Stability and turnover of tropical forest communities

Change in species abundances

Climate and forest change

Nordforsk PhD Summer School
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Richard Condit and …

… the CTFS Working Group

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A tendency for species to increase when rare, then, would constitute evidence for niche theory and against neutral theory.

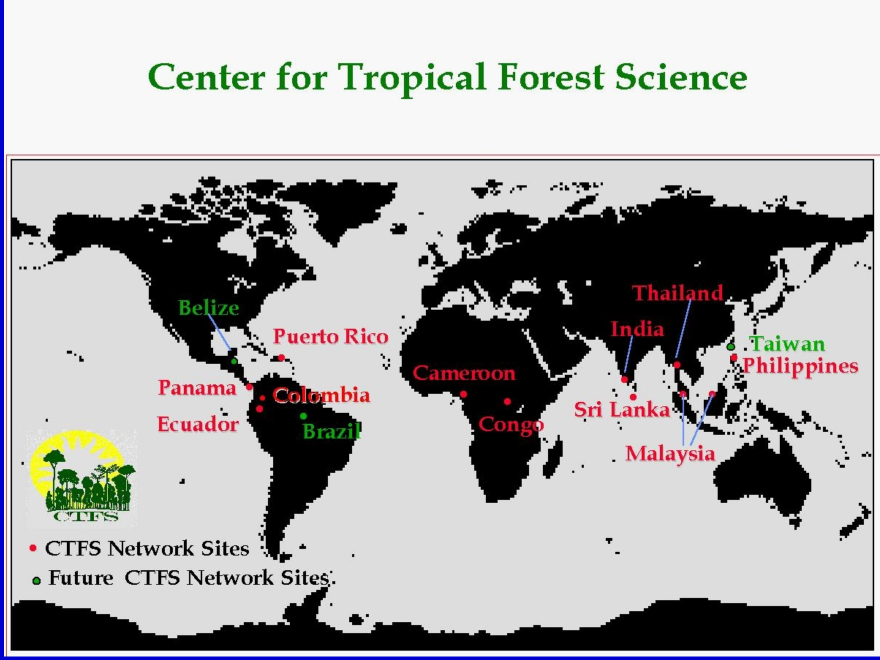
GREGORY M. MIKKELSON, *Biology and Philosophy* (2004)

A review of Jonathan M. Chase, J. M. and Mathew A. Leibold, *Ecological Niches: Linking Classical and Contemporary Approaches*, University of Chicago Press, Chicago, IL, 2003, 212 pp.

The data:

10 large-scale forest plots

- Sinharaja wet forest (Sri Lanka)
- Lambir wet dipterocarp forest (Borneo)
- Pasoh wet dipterocarp forest (Malaya)
- Mudumalai dry deciduous forest (SW India)
- Huai Khae Khaeng dryish evergreen forest (Thailand)
- Ituri monodominant caesalp forest (Congo)
- La Planada wet montane (Colombia)
- Yasuni wet Amazonian forest (Ecuador)
- Barro Colorado seasonal moist forest (Panama)



Counts of all individuals of all species (1 cm dbh)

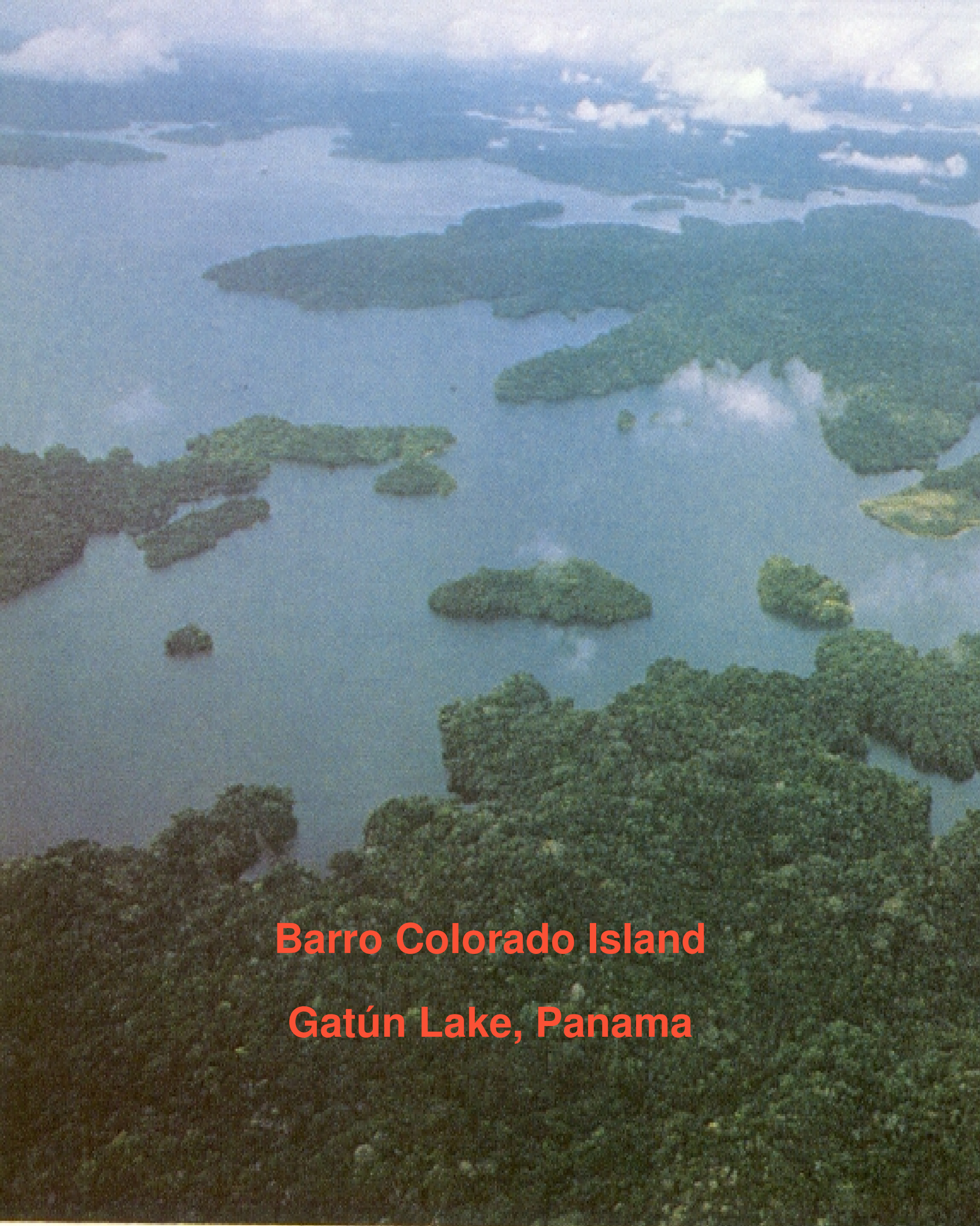
- 1,808,024 individuals and 4990 species-records

