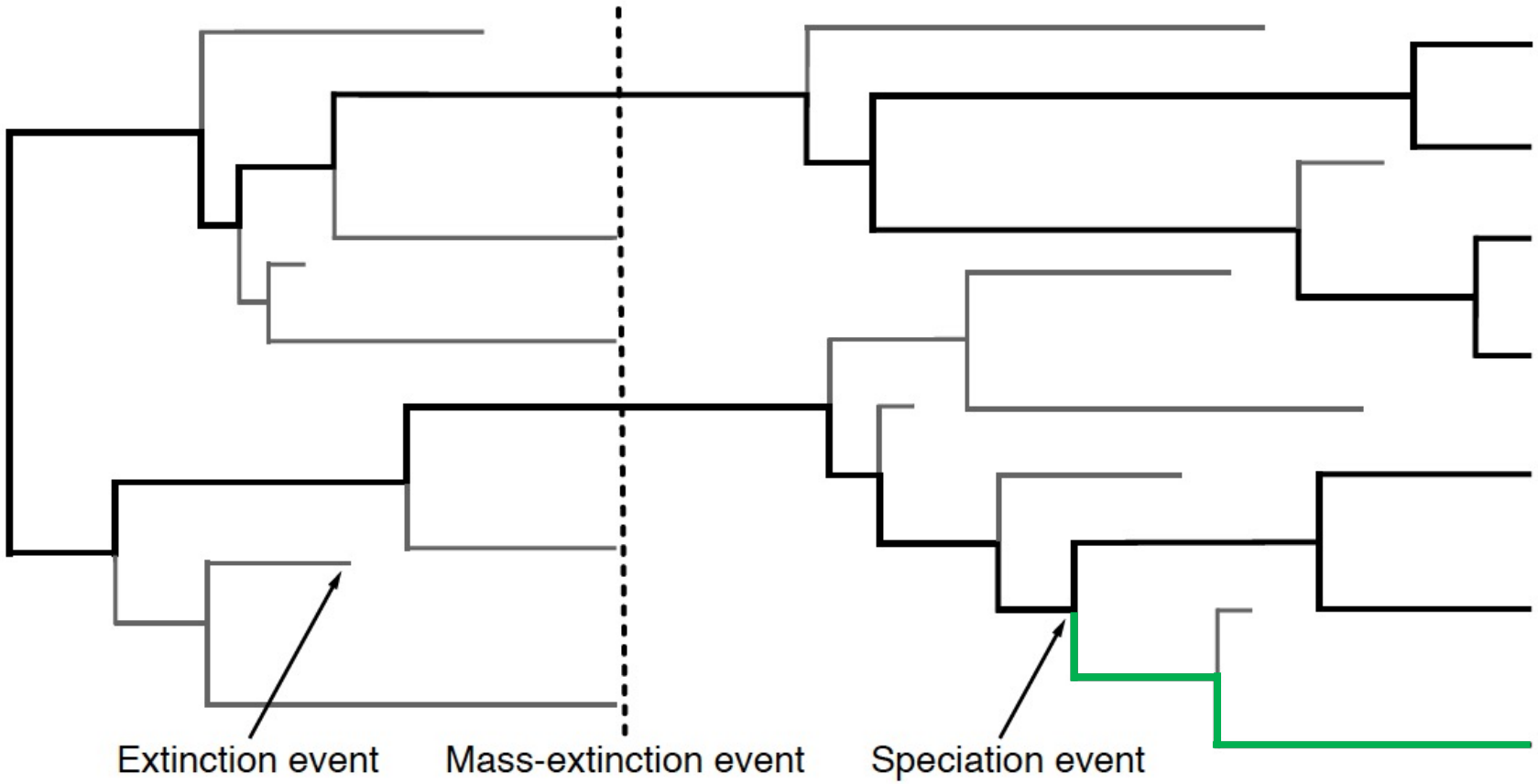
Misof et al., 2014



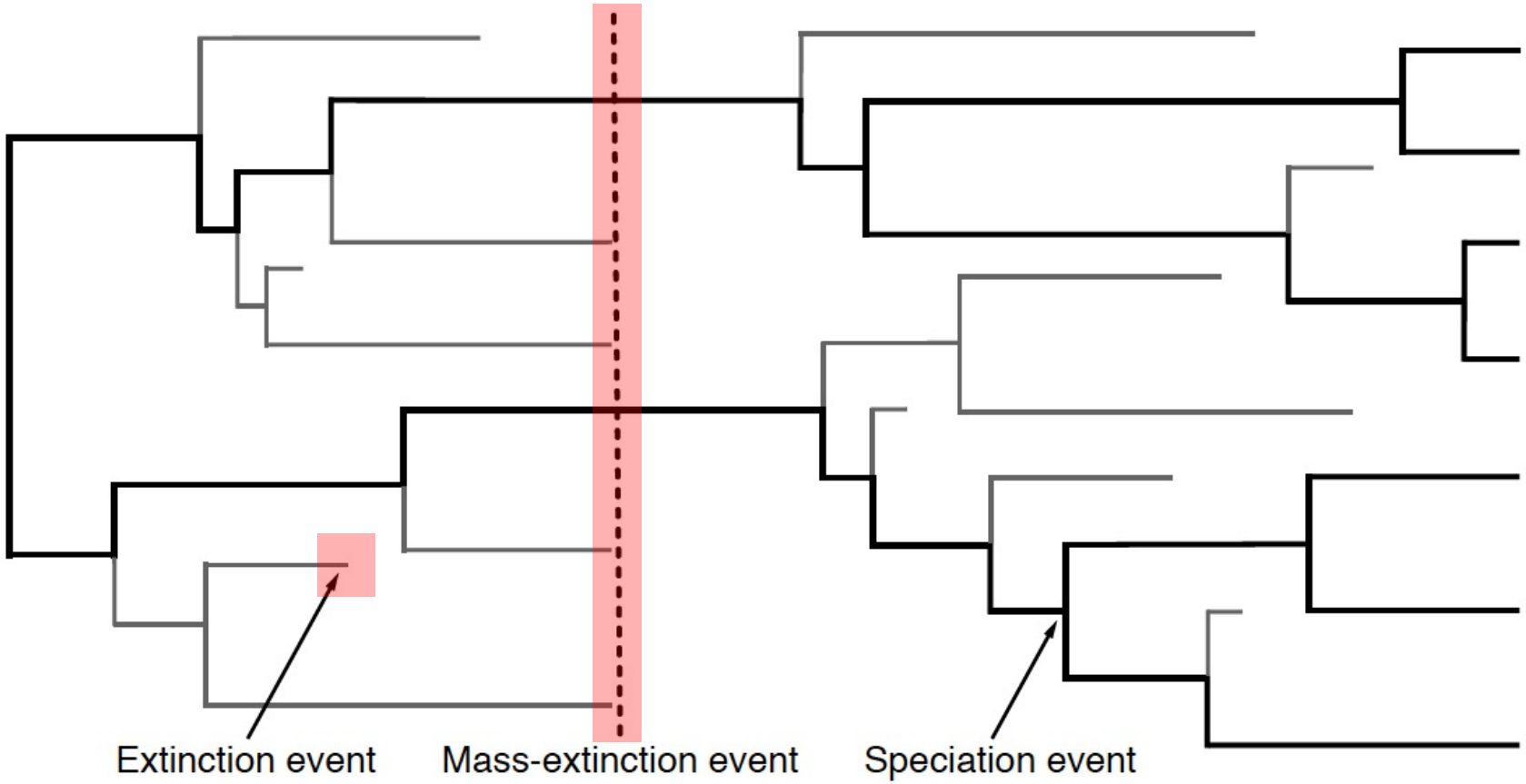
Misof et al., 2014



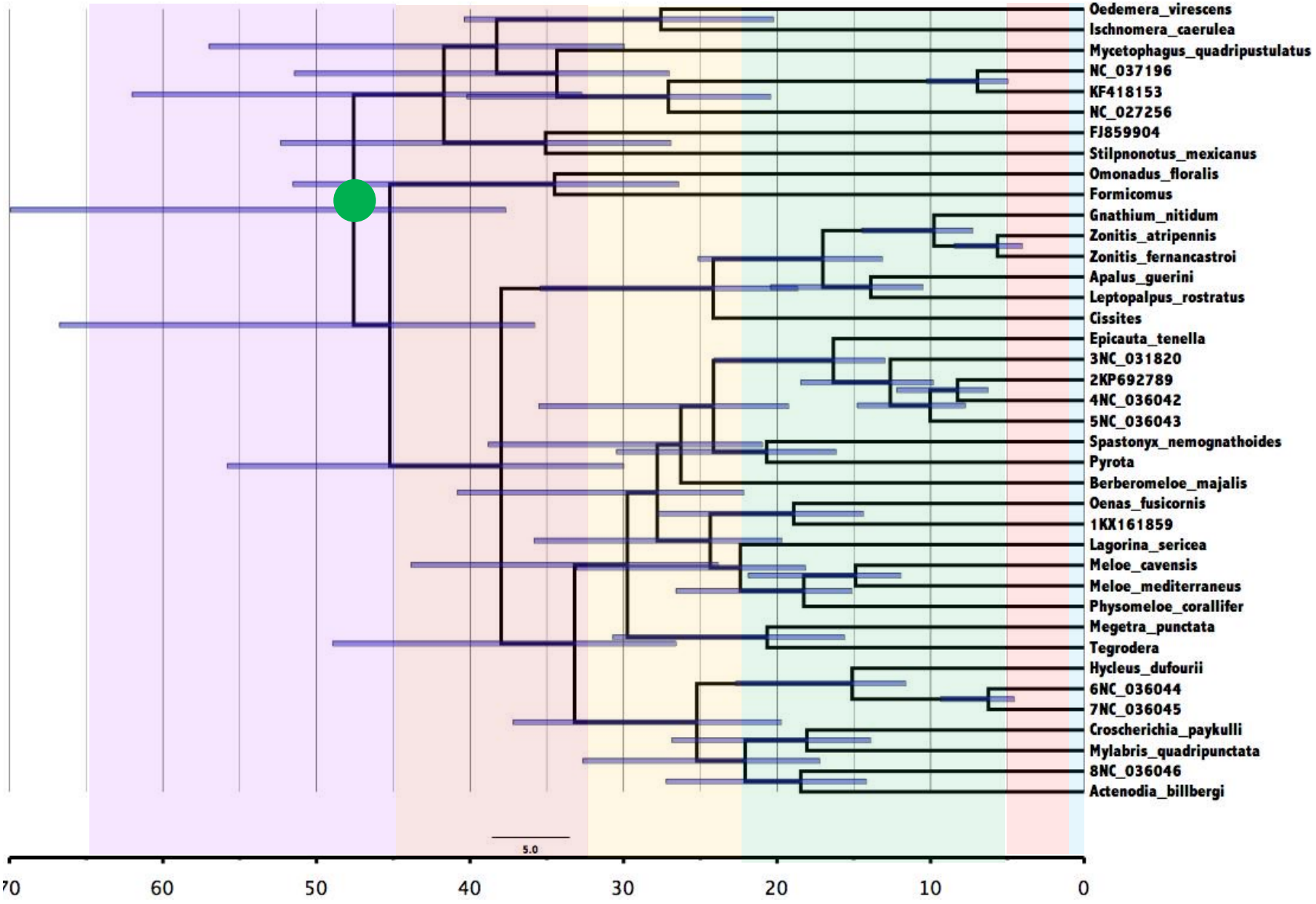
Misof et al., 2014

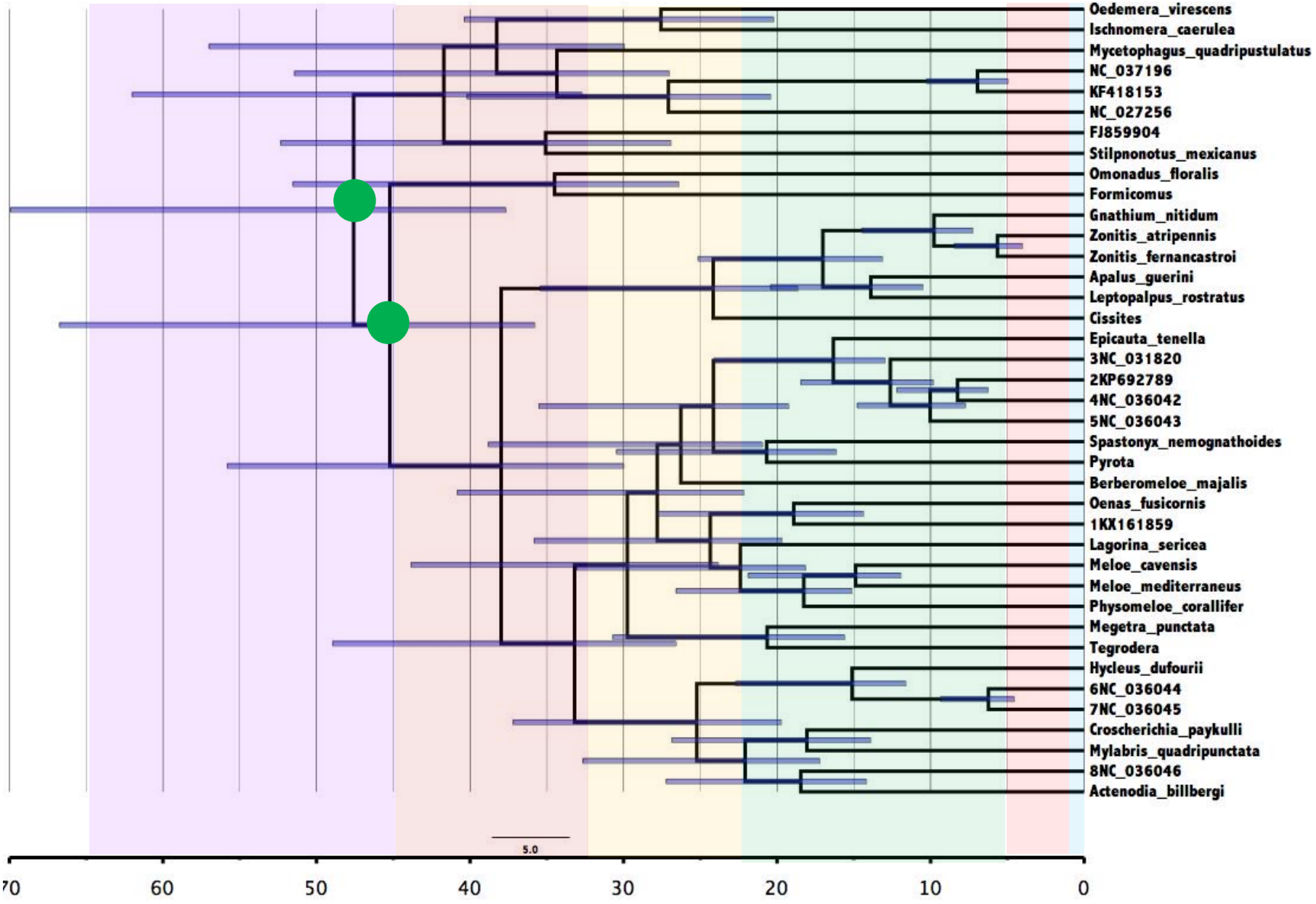


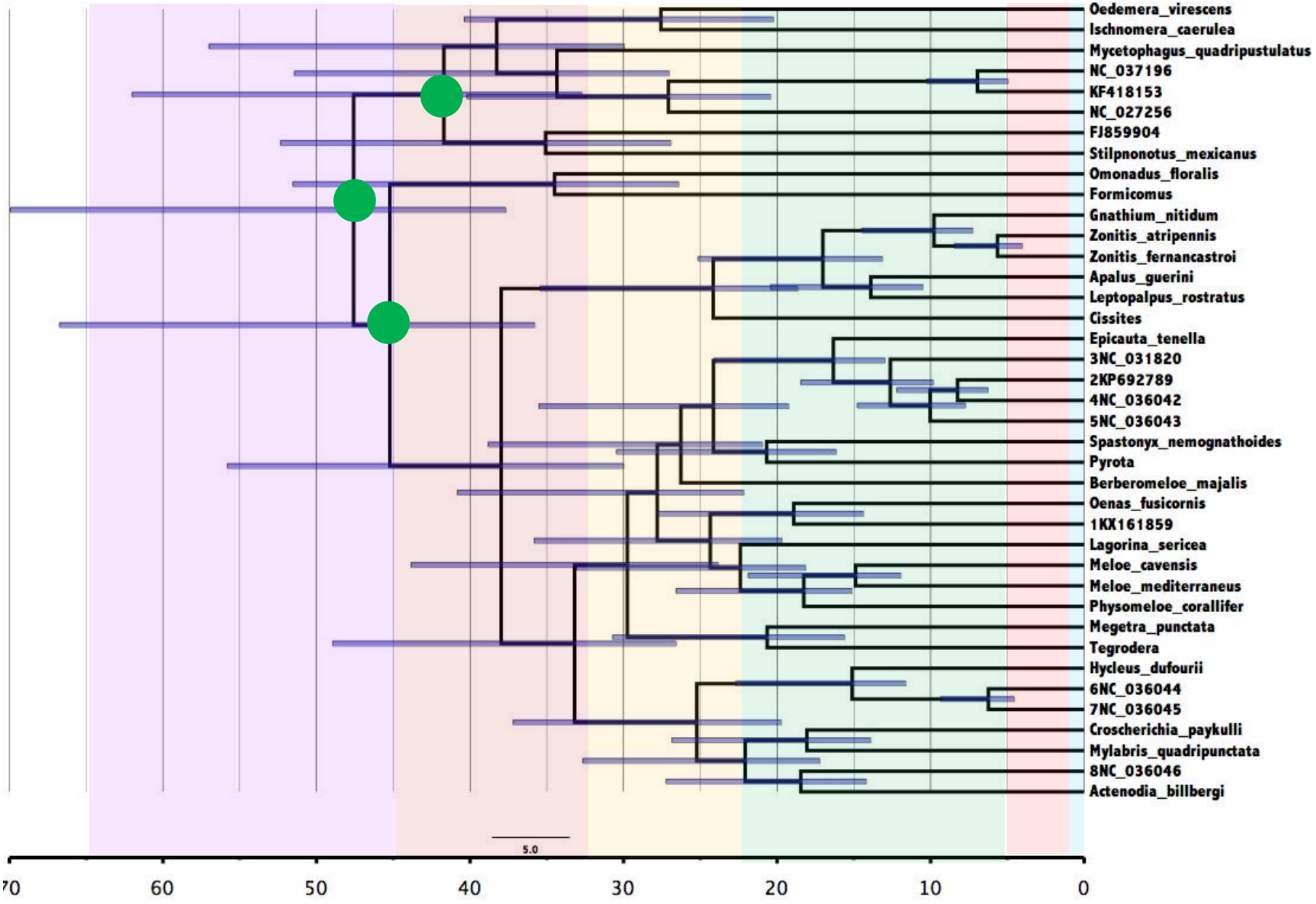
Höhna et al., 2015

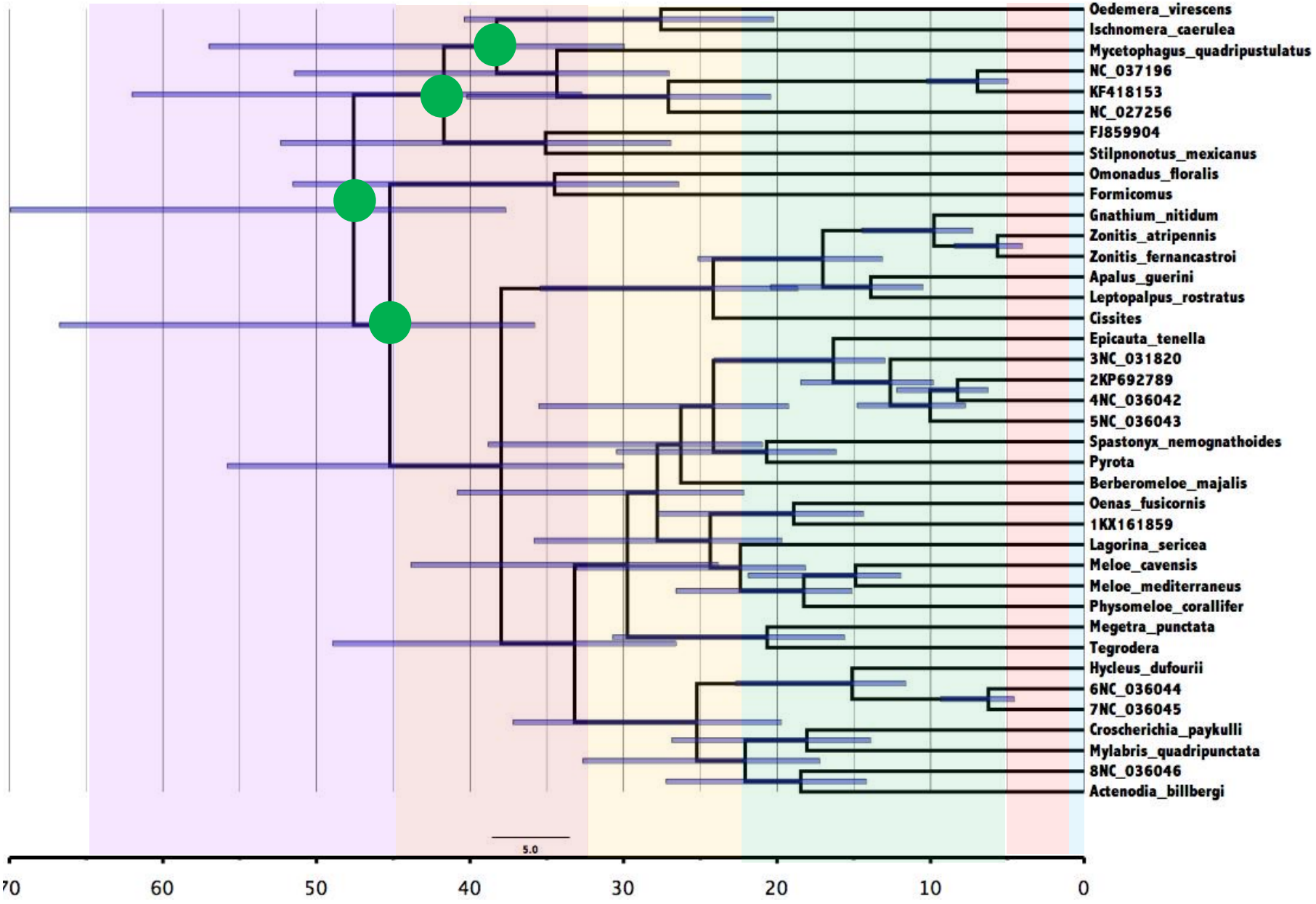


Höhna et al., 2015


Oedemera_virescens
Ischnomera_caerulea
Mycetophagus_quadripustulatus
NC_037196
KF418153
NC_027256
FJ859904
Stilpnonotus_mexicanus
Omonadus_floralis
Formicomus
Gnathium_nitidum
Zonitis_atripennis
Zonitis_fernancastroi
Apalus_guerini
Leptopalpus_rostratus
Cissites
Epicauta_tenella
3NC_031820
2KP692789
4NC_036042
5NC_036043
Spastonyx_nemognathoides
Pyrota
Berberomeloe_majalis
Oenas_fusicornis
1KX161859
Lagorina_sericea
Meloe_cavensis
Meloe_mediterraneus
Physomeloe_corallifer
Megetra_punctata
Tegrodera
Hycleus_dufourii
6NC_036044
7NC_036045
Croscherichia_paykulli
Mylabris_quadripunctata
8NC_036046
Actenodia_billbergi
5.0
70
60
50
40
30
20
10
0

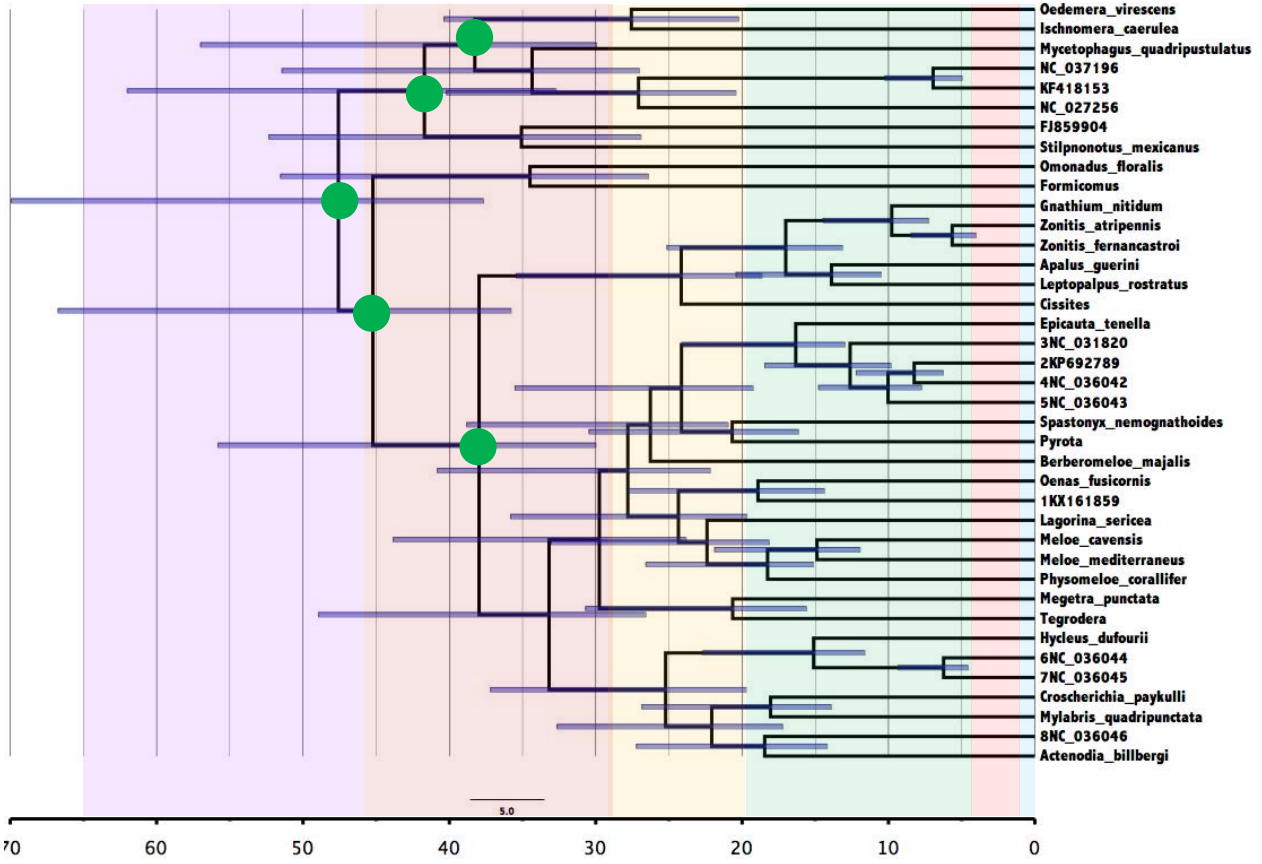

Oedemera_virescens
Ischnomera_caerulea
Mycetophagus_quadripustulatus
NC_037196
KF418153
NC_027256
FJ859904
Stilpnonotus_mexicanus
Omonadus_floralis
Formicomus
Gnathium_nitidum
Zonitis_atripennis
Zonitis_fernancastroi
Apalus_guerini
Leptopalpus_rostratus
Cissites
Epicauta_tenella
3NC_031820
2KP692789
4NC_036042
5NC_036043
Spastonyx_nemognathoides
Pyrota
Berberomeloe_majalis
Oenas_fusicornis
1KX161859
Lagorina_sericea
Meloe_cavensis
Meloe_mediterraneus
Physomeloe_corallifer