Two or more censuses at 3-8 year intervals

Forest Dynamics Plots

	species ≥ 1 cm dbh	annual rainfall (mm)	dry season (months)
Panama, BCI	274	2500	4
Ecuador, Yasuni	1104	3000	0
Colombia, La Planada	280	3500	0
Puerto Rico, Luquillo *	120	3500	0
India, Mudumalai	66	1200	6
Thailand, HKK	206	1450	6
Malaysia, Pasoh	785	1800	0
Malaysia, Lambir	1111	2700	0
Sri Lanka, Sinharaja	205	4400	0
Cameroon, Korup	482	5000	2
D.R. Congo, Ituri			
--monodominant *	403	1700	2
--mixed *	409	1700	2

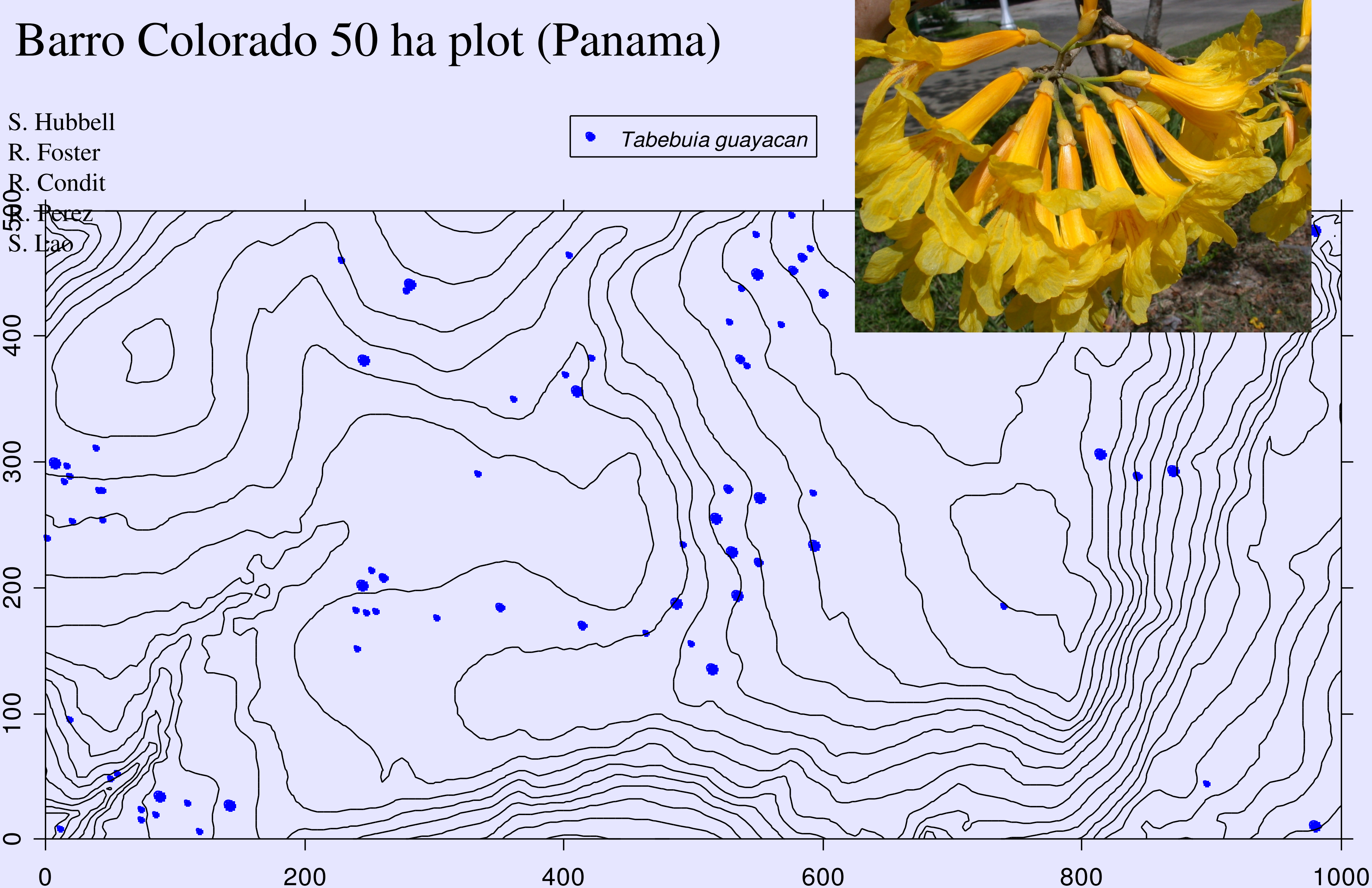
Species in 25 ha unless marked with *


Barro Colorado Island
Gatún Lake, Panama

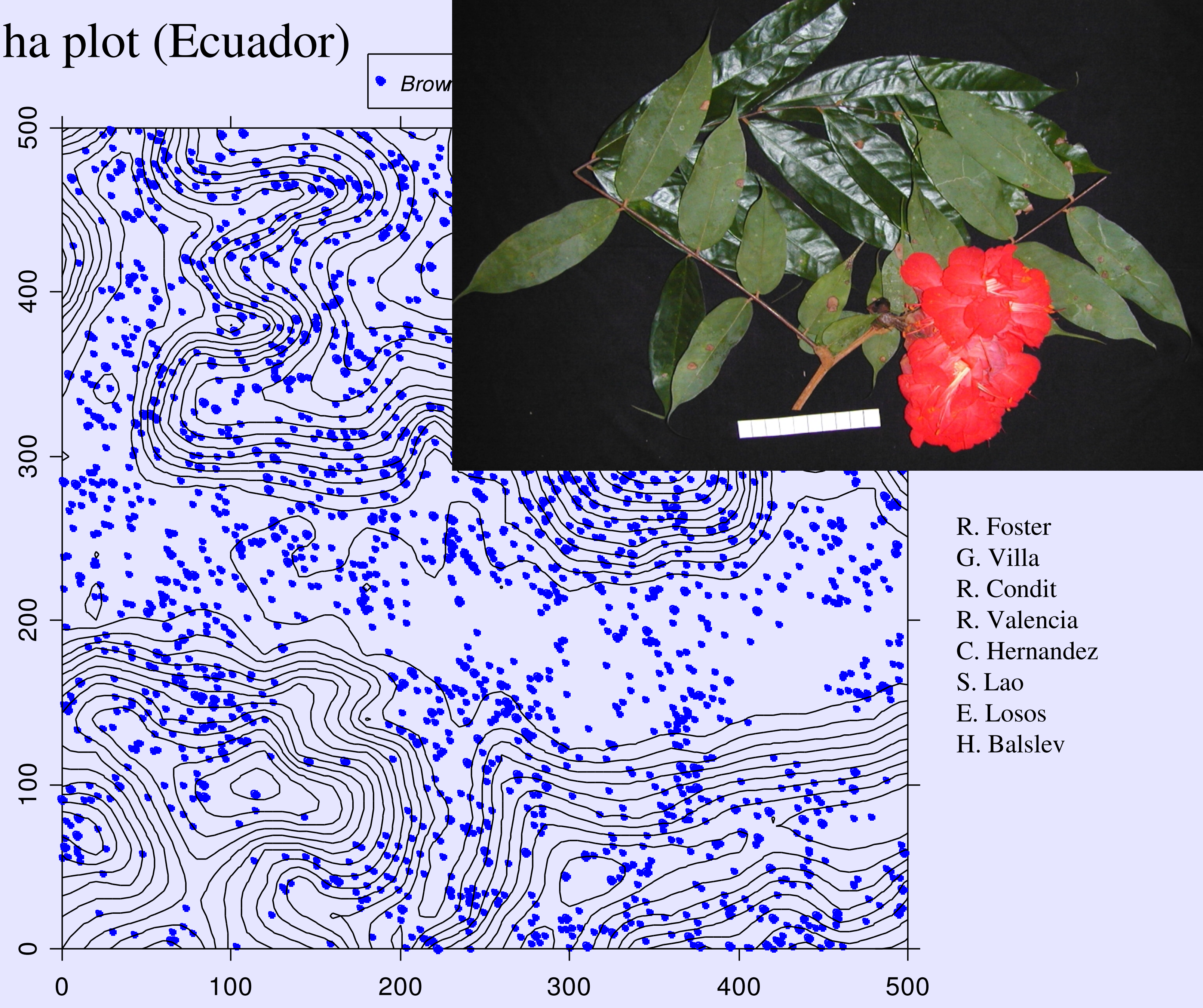

BARRO COLORADO ISLAND
BOHIO REACH
De Lesseps Island
BUENA VISTA REACH
GATUN LAKE
Orchid Island
Salt Island
Pepper Island
Peña Blanca Pt.
PEÑA BLANCA BAY
Laboratory Cove
Bat Cove
Kingfisher Pond (seasonally dry)
Lake
Big Tree
Mona Grita Is.
Approximate Channel
GIGANTE BAY
GATUN LAKE
SCALE
Meters
Yards
N
INSET

Barro Colorado 50 ha plot (Panama)

S. Hubbell
R. Foster
R. Condit
R. Perez
S. Lao



Yasuni 25 ha plot (Ecuador)



R. Foster
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E. Losos
H. Balslev

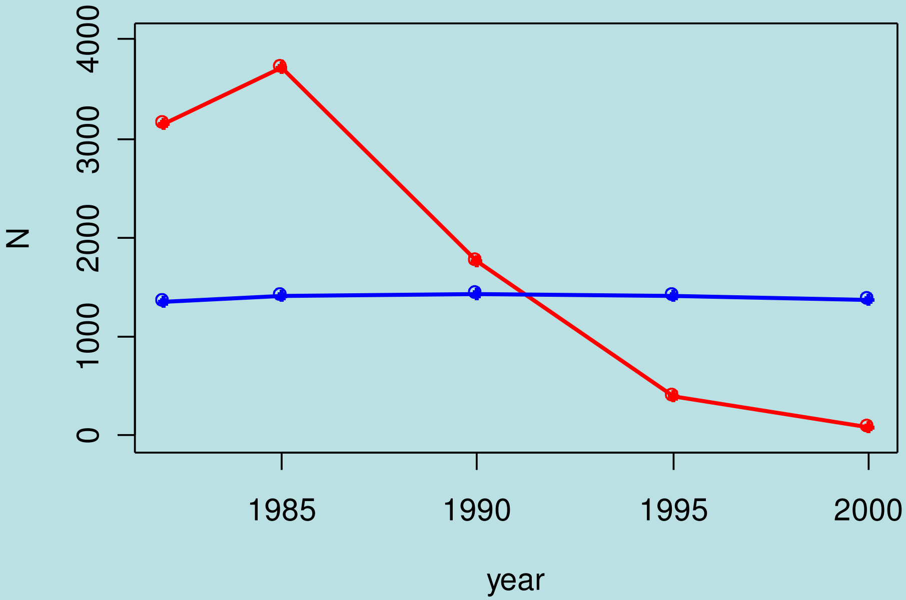
Are tree populations stable through time?