Megetra_punctata
Tegrodera
Hycleus_dufourii
6NC_036044
7NC_036045
Croscherichia_paykulli
Mylabris_quadripunctata
8NC_036046
Actenodia_billbergi
5.0
70
60
50
40
30
20
10
0

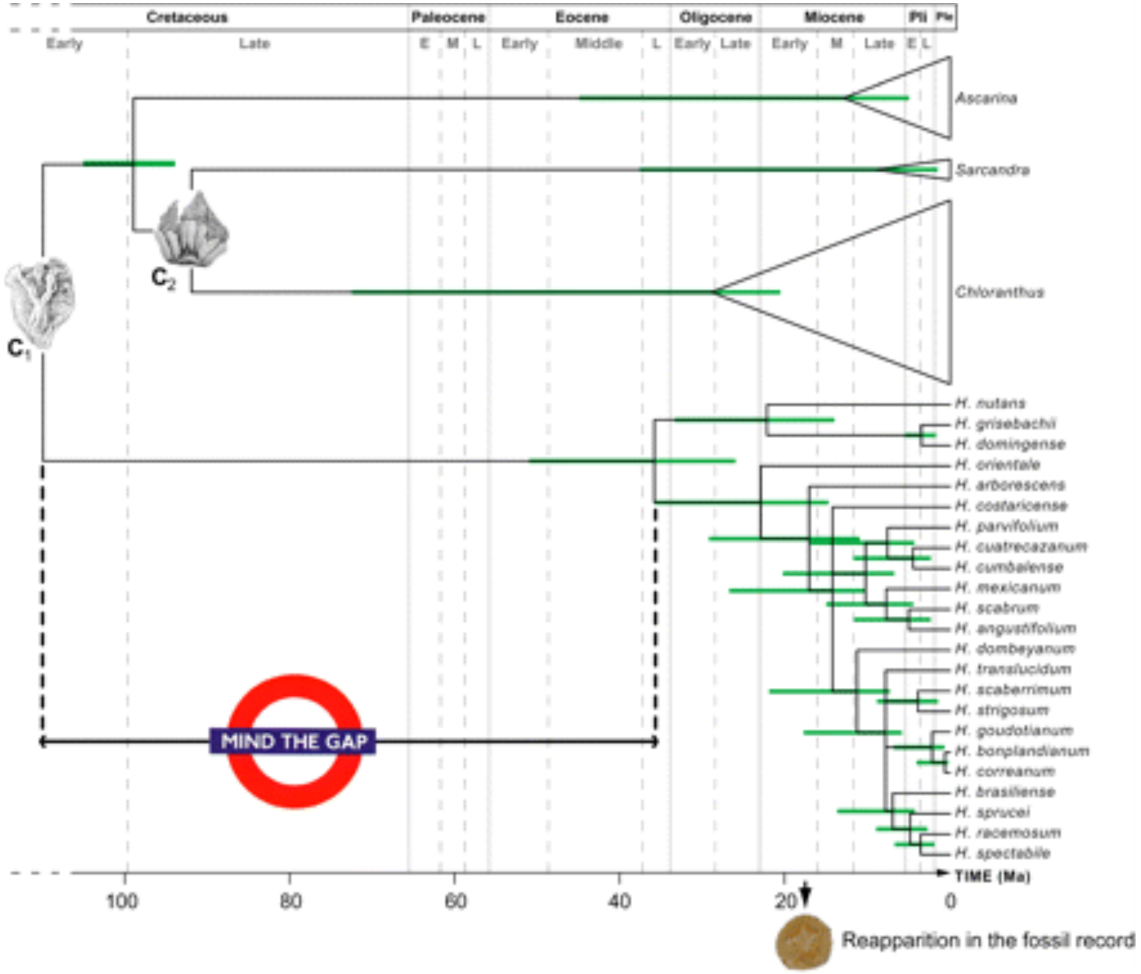

Oedemera_virescens
Ischnomera_caerulea
Mycetophagus_quadripustulatus
NC_037196
KF418153
NC_027256
FJ859904
Stilpnonotus_mexicanus
Omonadus_floralis
Formicomus
Gnathium_nitidum
Zonitis_atripennis
Zonitis_fernancastroi
Apalus_guerini
Leptopalpus_rostratus
Cissites
Epicauta_tenella
3NC_031820
2KP692789
4NC_036042
5NC_036043
Spastonyx_nemognathoides
Pyrota
Berberomeloe_majalis
Oenas_fusicornis
1KX161859
Lagorina_sericea
Meloe_cavensis
Meloe_mediterraneus
Physomeloe_corallifer
Megetra_punctata
Tegrodera
Hycleus_dufourii
6NC_036044
7NC_036045
Croscherichia_paykulli
Mylabris_quadripunctata
8NC_036046
Actenodia_billbergi
5.0
70
60
50
40
30
20
10
0


Oedemera_virescens
Ischnomera_caerulea
Mycetophagus_quadripustulatus
NC_037196
KF418153
NC_027256
FJ859904
Stilpnonotus_mexicanus
Omonadus_floralis
Formicomus
Gnathium_nitidum
Zonitis_atripennis
Zonitis_fernancastroi
Apalus_guerini
Leptopalpus_rostratus
Cissites
Epicauta_tenella
3NC_031820
2KP692789
4NC_036042
5NC_036043
Spastonyx_nemognathoides
Pyrota
Berberomeloe_majalis
Oenas_fusicornis
1KX161859
Lagorina_sericea
Meloe_cavensis
Meloe_mediterraneus
Physomeloe_corallifer
Megetra_punctata
Tegrodera
Hycleus_dufourii
6NC_036044
7NC_036045
Croscherichia_paykulli
Mylabris_quadripunctata
8NC_036046
Actenodia_billbergi
5.0
70
60
50
40
30
20
10
0