--Determine how much a population would change under random drift (random mortality and recruitment)

--Estimate a community-wide distribution of rates of population change as a measure of forest stability (correcting for random change)

--Compare stability of different forests

--Compare stability of rare and common species



Prioria copaifera, BCI

λ = 1.001

Piper cordulatum, BCI

λ = 0.819

Variance in population size through time

--Stochastic variance: random drift (random mortality and recruitment)

--Environmental variance: external forces affecting population

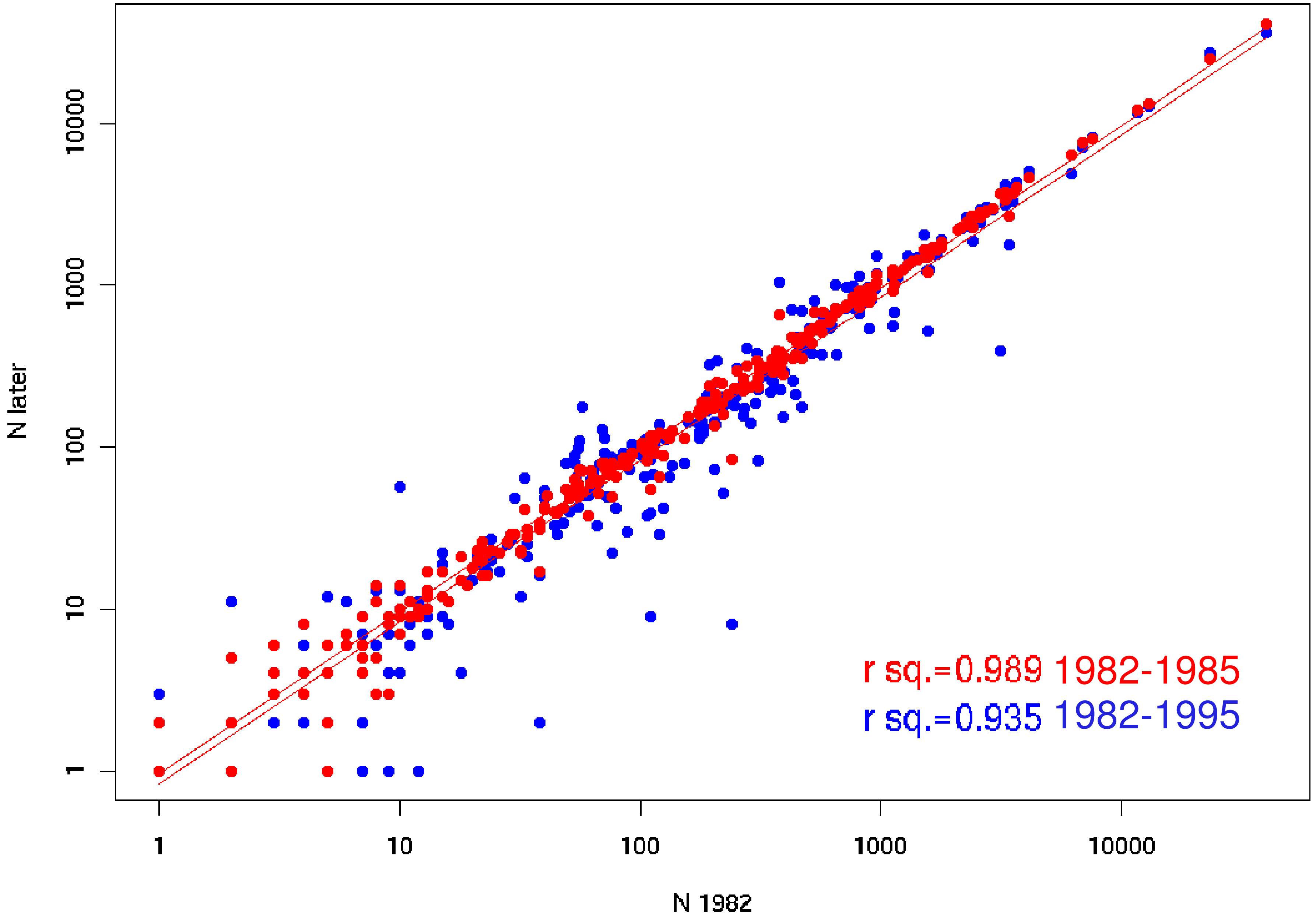
Lande, R., Engen, S., and Saether, B.-E. 2000. *Stochastic Population Dynamics in Ecology and Conservation*. Oxford.

Allen, Andrew P.; Savage, Van M.2007. Setting the absolute tempo of biodiversity dynamics. Ecology Letters 10: 637-646.