Especiación

$$\lambda = x$$





Antonelli & Sanmartin, 2011

Extinción

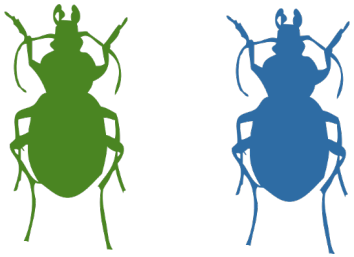
$$\mu = y$$

Diversificación

$$r = (\lambda - \mu)$$

Diversificación

$$r = (\lambda - \mu)$$

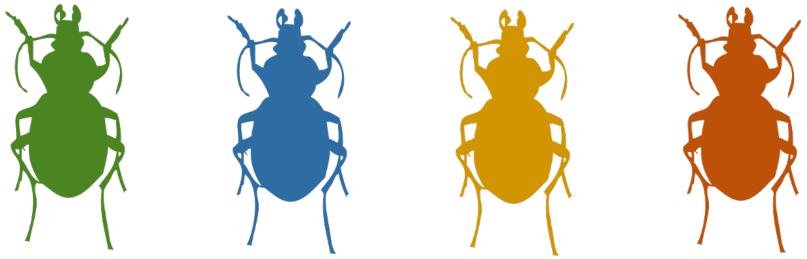


Diversificación

$$r = (\lambda - \mu)$$

Diversificación

$$r = (\lambda - \mu)$$

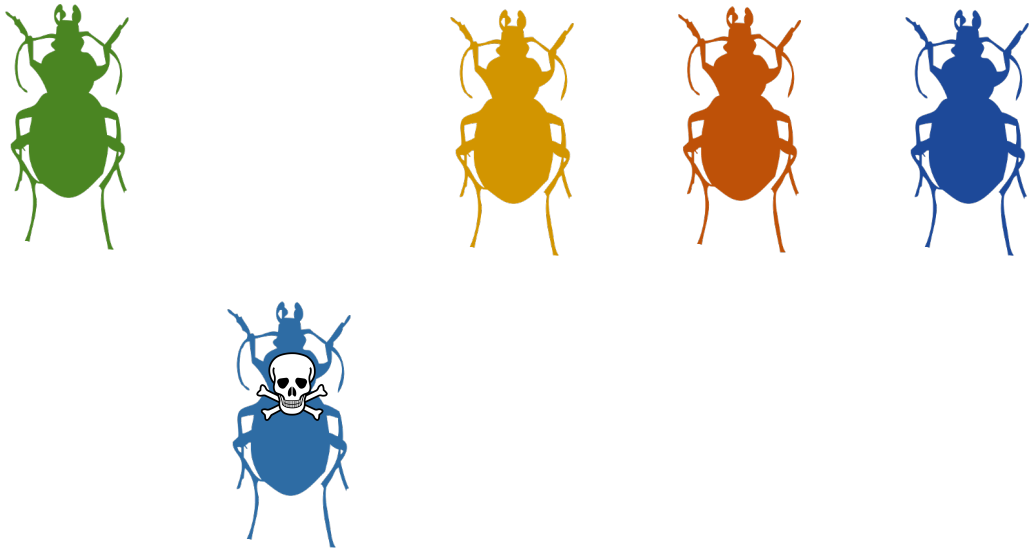


Diversificación

$$r = (\lambda - \mu)$$

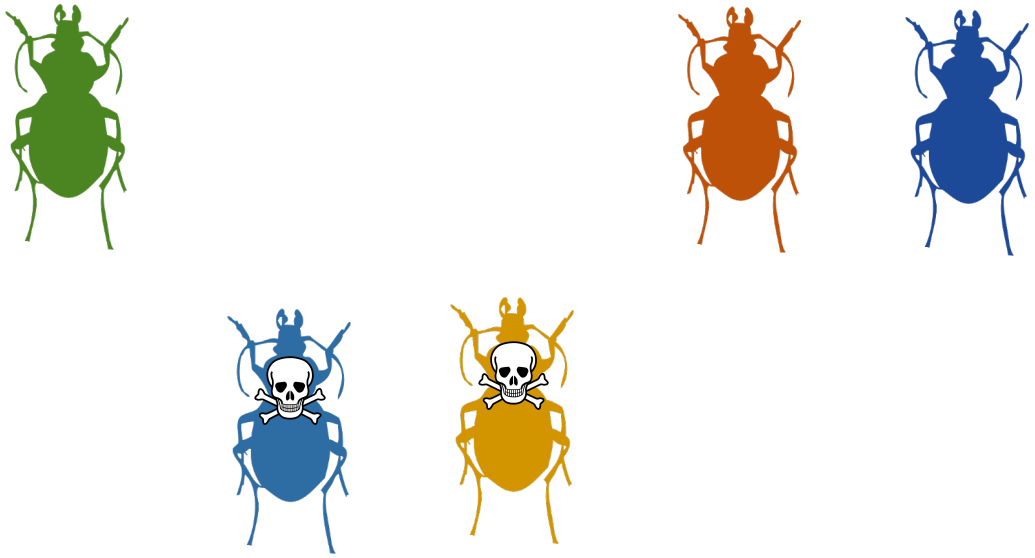
Diversificación

$$r = (\lambda - \mu)$$



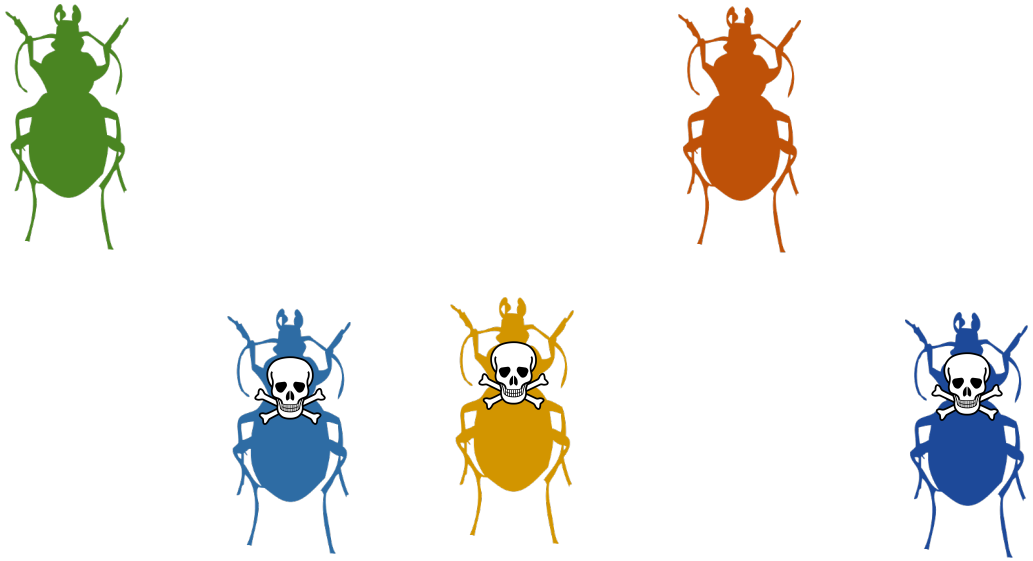
Diversificación

$$r = (\lambda - \mu)$$



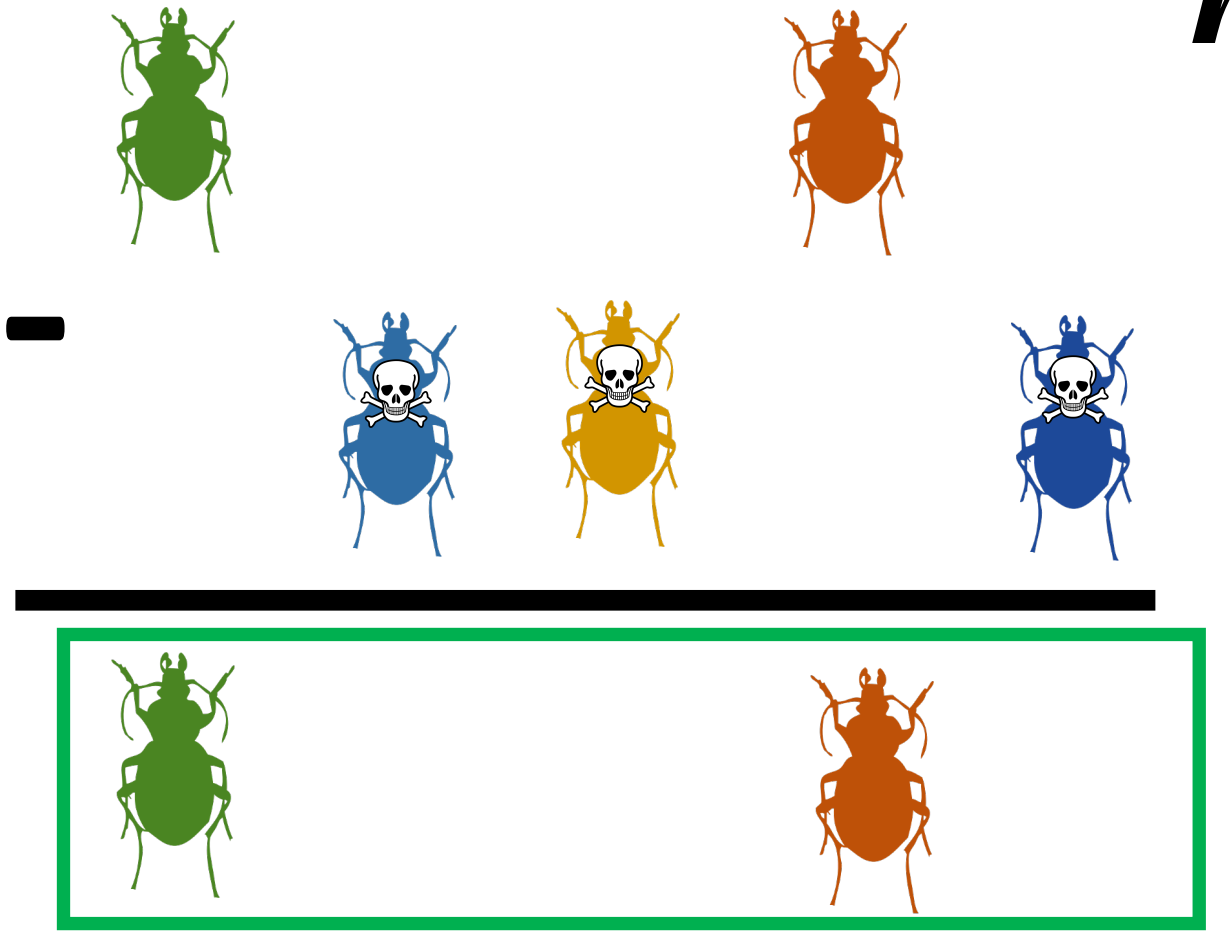
Diversificación

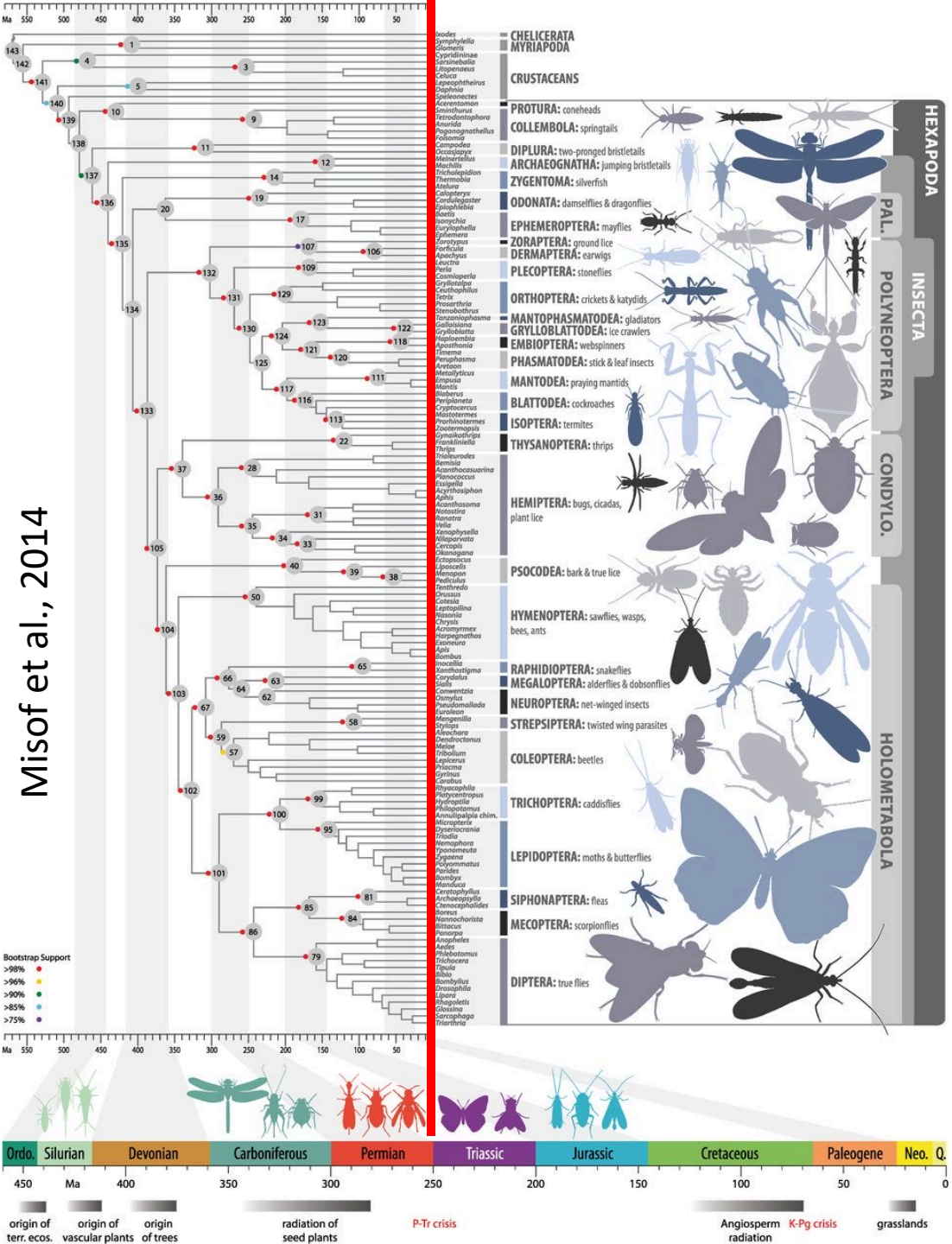
$$r = (\lambda - \mu)$$



Diversificación

$$r = (\lambda - \mu)$$





¿Qué es lo que vemos hoy?

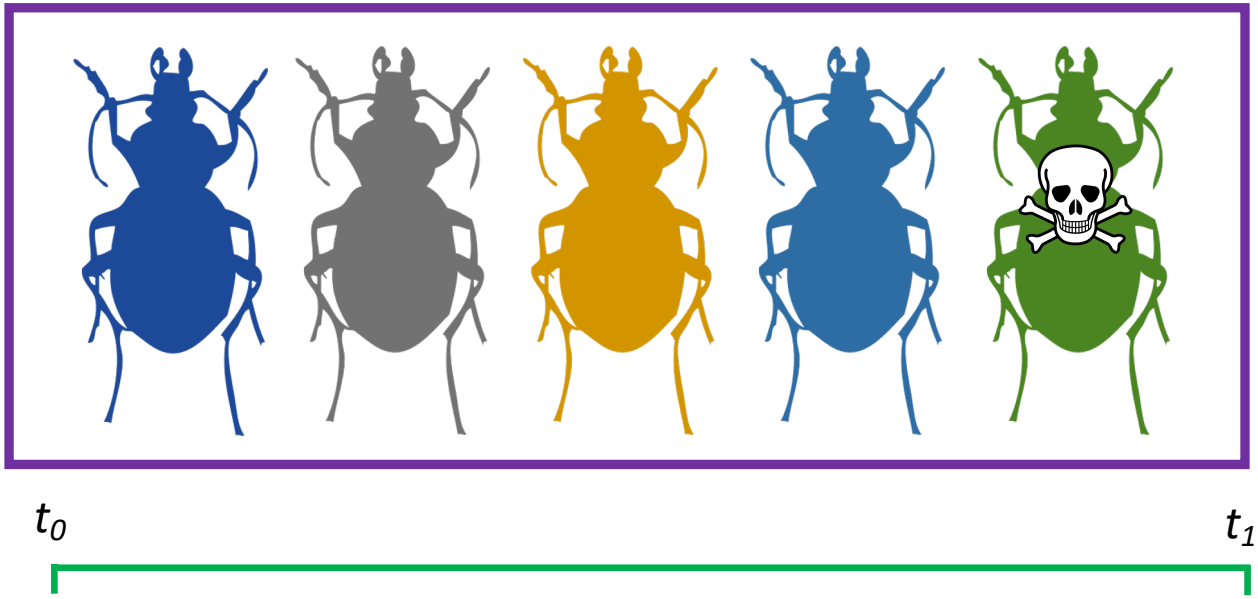
Extinción relativa
Recambio (*turnover*)

$$\varepsilon = (\mu/\lambda)$$

t_0 t_1

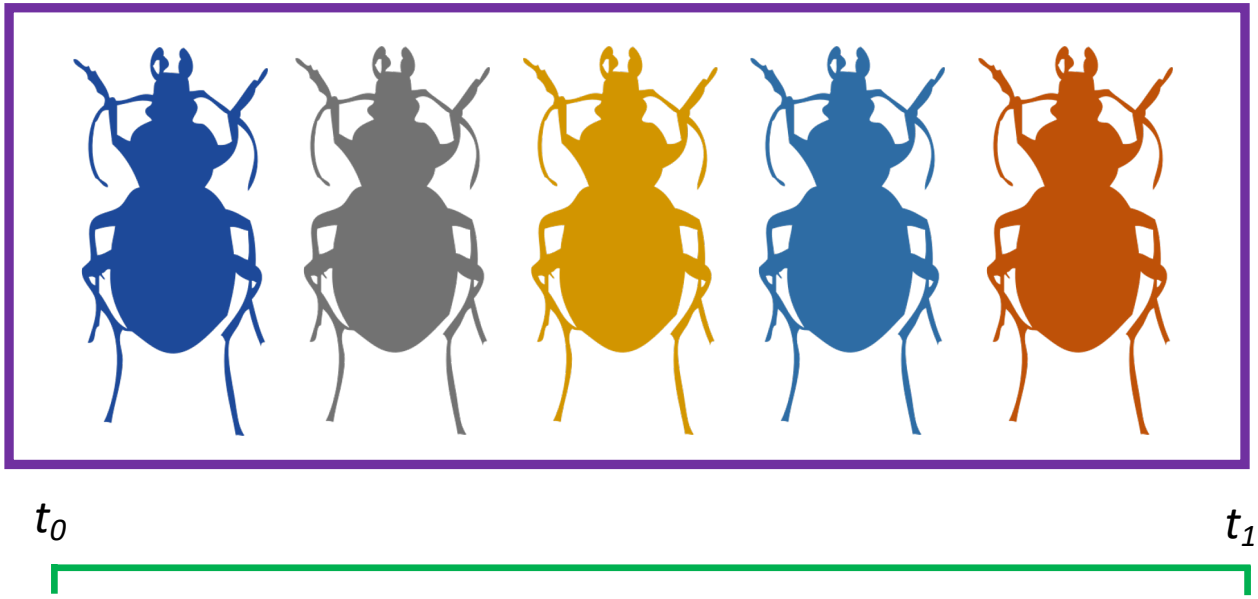
Extinción relativa
Recambio (*turnover*)

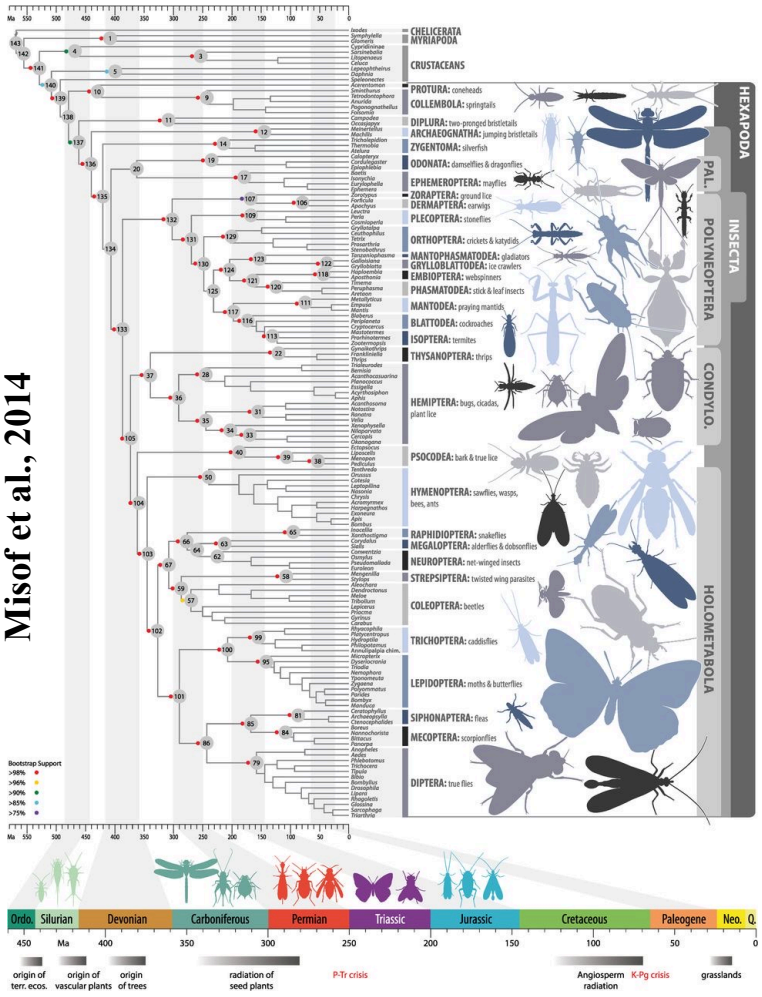
$$\varepsilon = (\mu/\lambda)$$



Extinción relativa
Recambio (*turnover*)

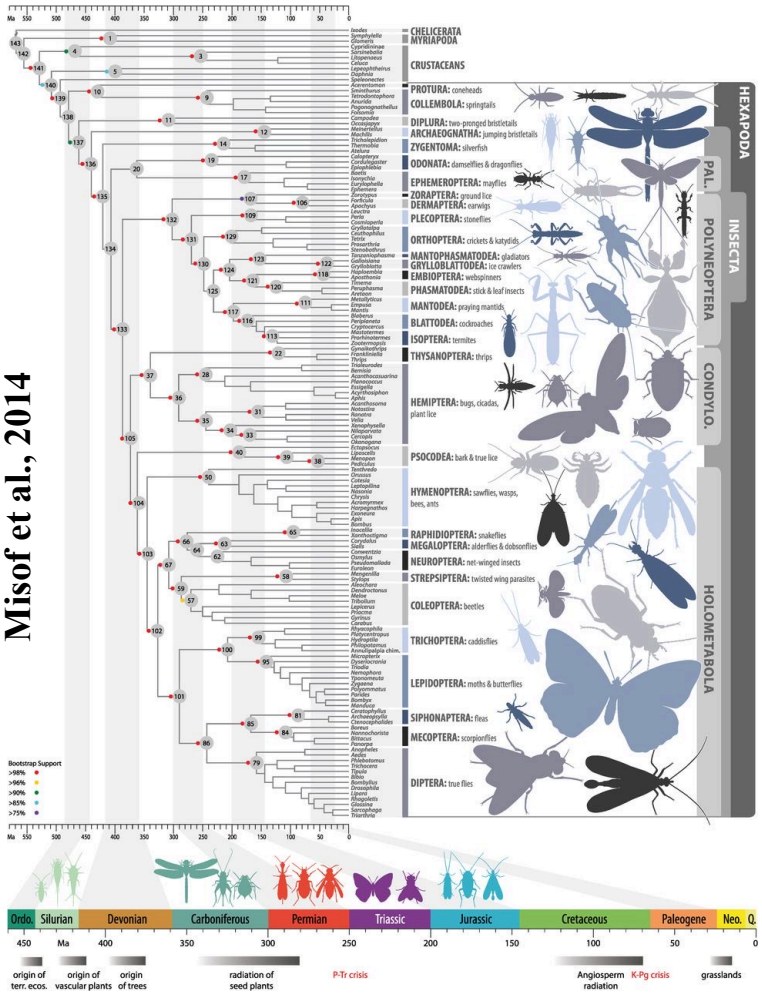
$$\varepsilon = (\mu/\lambda)$$





Misof et al., 2014

¿Por qué hay tantos insectos?

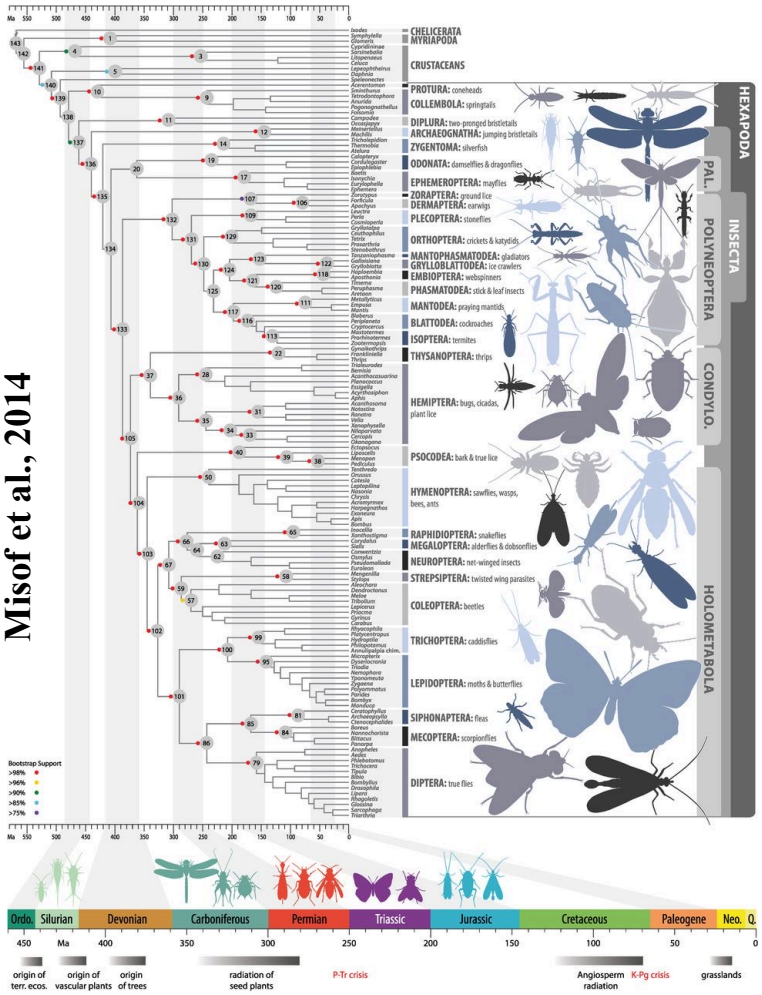


Misof et al., 2014

¿A qué ritmo se lleva a cabo el proceso de especiación en insectos?

$$\lambda_{(\text{Insectos})} = ??$$

DivBayes/SubT Ryberg et al., 2011

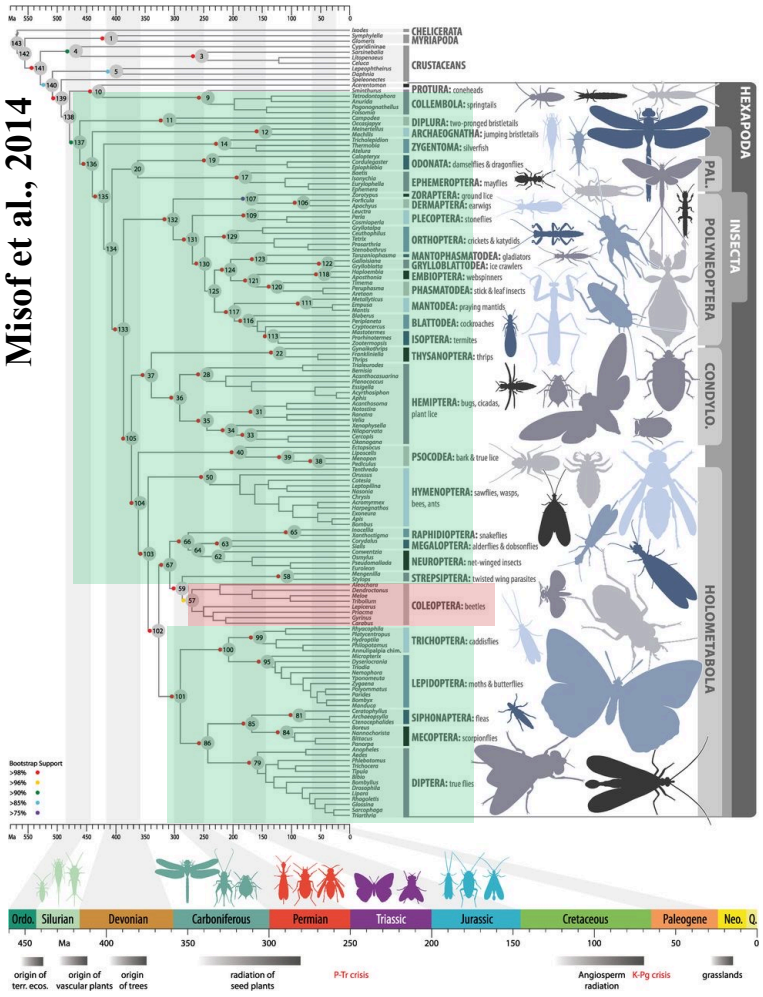


Misof et al., 2014

¿A qué ritmo se extinguen las especies de insectos?

$$\mu_{(\text{Insectos})} = ??$$

DivBayes/SubT Ryberg et al., 2011



¿La especiación en coleópteros es mucho más alta que en el resto de los insectos ?

$$\lambda_{(\text{Insectos})} < \lambda_{(\text{Coleoptera})}$$

¿El resto de los insectos se extingue más que los coleópteros?

$$\mu_{(\text{Insectos})} > \mu_{(\text{Coleoptera})}$$

BAMM Bayesian Analysis of Macroevolutionary Mixtures

Rabosky, 2014

Methods in Ecology and Evolution | BRITISH ECOLOGICAL SOCIETY

Application | Free Access

RPANDA: an R package for macroevolutionary analyses on phylogenetic trees

Hélène Morlon, Eric Lewitus, Fabien L. Condamine, Marc Manceau, Julien Clavel, Jonathan Drury

First published: 15 December 2015 | https://doi.org/10.1111/2041-210X.12526 | Cited by: 49

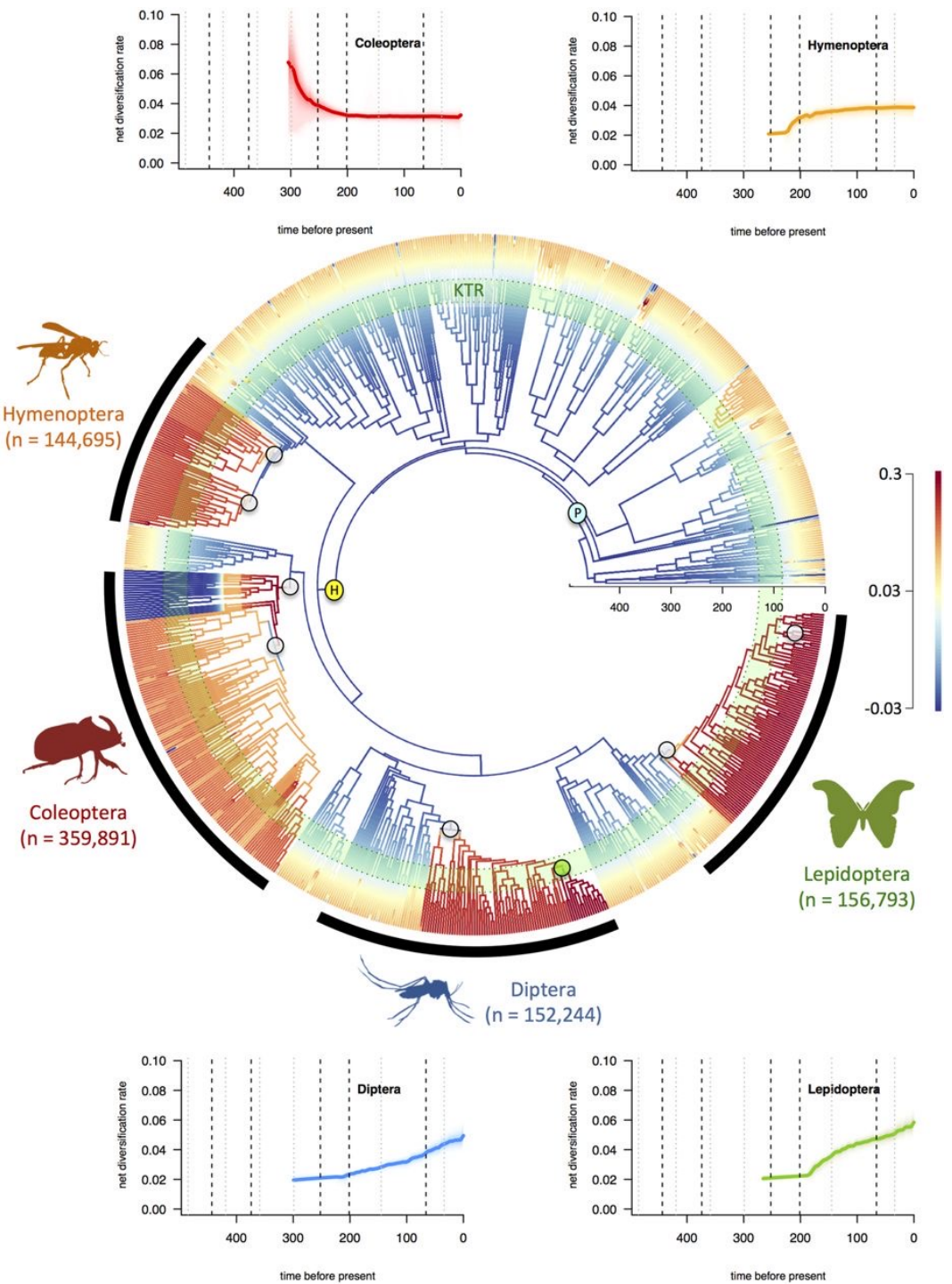
Morlon et al., 2015

Software Tutorials Workshops Jobs Developer

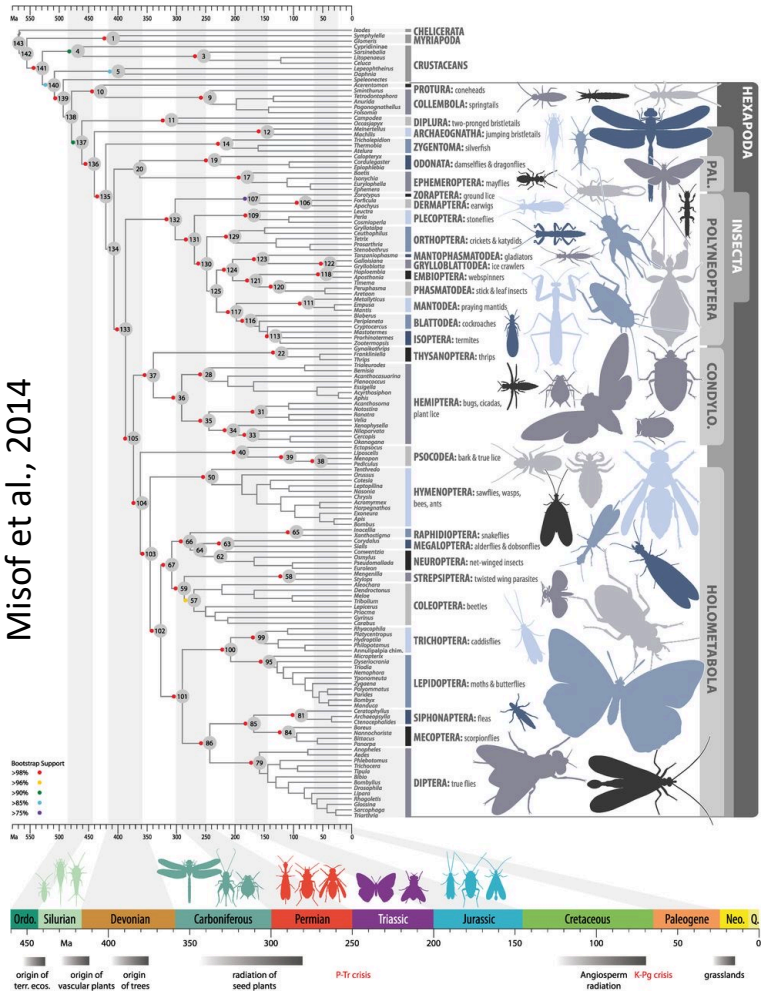
RevBayes

Bayesian phylogenetic inference using probabilistic graphical models and an interpreted language

Höhna et al., 2016



Condamine et al., 2016



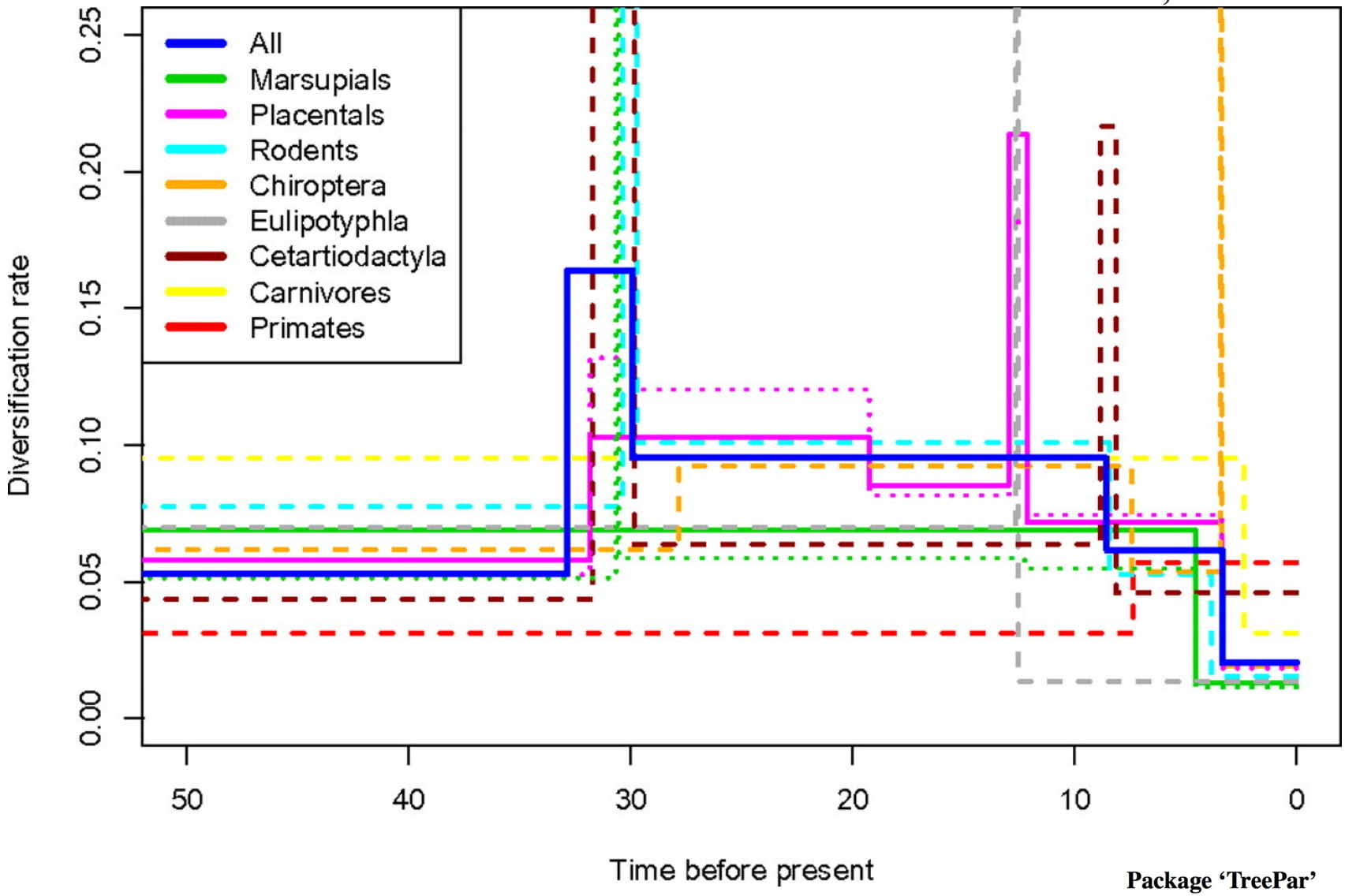
Misof et al., 2014

¿Ha habido cambios significativos en la tasa de diversificación de los insectos a lo largo del tiempo?