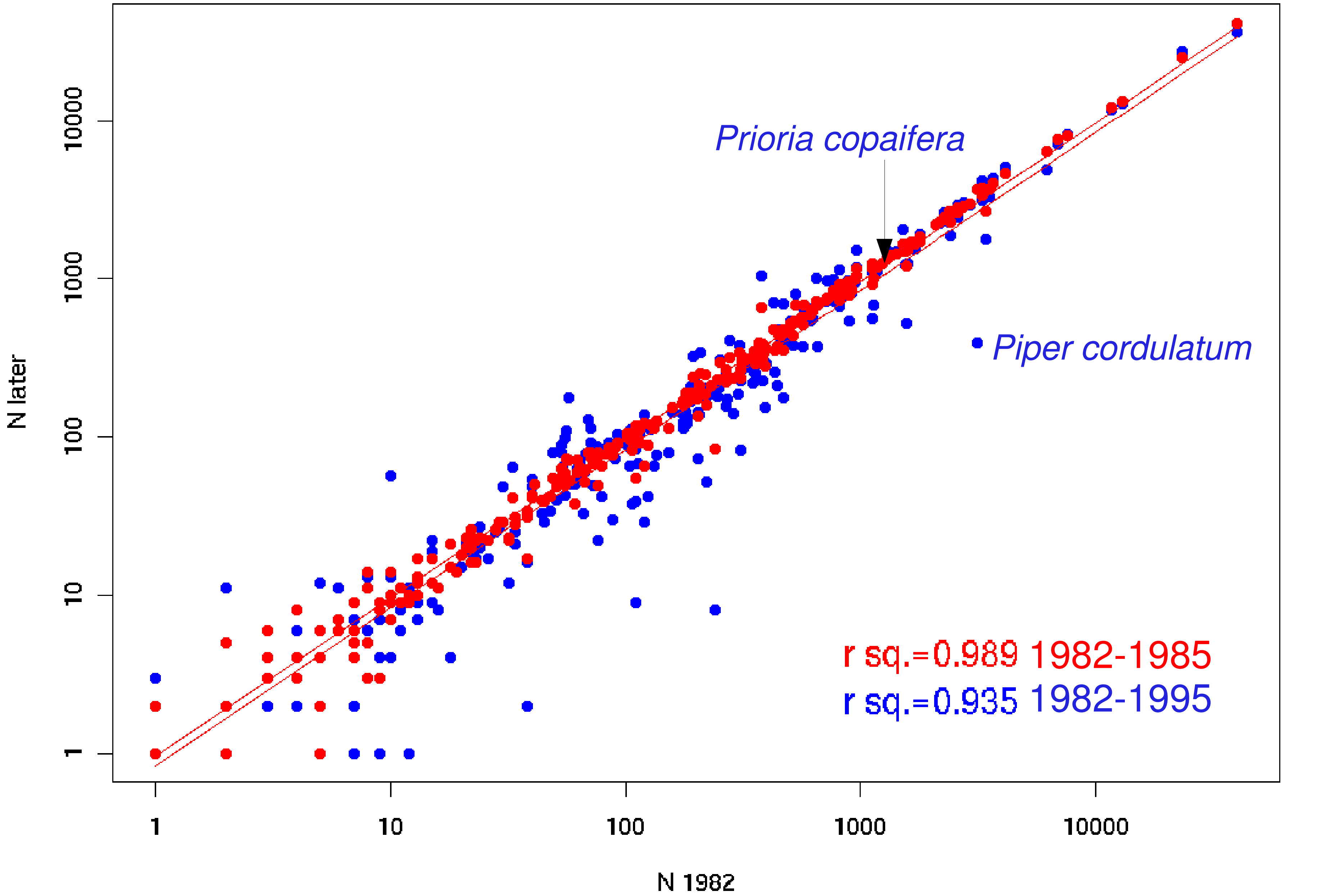
abundance data from Ituri 20 ha plot (Congo)

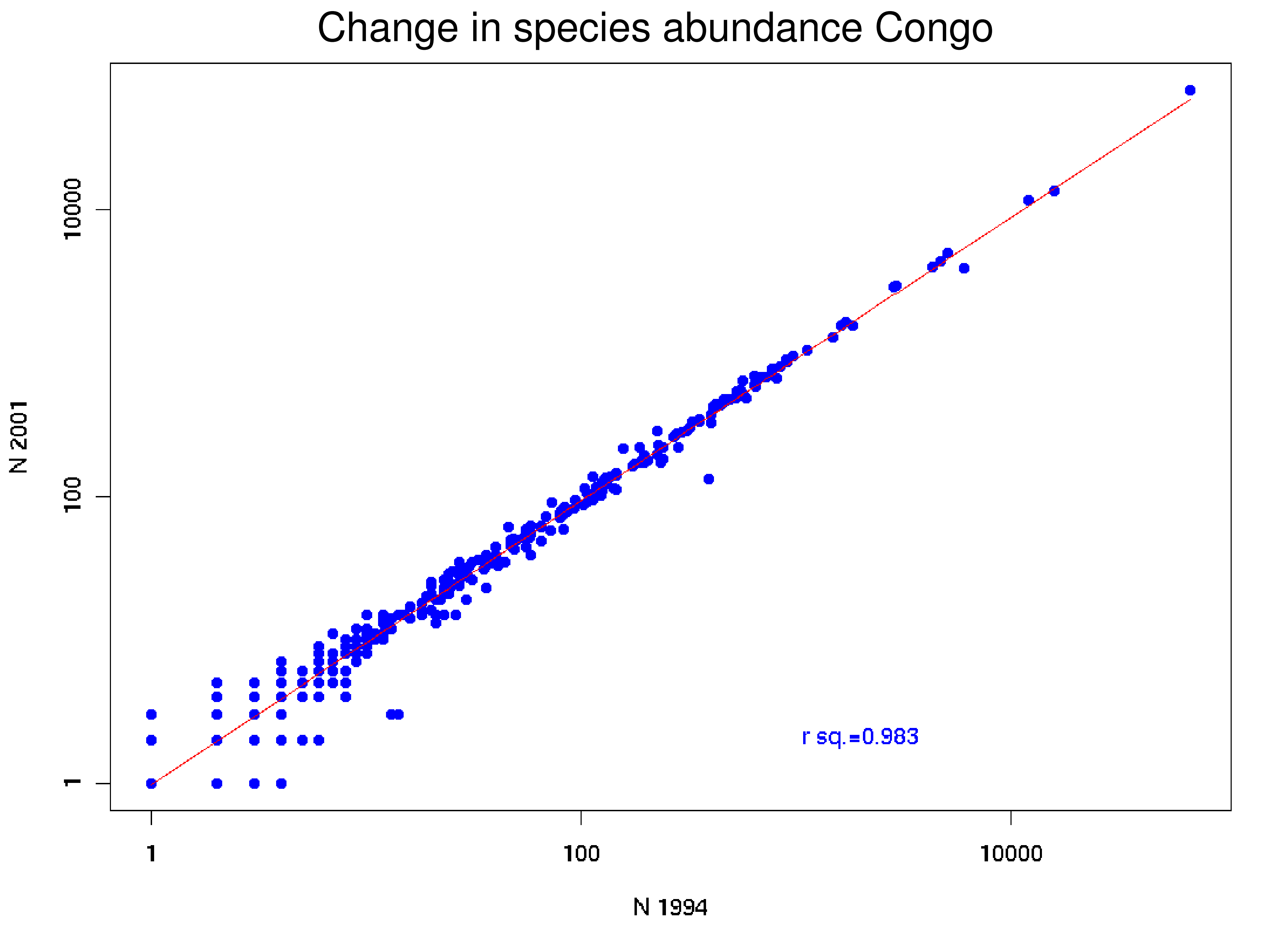
species	N1	N2	interval (yr)	lambda
Afrostyrax lepidophyllus	3	3	6.35	1.000
Afzelia bipindensis	8	8	6.05	1.000
Aidia micrantha	638	694	6.25	1.014
Albizia ealaensis	0	1	6.37	Inf
Albizia gumifera	125	109	6.36	0.979
Albizia leptophylla	2	1	5.85	0.888
Albizia zygia	3	3	6.16	1.000
Alchornea floribunda	5999	3896	6.03	0.931
Allanblackia floribunda	5	6	6.61	1.028
Allophylus africanus	124	101	6.17	0.967
Allophylus longicuneatus	20	24	6.32	1.029
Allophylus schweinfurthii	4	6	6.54	1.064
Alstonia boonei	65	49	6.08	0.955
Amphimas ferrugineus	4	4	6.35	1.000