$$r_{t0} < \Delta r_{t1}$$

$$r_{t0} > \Delta r_{t1}$$

Stadler, 2011



Software Tutorials Workshops Jobs Developer

RevBayes

Bayesian phylogenetic inference using probabilistic graphical models and an interpreted language

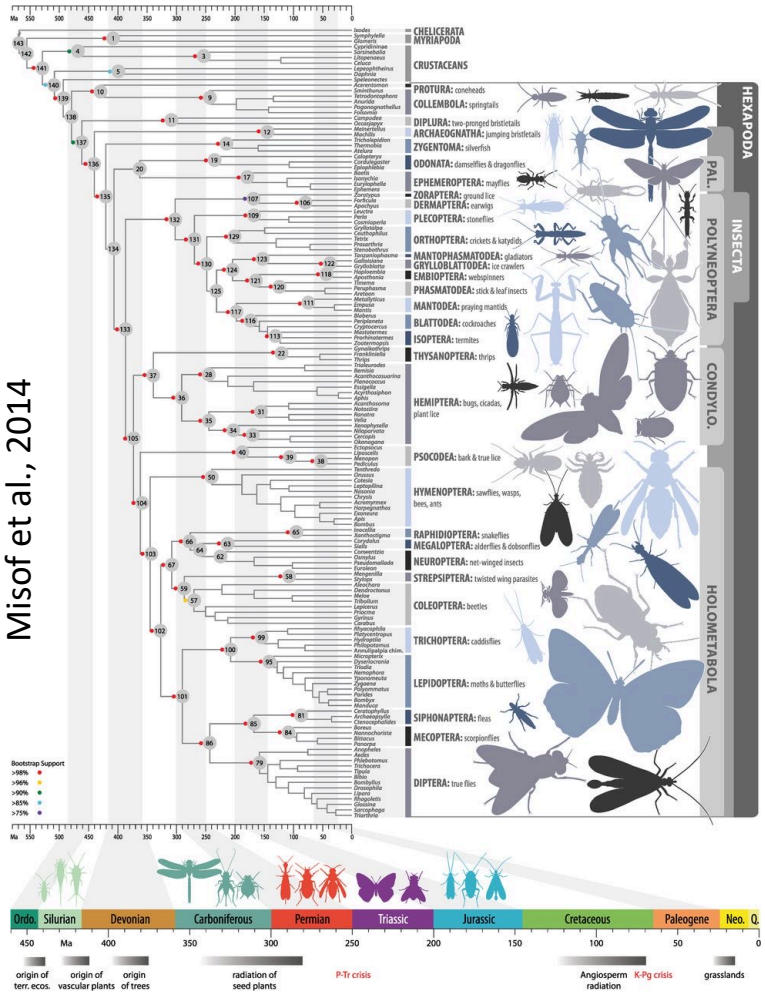
Höhna et al., 2016

Package 'TreePar'

February 19, 2015

Type Package
Title Estimating birth and death rates based on phylogenies
Version 3.3
Date 2015-01-02
Author Tanja Stadler

Stadler, 2011



Misof et al., 2014

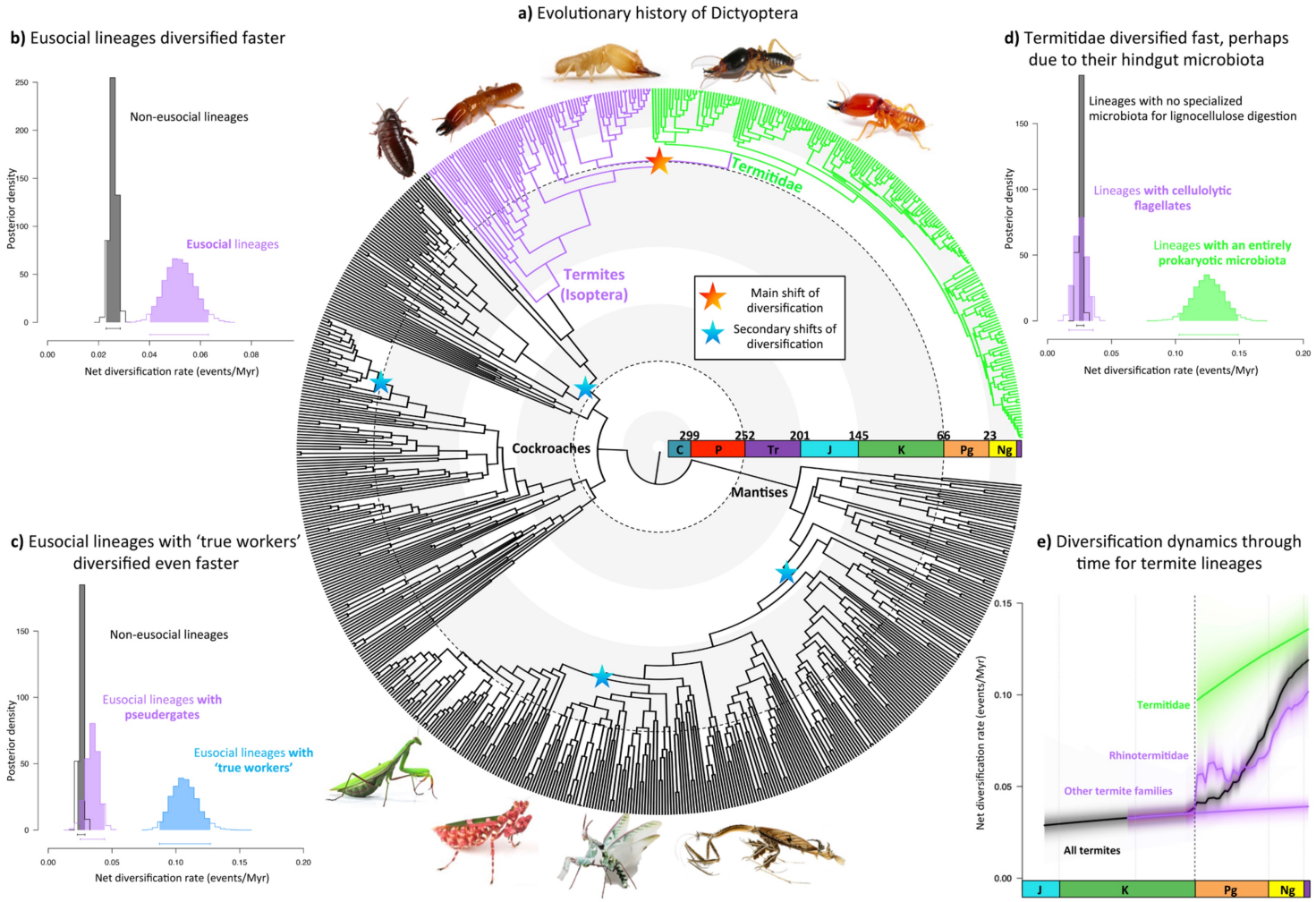
¿El aumento en la tasa de diversificación está asociado a un estado de carácter?

$$r \sim f(A)$$

ó

$$r \sim f(B)$$

Legendre & Condamine, 2018



Package 'diversitree'

April 5, 2017

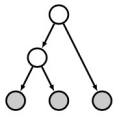
Version 0.9-10

Title Comparative 'Phylogenetic' Analyses of Diversification

Author Richard G. FitzJohn <fitzjohn@zoology.ubc.ca>, with 'GeoSSE' and 'ClaSSE' by Emma E. Goldberg <eeg@uic.edu>, and 'BiSSE-ness' by Karen Magnuson-Ford.

FitzJohn et al., 2012

Software Tutorials Workshops Jobs Developer



RevBayes

Bayesian phylogenetic inference using probabilistic graphical models and an interpreted language

Höhna et al., 2016

Methods in Ecology and Evolution | BRITISH ECOLOGICAL SOCIETY

Application | Free Access

RPANDA: an R package for macroevolutionary analyses on phylogenetic trees

Hélène Morlon, Eric Lewitus, Fabien L. Condamine, Marc Manceau, Julien Clavel, Jonathan Drury

First published: 15 December 2015 | https://doi.org/10.1111/2041-210X.12526 | Cited by: 49

BAMM — Bayesian Analysis of Macroevolutionary Mixtures

Methods in Ecology and Evolution | BRITISH ECOLOGICAL SOCIETY

Research Article | Open Access

A Bayesian approach for detecting the impact of mass-extinction events on molecular phylogenies when rates of lineage diversification may vary

Michael R. May, Sebastian Höhna, Brian R. Moore

First published: 26 March 2016 | https://doi.org/10.1111/2041-210X.12563 | Cited by: 17

Package 'TreePar'

February 19, 2015

Type Package

Title Estimating birth and death rates based on phylogenies

Version 3.3

Date 2015-01-02

Author Tanja Stadler

Package 'diversitree'

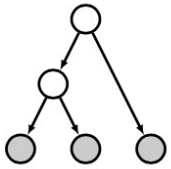
April 5, 2017

Version 0.9-10

Title Comparative 'Phylogenetic' Analyses of Diversification

Author Richard G. FitzJohn <fitzjohn@zoology.ubc.ca>, with 'GeoSSE' and 'ClaSSE' by Emma E. Goldberg <eeg@uic.edu>, and 'BiSSE-ness' by Karen Magnuson-Ford.

Software Tutorials Workshops Jobs Developer



RevBayes

Bayesian phylogenetic inference using probabilistic graphical models and an interpreted language

$$\lambda \sim f(_{\text{wings}}) \quad \lambda \sim f(_{\text{wingless}}) \quad + \quad \lambda_{t0} < \Delta\, \lambda_{t1}$$

$$+ \quad \lambda_{(\text{Strepsiptera})} < \lambda_{(\text{Coleoptera})} \quad + \quad \text{MEE}$$

$$+ \quad \lambda_{(\text{Insects})} = \text{Insect diversification dynamics}$$

Introduction to diversification methods
Summary

- **It is possible to estimate past diversification and turnover rates from neontological data.**
- **To estimate diversification rates a reliable timetree is fundamental**
- **To select the proper method to estimate diversification rates we must focus on what we want to know about diversification dynamics.**
- **The are no a “all-in-one” model, that is why the question will guide the methodological pipeline.**

References

Barraclough, T. G., Vogler, A. P., & Harvey, P. H. (1998). Revealing the factorsthat promote speciation. Philosophical Transactions of the Royal Society B, 353(1366), 241–249.

Beaulieu, J. M., & O'Meara, B. C. (2016). Detecting hidden diversification shifts in models of trait-dependent speciation and extinction. Systematic Biology, 65(4), 583–601. https://doi.org/10.1093/sysbio/syw022

Caetano, D. S., O'Meara, B. C., & Beaulieu, J. M. (2018). Hidden state models improve state-dependent diversification approaches, including biogeographical models. Evolution, 72(11), 2308–2324. https://doi.org/10.1111/evo.13602

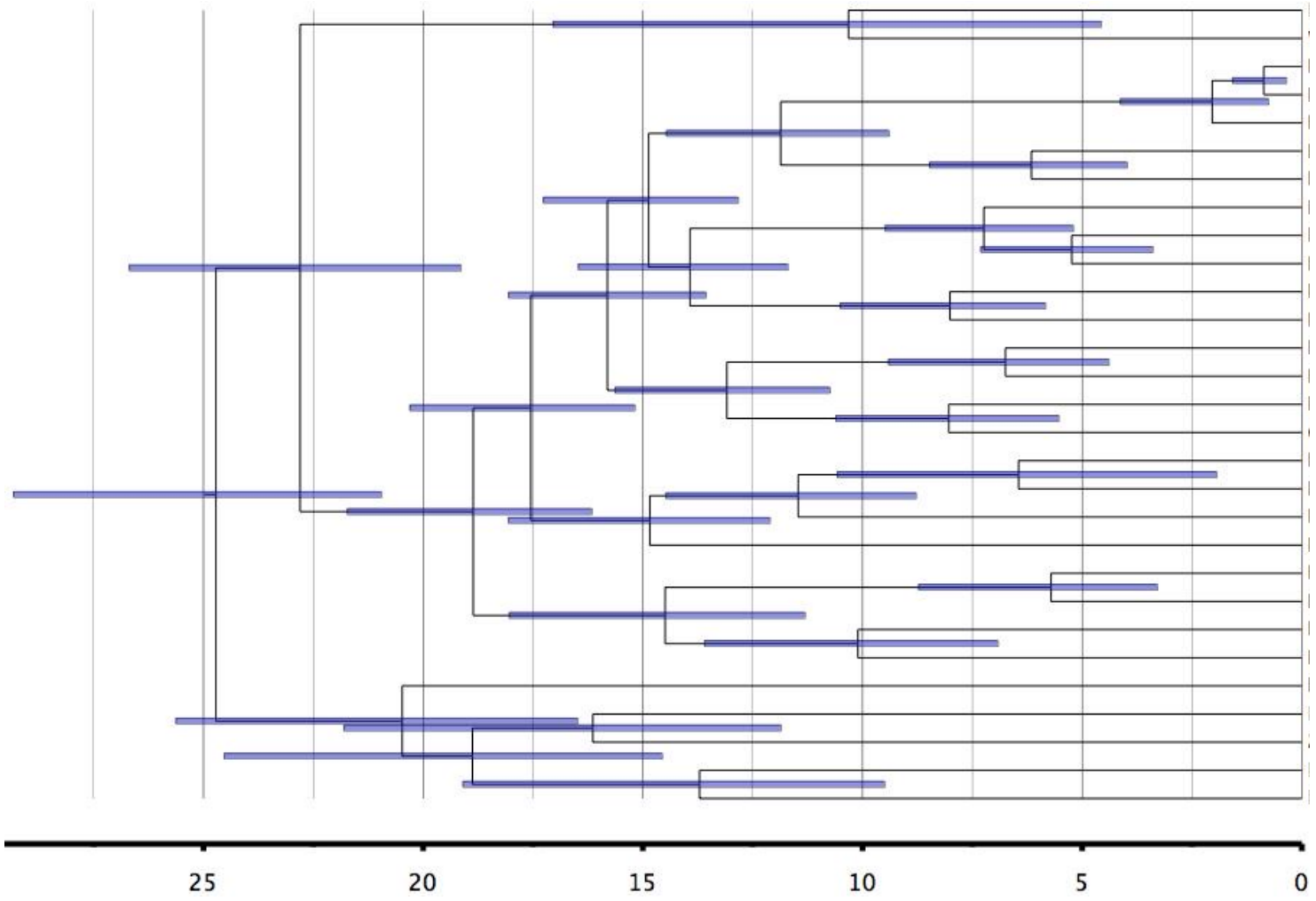
Condamine, F. L., Rolland, J., Höhna, S., Sperling, F. A., & Sanmartín, I. (2018). Testing the role of the Red Queen and Court Jester as drivers of the macroevolution of Apollo butterflies. Systematic Biology, 67(6), 940–964. https://doi.org/10.1093/sysbi o/syy009

Sanmartín, I., & Meseguer, A. S. (2016). Extinction in phylogenetics and biogeography: from timetrees to patterns of biotic assemblage. Frontiers in Genetics, 7, 35. https://doi.org/10.3389/fgene.2016.00035

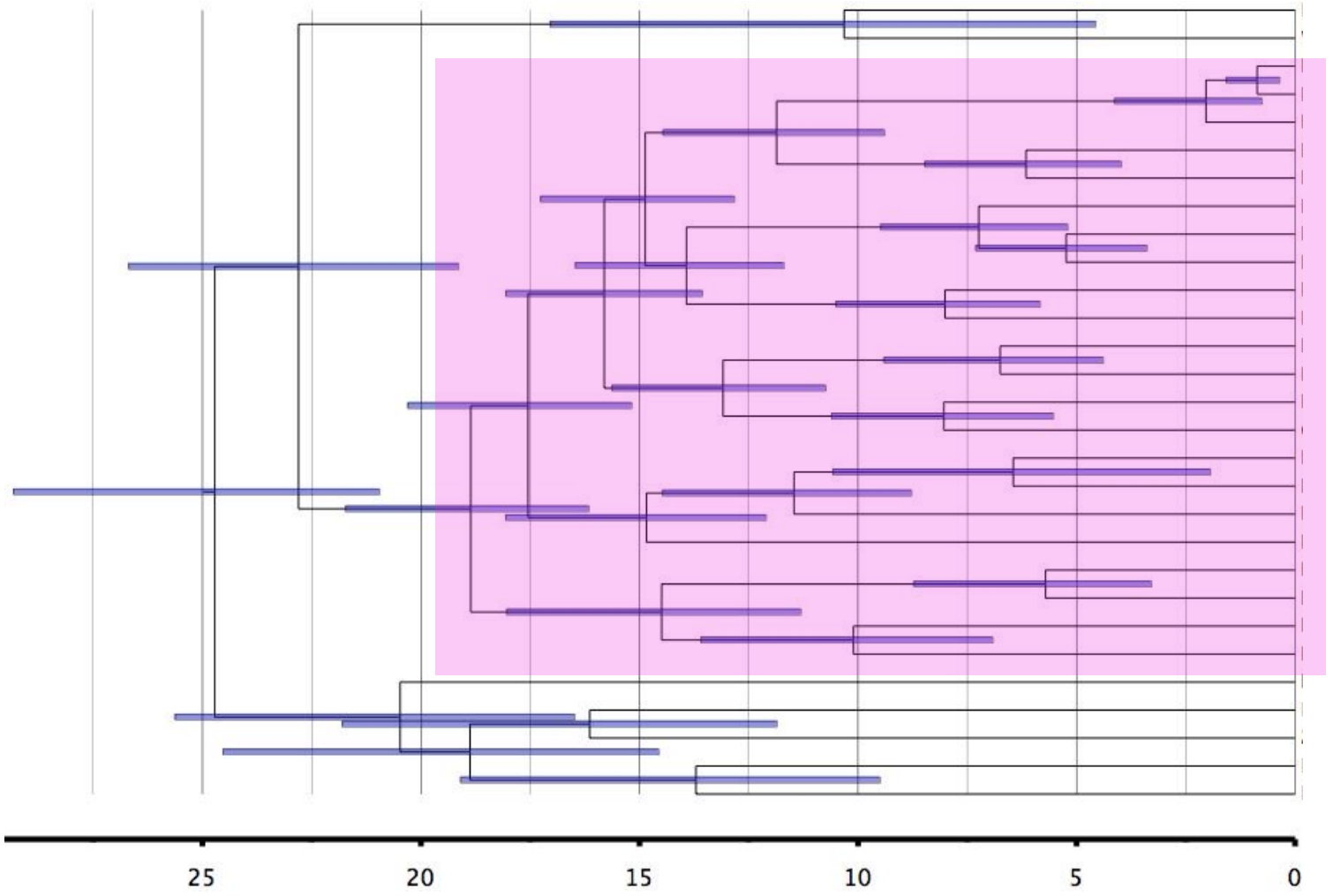
López-Estrada, E. K., Sanmartín, I., Uribe, J. E., Abalde, S., Jiménez-Ruiz, Y., & García-París, M. (2022). Mitogenomics and hidden-trait models reveal the role of phoresy and host shifts in the diversification of parasitoid blister beetles (Coleoptera: Meloidae). Molecular Ecology, 31(8), 2453-2474.

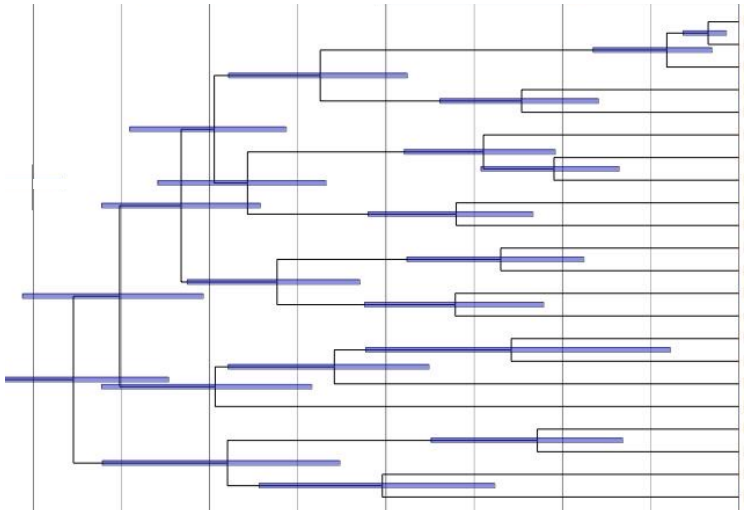
López-Estrada, E. K., Sanmartín, I., García-París, M., & Zaldívar-Riverón, A. (2019). High extinction rates and non-adaptive radiation explains patterns of low diversity and extreme morphological disparity in North American blister beetles (Coleoptera, Meloidae). Molecular Phylogenetics and Evolution, 130, 156–168. https://doi.org/10.1016/j.ympev.2018.09.014

Estimas de tasas de diversificación y extinción: Metodología



Estimas de tasas de diversificación y extinción: Metodología





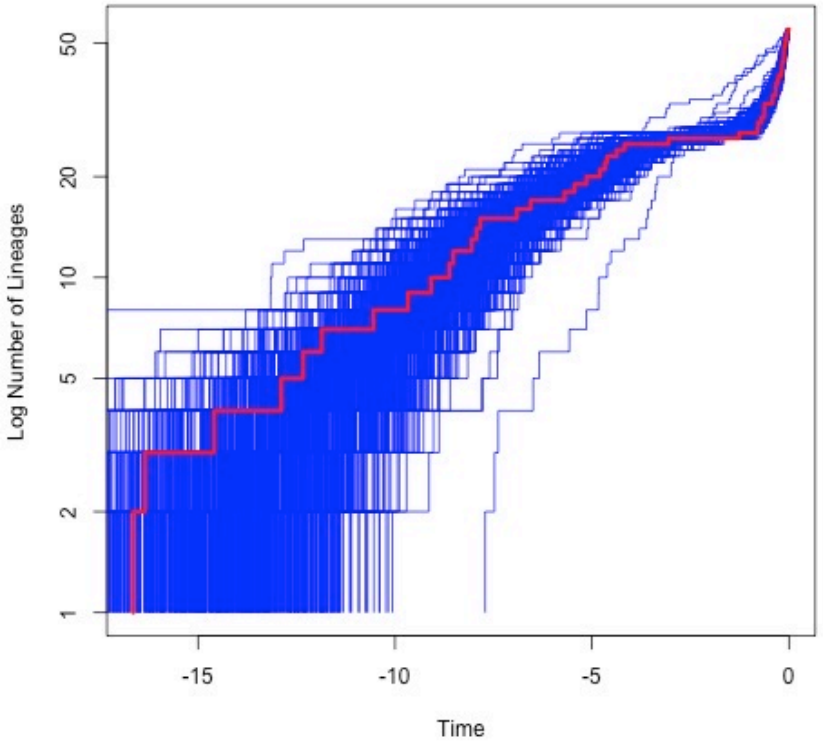
Linajes a lo largo del tiempo

(Lineage through time plot)

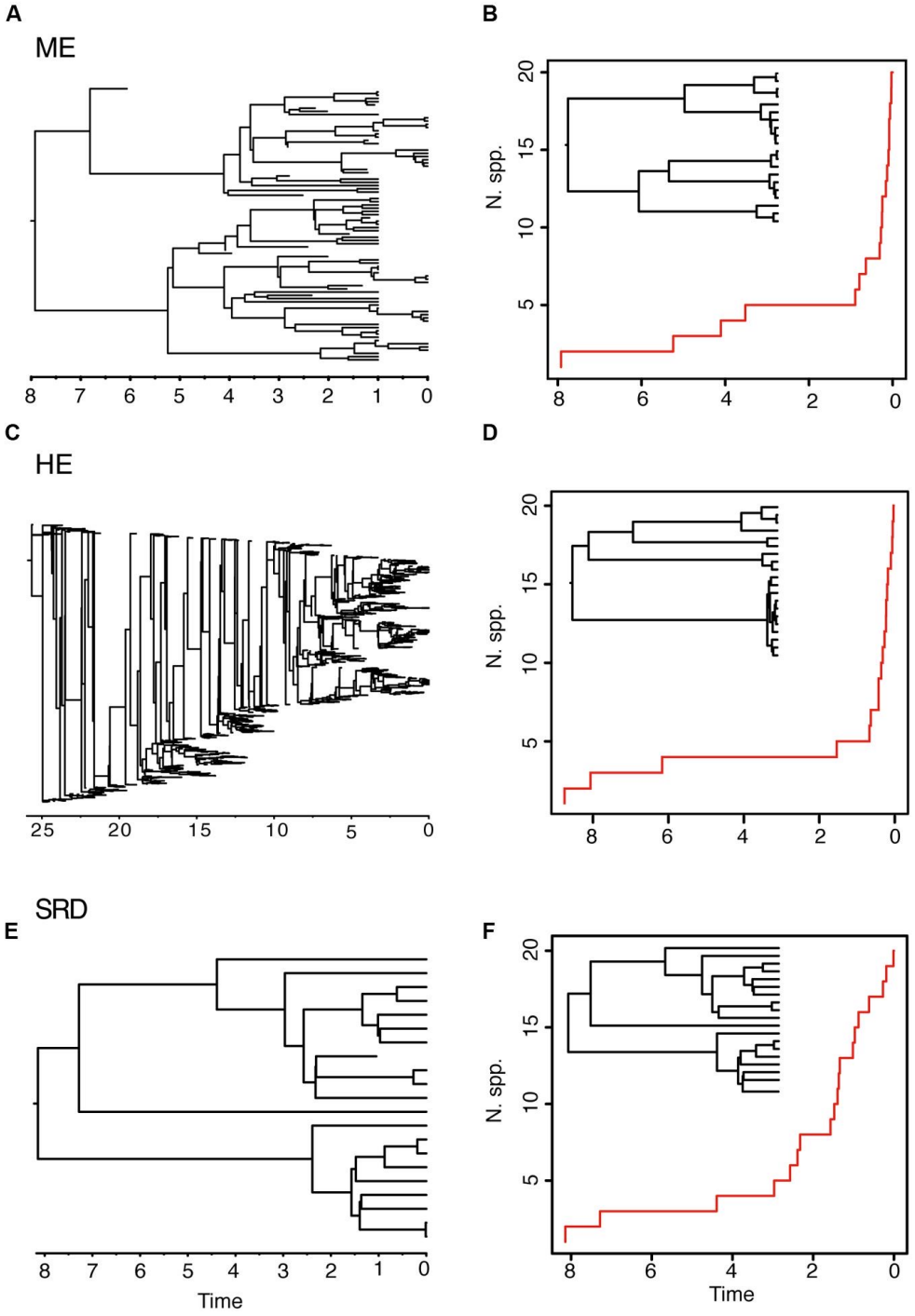
ltt.plot (ape R package)

Explorar el patrón GENERAL de diversificación

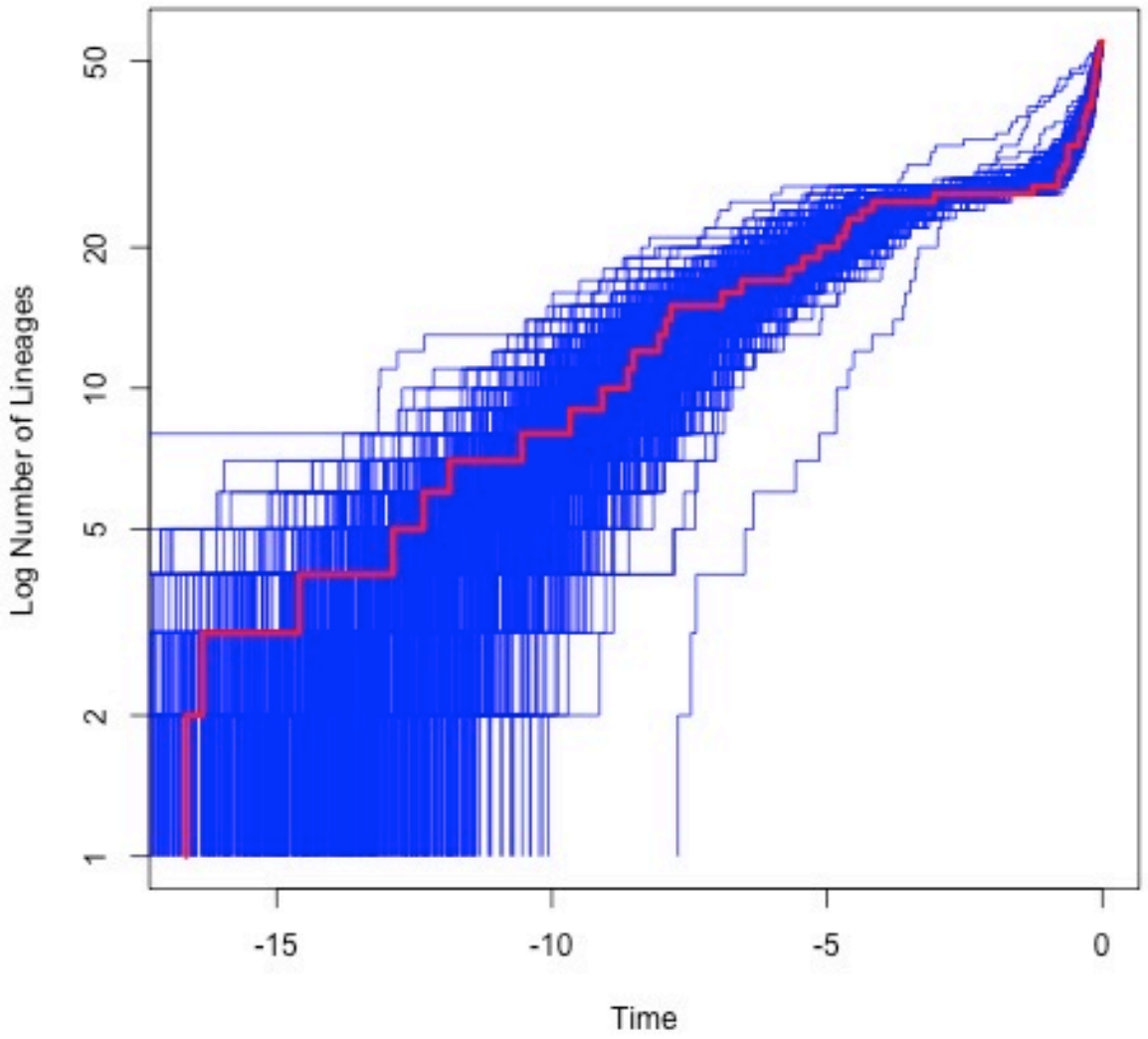
Diferentes historias evolutivas reconstruyen
el mismo patrón



"Pull of the present"