Change in species abundance at BCI



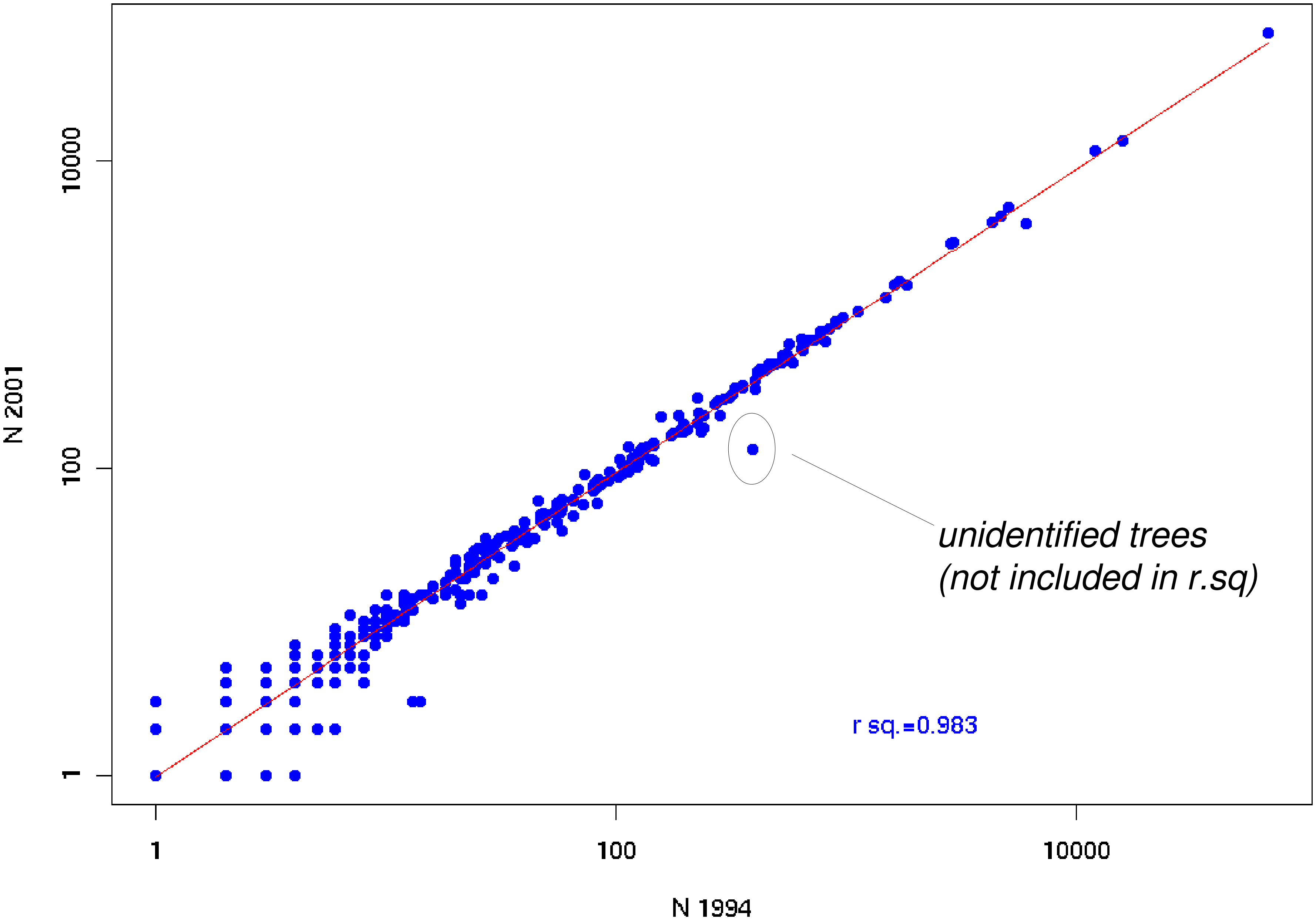
Change in species abundance at BCI

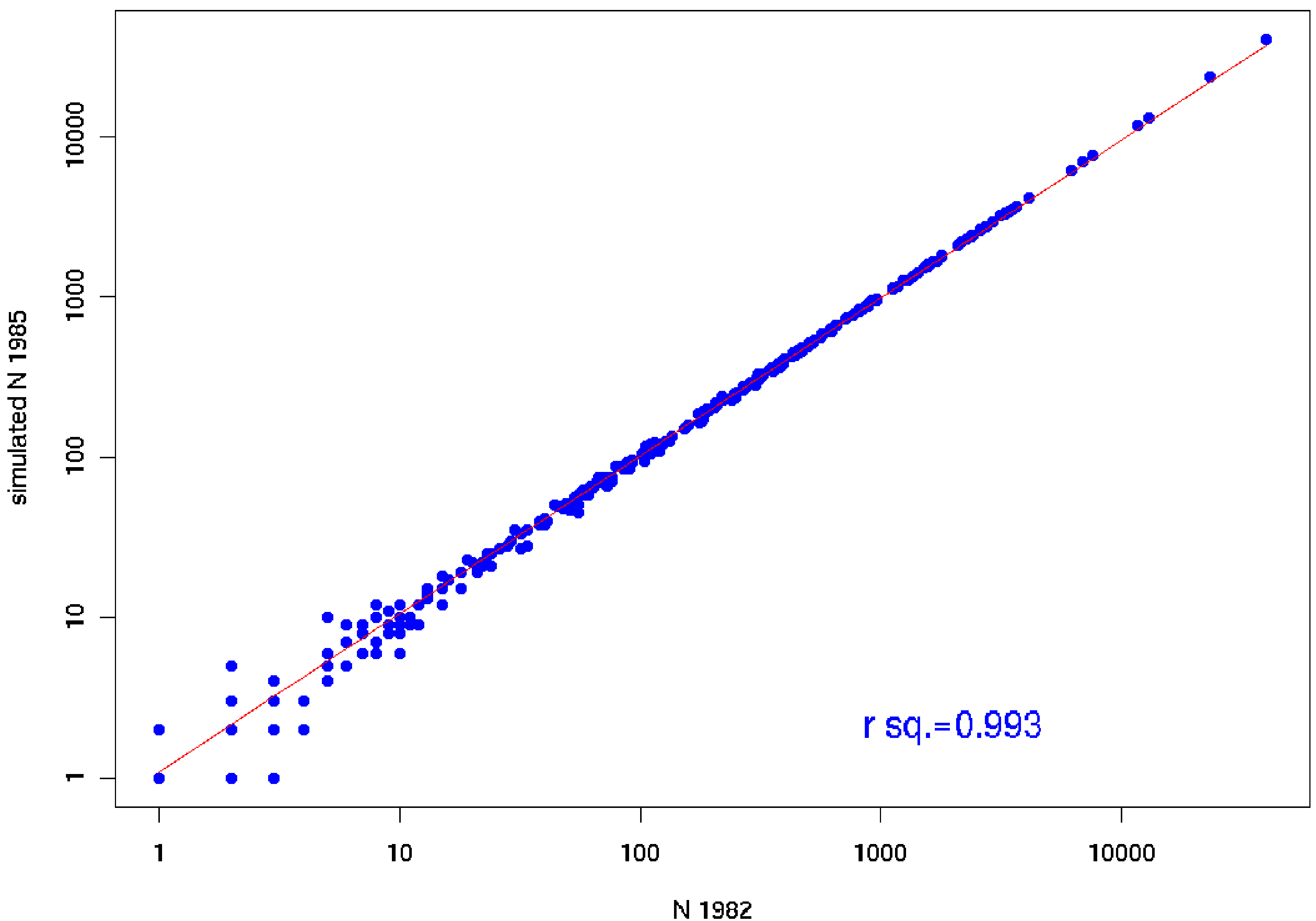




Change in species abundance Congo
N 2001
N 1994
1
100
10000
1
100
10000
r sq.=0.983