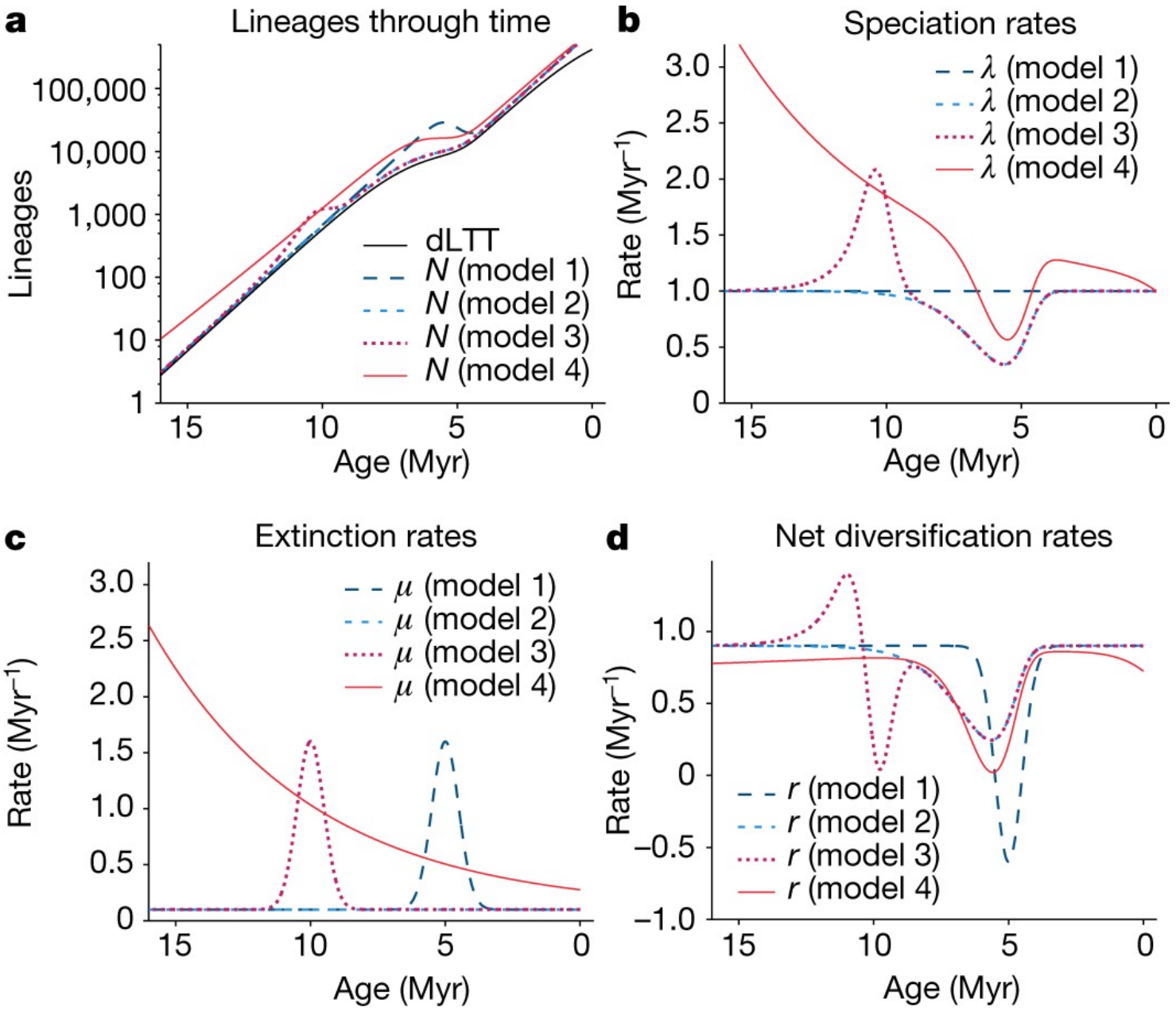


Sanmartín & Meseguer, 2016

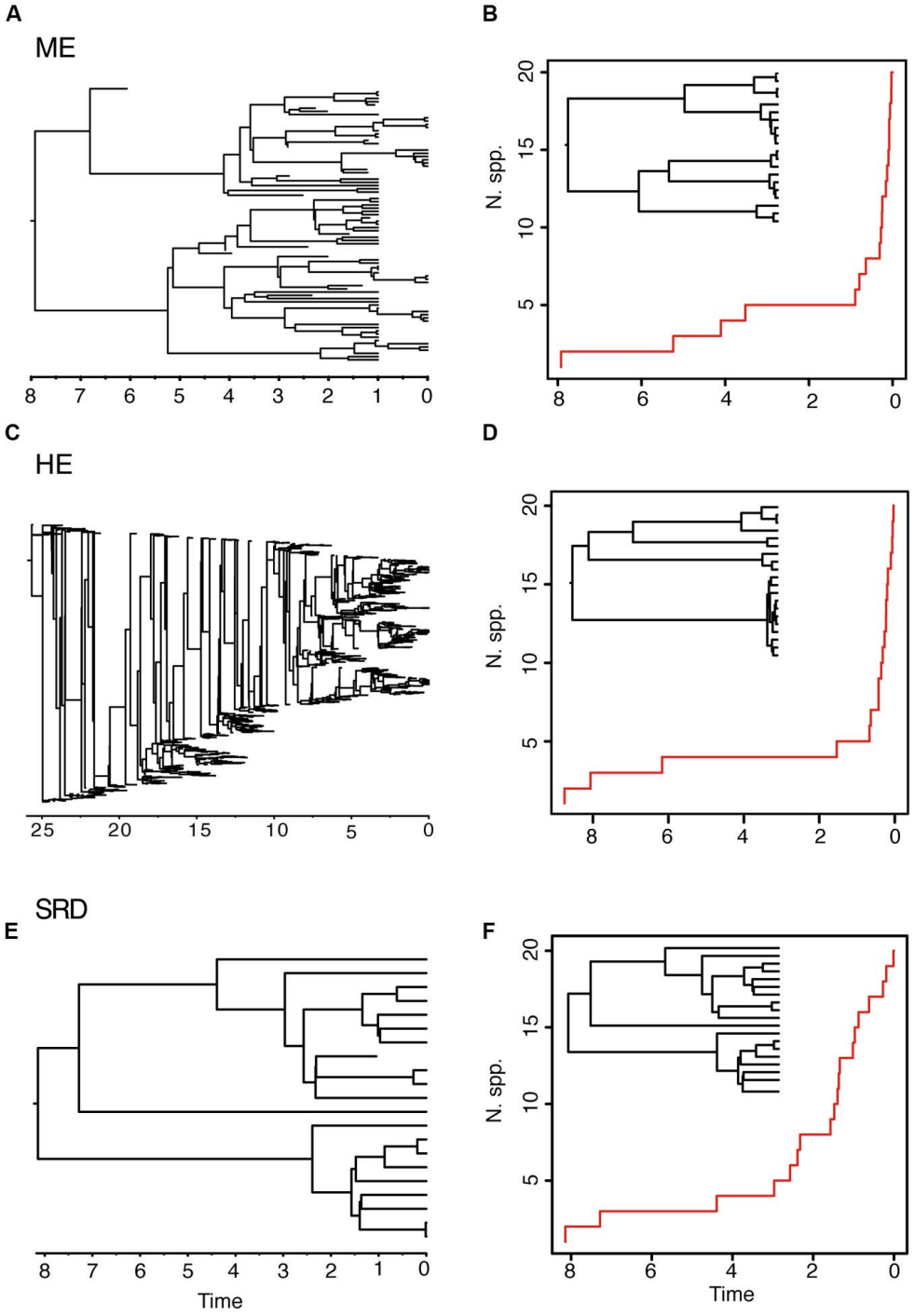


Trees = 600

Remuestreo
MCC BEAST

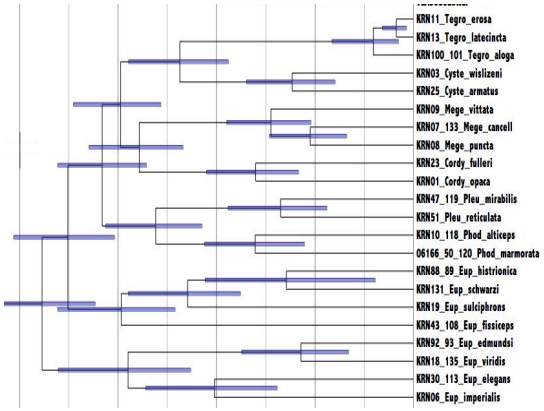


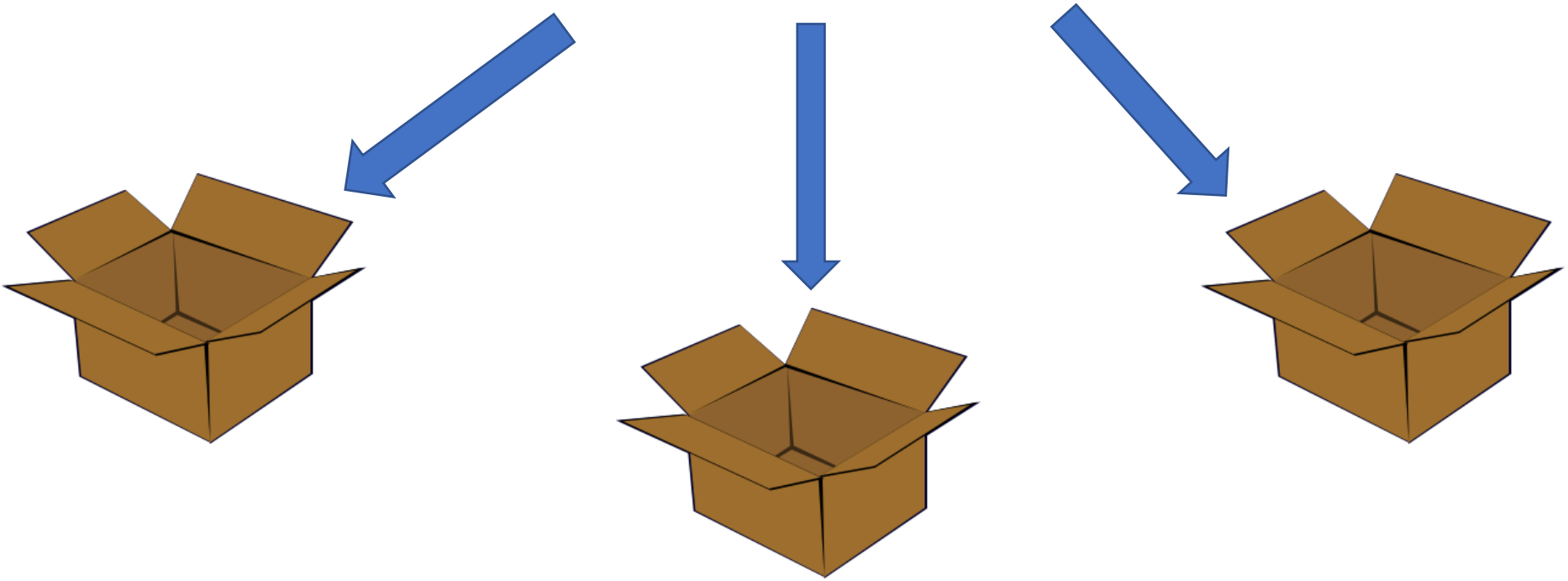
Louca y Pennell, 2020; Nature

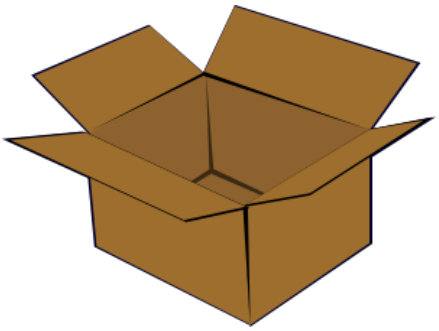


Sanmartín & Meseguer, 2016

Ajuste estadístico a modelos de especiación



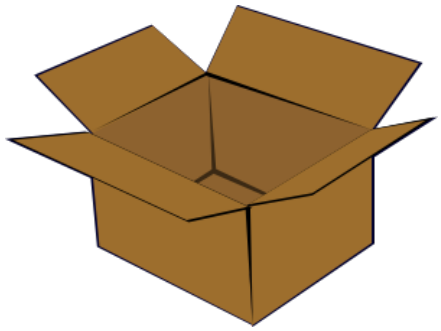




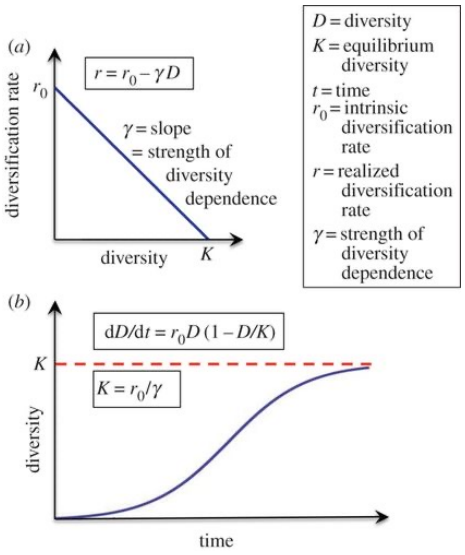
Diversificación constante

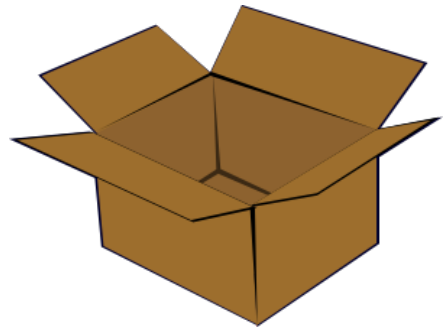
$\lambda = cte.$

$\mu = 0$



Diversificación Dependiente de la densidad





$\lambda \ \mu \neq 0$

Modelo	Características principales	Supuestos	Aplicaciones específicas
Yule (Pure Birth)			
Birth-Death			
Density-Dependent (DD)			

bd.shifts.optim

(TreePar R package)

bd.densdep.optim

bd.shifts.optim(tr,rho,grid,start,end,yule=TRUE)

bd.shifts.optim

(TreePar R package)

bd.densdep.optim

Longitud de las ramas

bd.shifts.optim(tr,rho,grid,start,end,yule=TRUE)

bd.shifts.optim

(TreePar R package)

bd.densdep.optim

Porcentaje de efectividad del muestreo

bd.shifts.optim(tr,rho,grid,start,end,yule=TRUE)

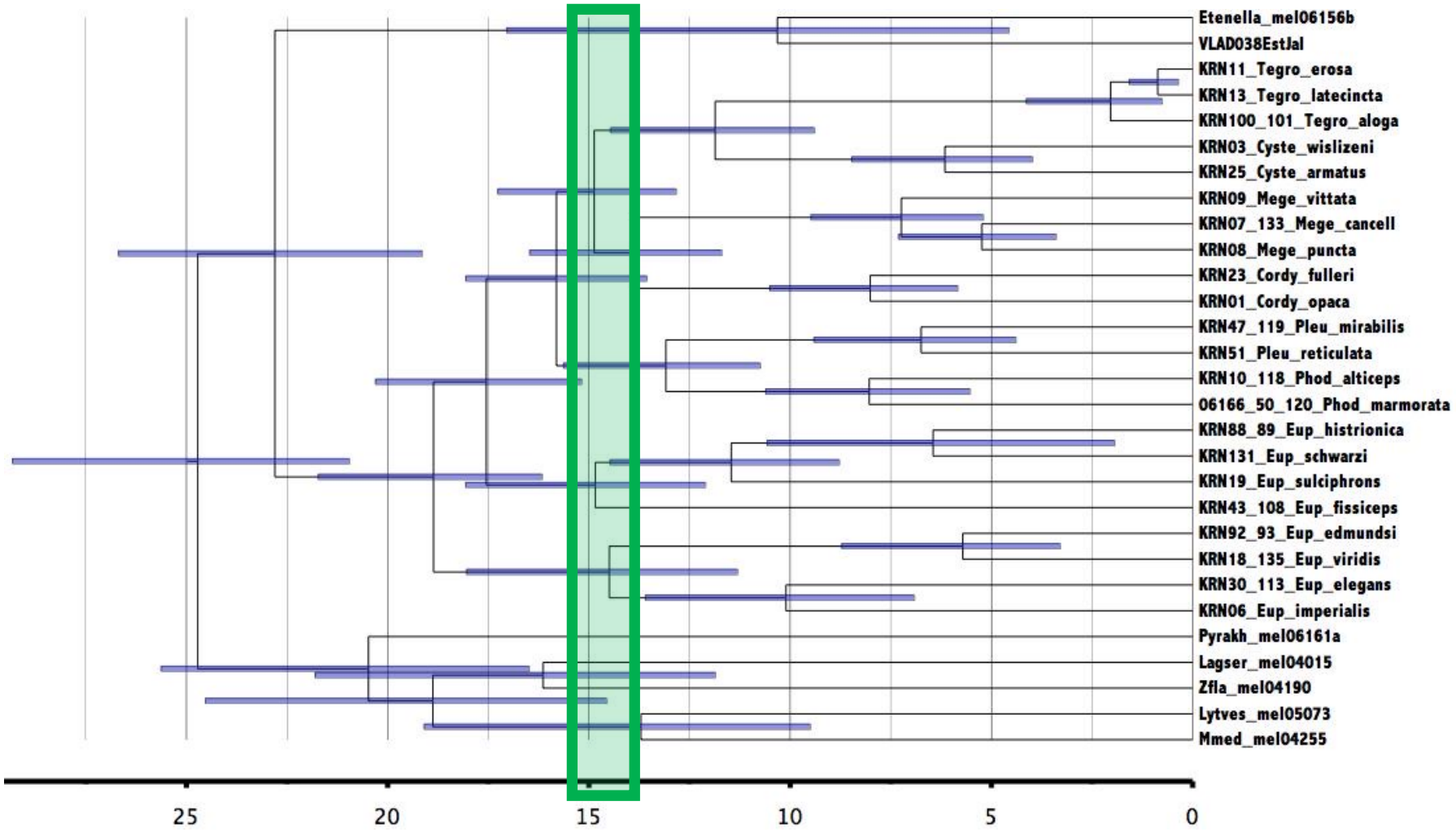
bd.shifts.optim

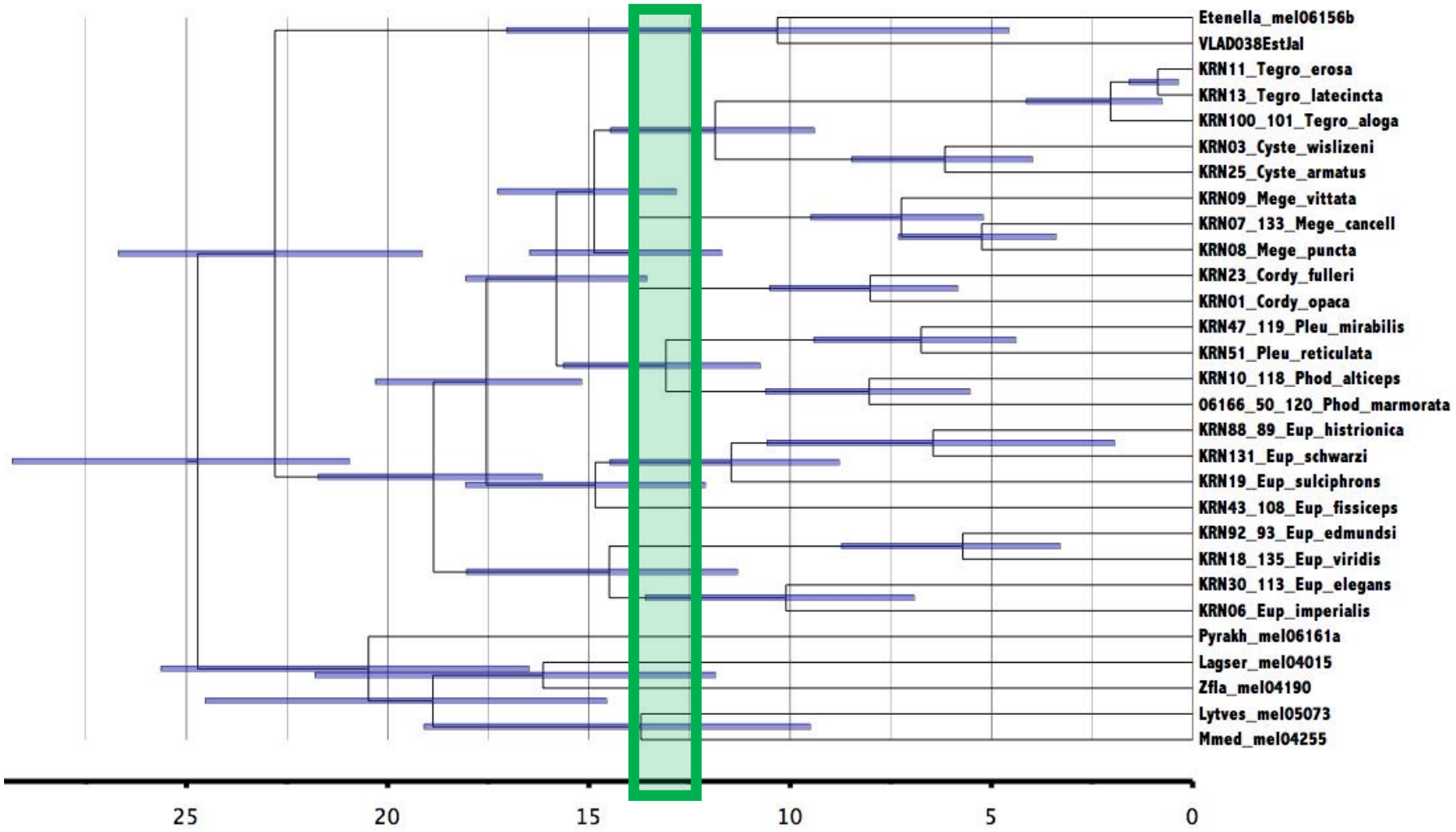
(TreePar R package)

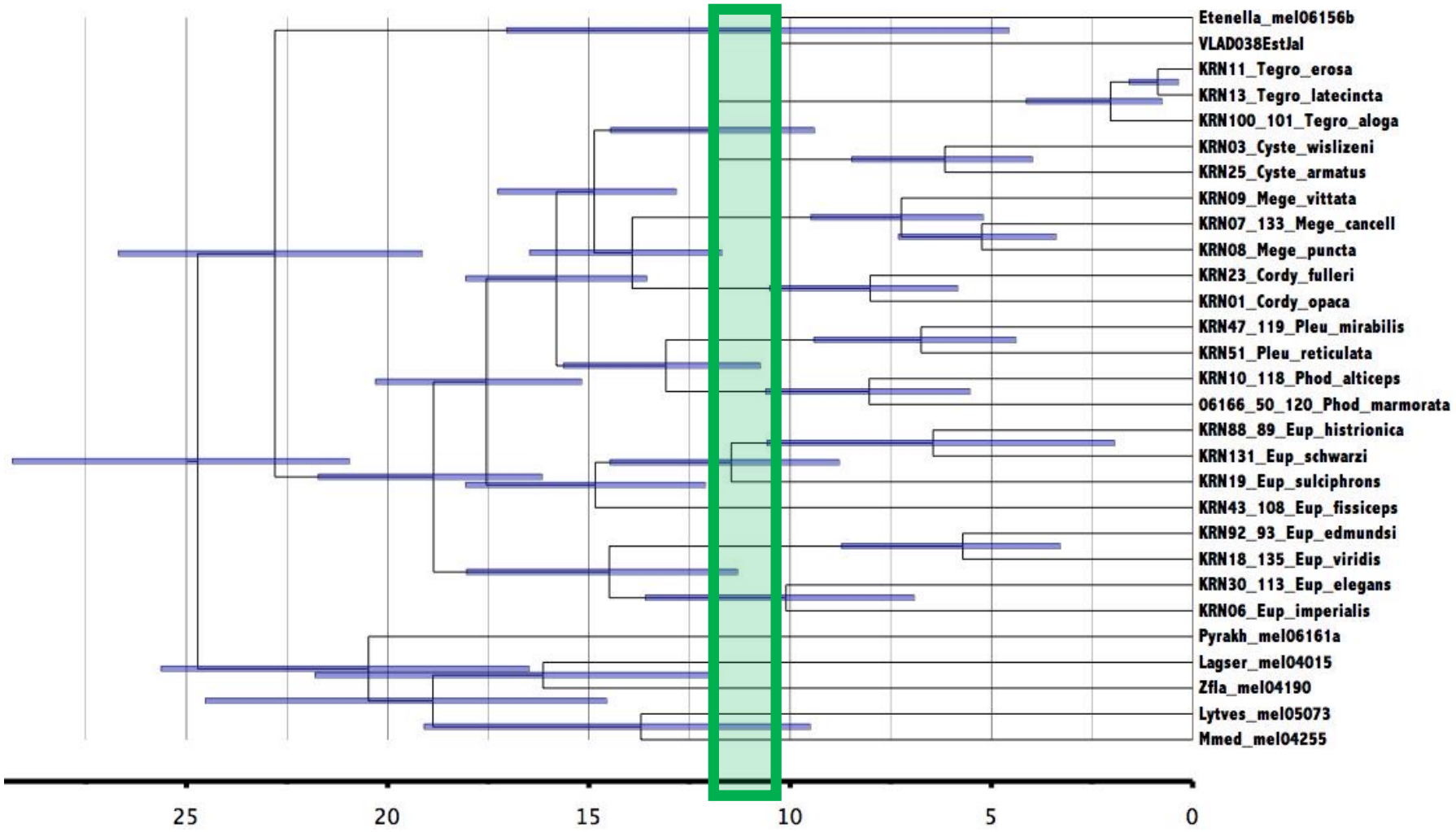
bd.densdep.optim

“ventana” de actualización

bd.shifts.optim(tr,rho,grid,start,end,yule=TRUE)


Etenella_mel06156b
VLAD038EstJal
KRN11_Tegro_erosa
KRN13_Tegro_latecincta
KRN100_101_Tegro_aloga
KRN03_Cyste_wislizeni
KRN25_Cyste_armatus
KRN09_Mege_vittata
KRN07_133_Mege_cancell
KRN08_Mege_puncta
KRN23_Cordy_fulleri
KRN01_Cordy_opaca
KRN47_119_Pleu_mirabilis
KRN51_Pleu_reticulata
KRN10_118_Phod_alticeps
06166_50_120_Phod_marmorata
KRN88_89_Eup_histrionica
KRN131_Eup_schwarzi
KRN19_Eup_sulciphrons
KRN43_108_Eup_fissiceps
KRN92_93_Eup_edmundsi
KRN18_135_Eup_viridis
KRN30_113_Eup_elegans
KRN06_Eup_imperialis
Pyrakh_mel06161a
Lagser_mel04015
Zfla_mel04190
Lytves_mel05073
Mmed_mel04255
25
20
15
10
5
0


Etenella_mel06156b
VLAD038EstJal
KRN11_Tegro_erosa
KRN13_Tegro_latecincta
KRN100_101_Tegro_aloga
KRN03_Cyste_wislizeni
KRN25_Cyste_armatus
KRN09_Mege_vittata
KRN07_133_Mege_cancell
KRN08_Mege_puncta
KRN23_Cordy_fulleri
KRN01_Cordy_opaca
KRN47_119_Pleu_mirabilis
KRN51_Pleu_reticulata
KRN10_118_Phod_alticeps
06166_50_120_Phod_marmorata
KRN88_89_Eup_histrionica
KRN131_Eup_schwarzi
KRN19_Eup_sulciphrons
KRN43_108_Eup_fissiceps
KRN92_93_Eup_edmundsi
KRN18_135_Eup_viridis
KRN30_113_Eup_elegans
KRN06_Eup_imperialis
Pyrakh_mel06161a
Lagser_mel04015
Zfla_mel04190
Lytves_mel05073
Mmed_mel04255
25
20
15
10
5
0


Etenella_mel06156b
VLAD038EstJal
KRN11_Tegro_erosa
KRN13_Tegro_latecincta
KRN100_101_Tegro_aloga
KRN03_Cyste_wislizeni
KRN25_Cyste_armatus
KRN09_Mege_vittata
KRN07_133_Mege_cancell
KRN08_Mege_puncta
KRN23_Cordy_fulleri
KRN01_Cordy_opaca
KRN47_119_Pleu_mirabilis
KRN51_Pleu_reticulata
KRN10_118_Phod_alticeps
06166_50_120_Phod_marmorata
KRN88_89_Eup_histrionica
KRN131_Eup_schwarzi
KRN19_Eup_sulciphrons
KRN43_108_Eup_fissiceps
KRN92_93_Eup_edmundsi
KRN18_135_Eup_viridis
KRN30_113_Eup_elegans
KRN06_Eup_imperialis
Pyrakh_mel06161a
Lagser_mel04015
Zfla_mel04190
Lytves_mel05073
Mmed_mel04255
25
20
15
10
5
0

bd.shifts.optim

(TreePar R package)

bd.densdep.optim

t_0

bd.shifts.optim(tr,rho,grid,start,end,yule=TRUE)

bd.shifts.optim

(TreePar R package)

bd.densdep.optim

Último evento de especiación

bd.shifts.optim(tr,rho,grid,start,end,yule=TRUE)

bd.shifts.optim

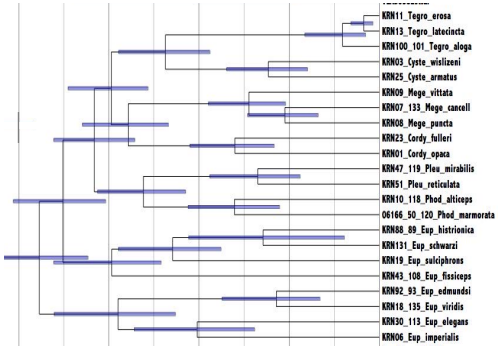
(TreePar R package)

bd.densdep.optim

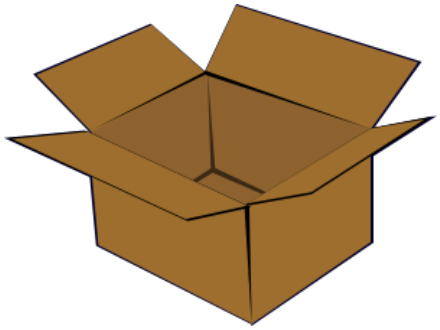
bd.shifts.optim(tr,rho,grid,start,end,yule=TRUE)

$\mu = 0$

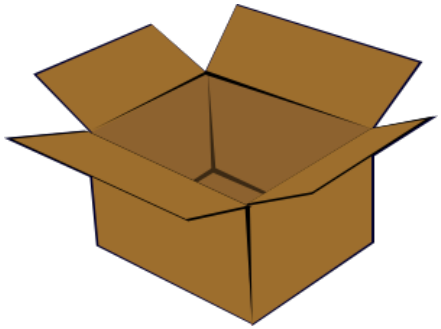
$\mu \neq 0$



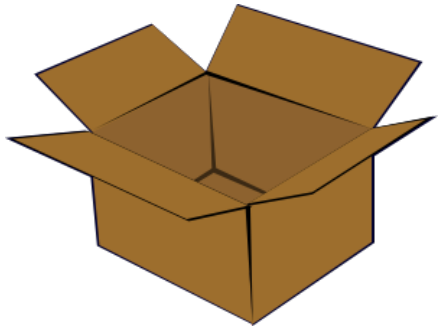
Likelihood ratio test



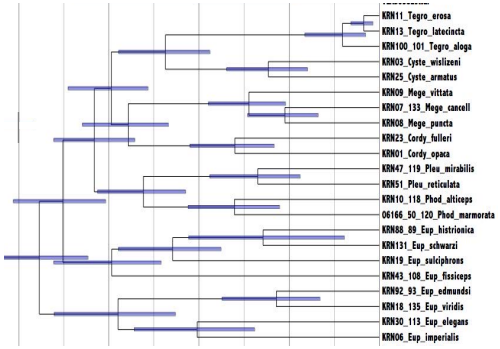
Yule



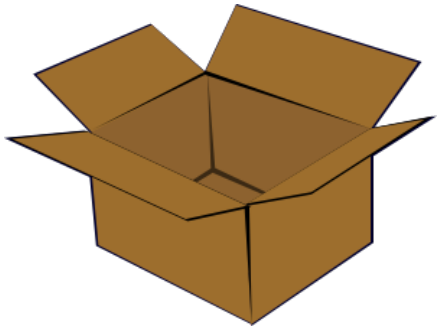
DD



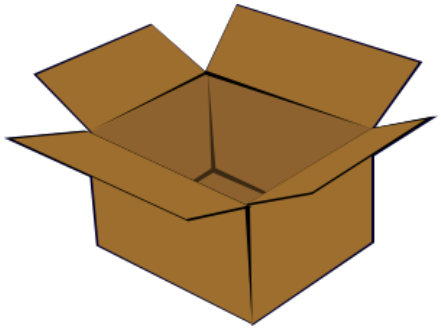
BD



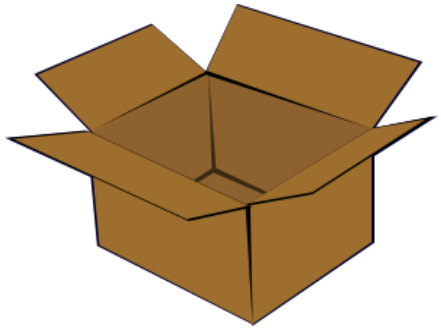
Likelihood ratio test



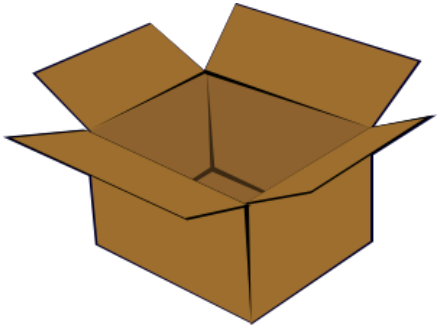
1-Shift



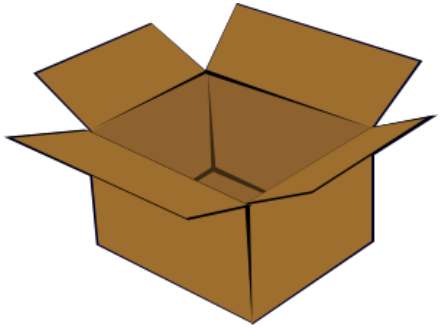
2-Shift



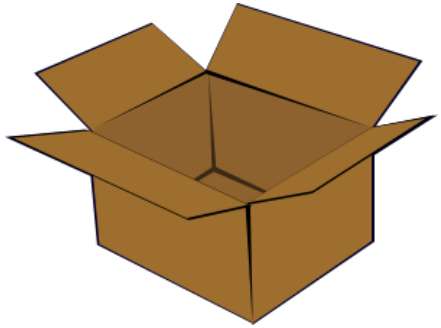
3-Shift



1-MEE

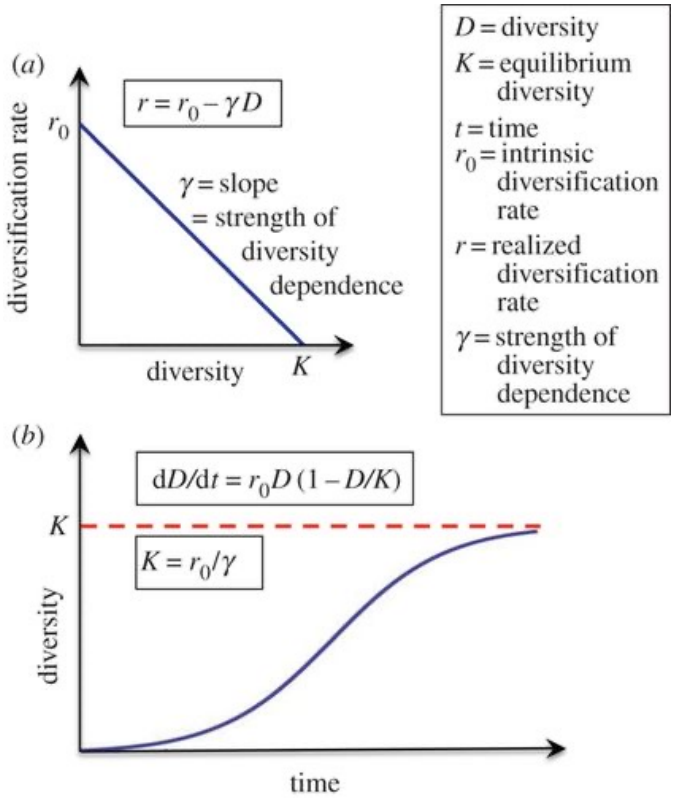


2-MEE



3-MEE

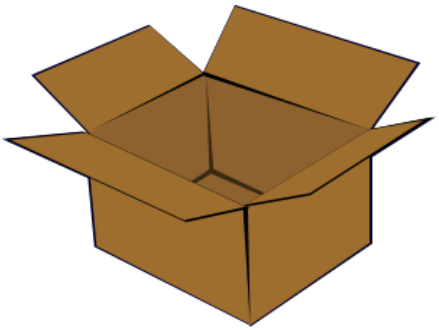
bd.densdep.optim



bd.densdep.optim(x,minK,maxK,discrete=TRUE,continuous=FALSE,lambdainit=2,
muinit=1,Kinit=0,Yule=FALSE,muset=0,rho=1,model=-1)

Prueba de razón de verosimilitud

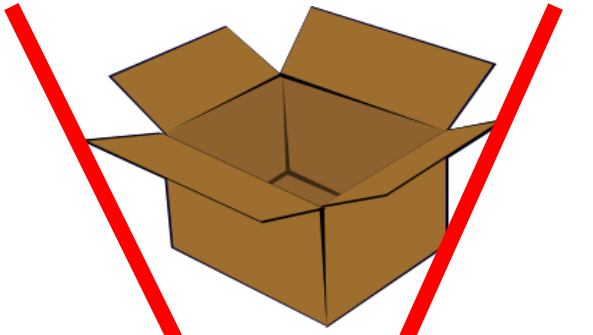
- La prueba de razón de verosimilitud es una prueba de la suficiencia de un modelo más pequeño frente a un modelo más complejo. La hipótesis nula de la prueba indica que el modelo más pequeño proporciona un ajuste tan bueno para los datos como el modelo más grande. Si se rechaza la hipótesis nula, el modelo alternativo más grande proporciona una mejora significativa sobre el modelo más pequeño.
- Para utilizar la prueba de razón de verosimilitud, el modelo de hipótesis nula debe ser un modelo anidado dentro, es decir, un caso especial del modelo de hipótesis alternativo



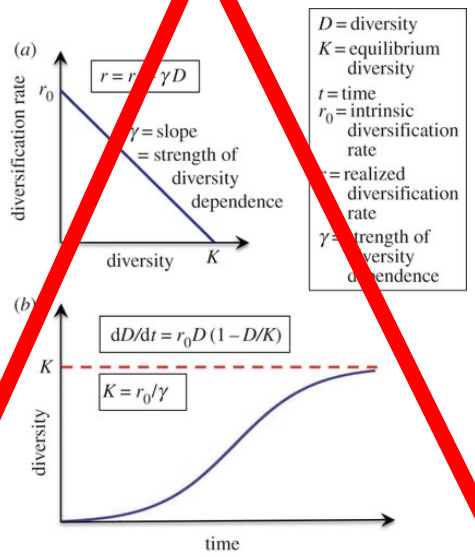
Diversificación constante

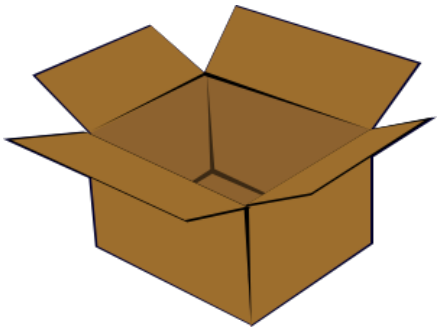
$\lambda = cte.$

$\mu = 0$



Diversificación Dependiente de la densidad





$\lambda \ \mu \neq 0$

LR = 2*(lnL1-lnL2)

Modelos en RevBayes

Bayes Factor en RevBayes