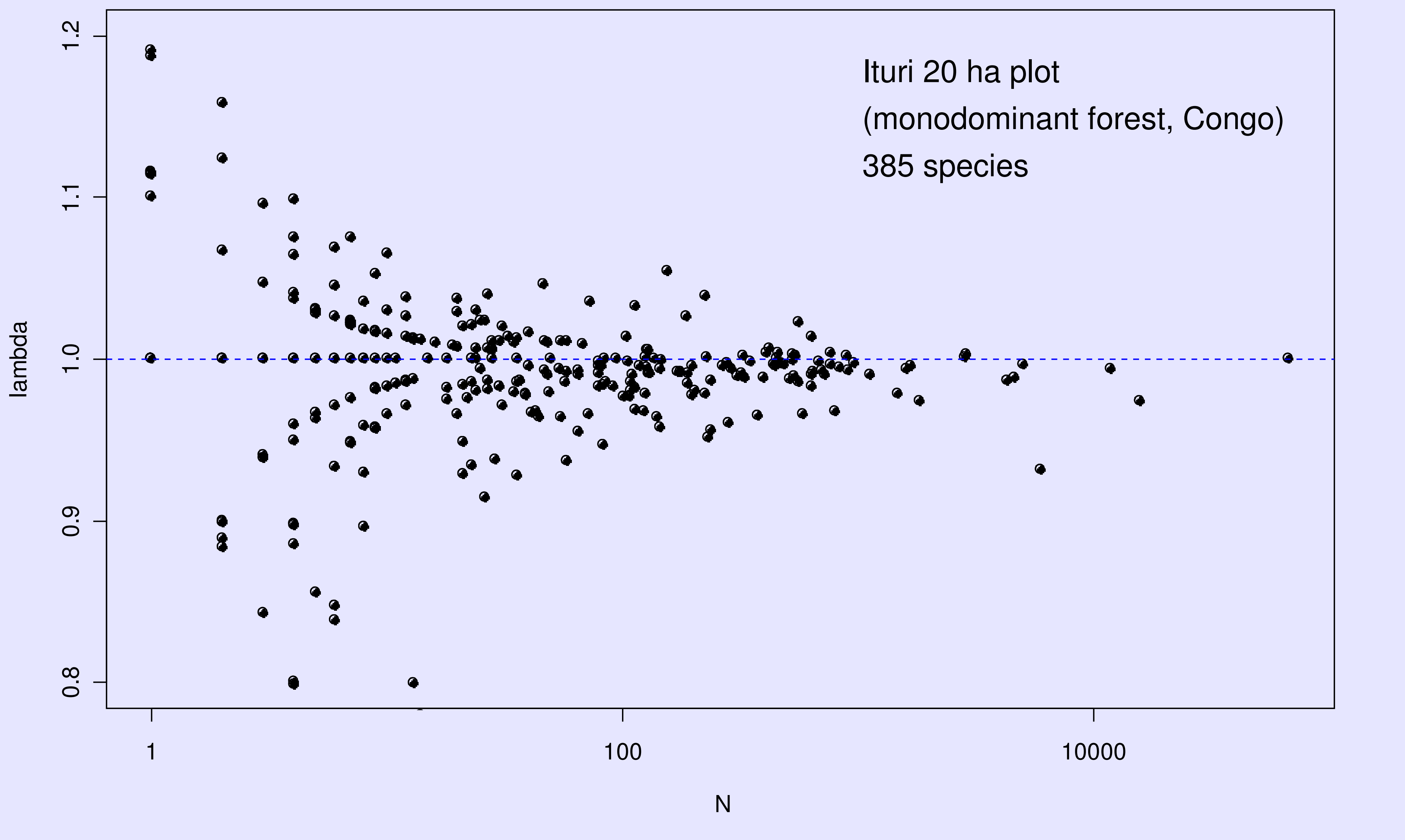
Change in species abundance Congo



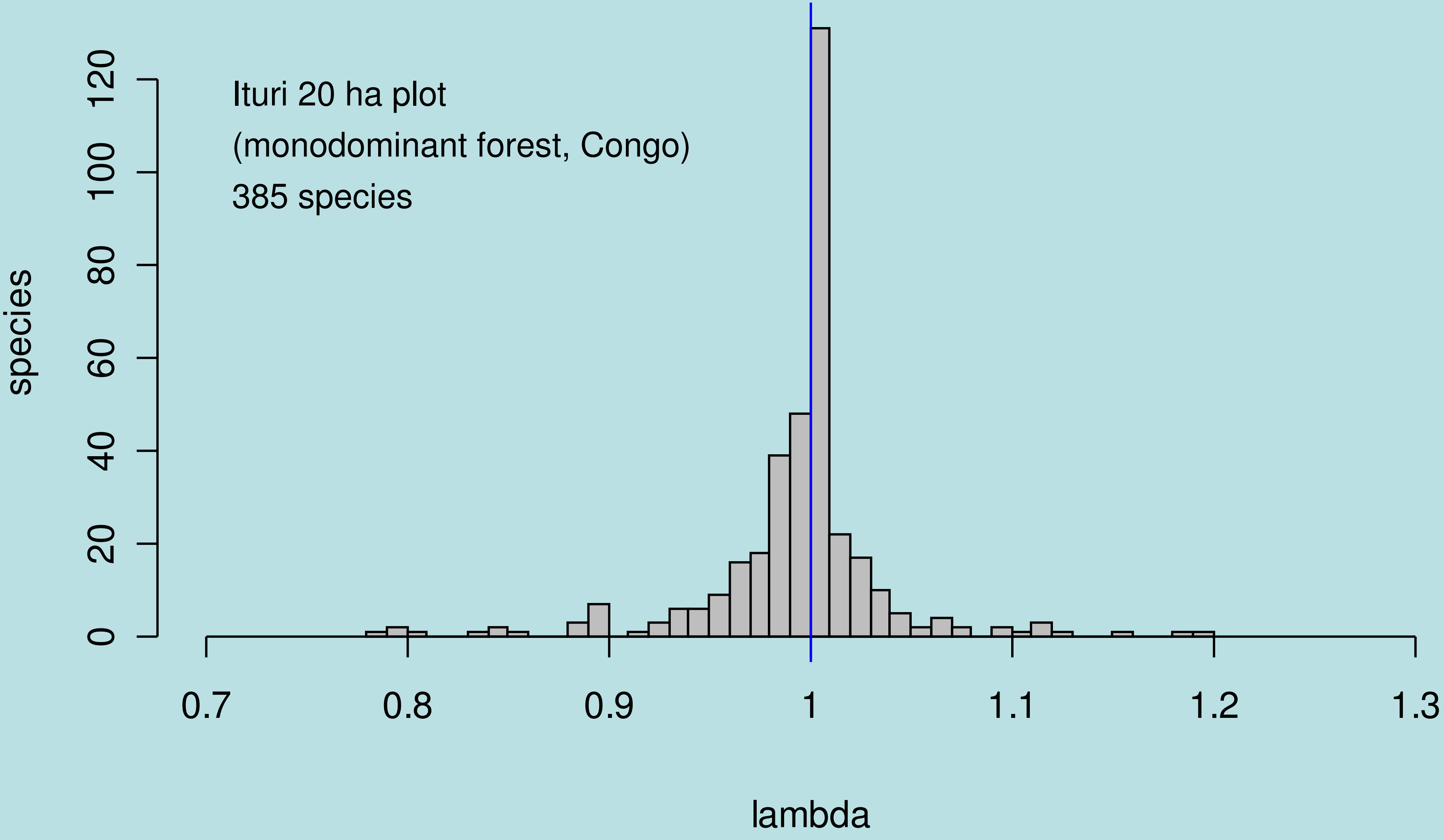


simulated N 1985
N 1982
r sq.=0.993
1
10
100
1000
10000

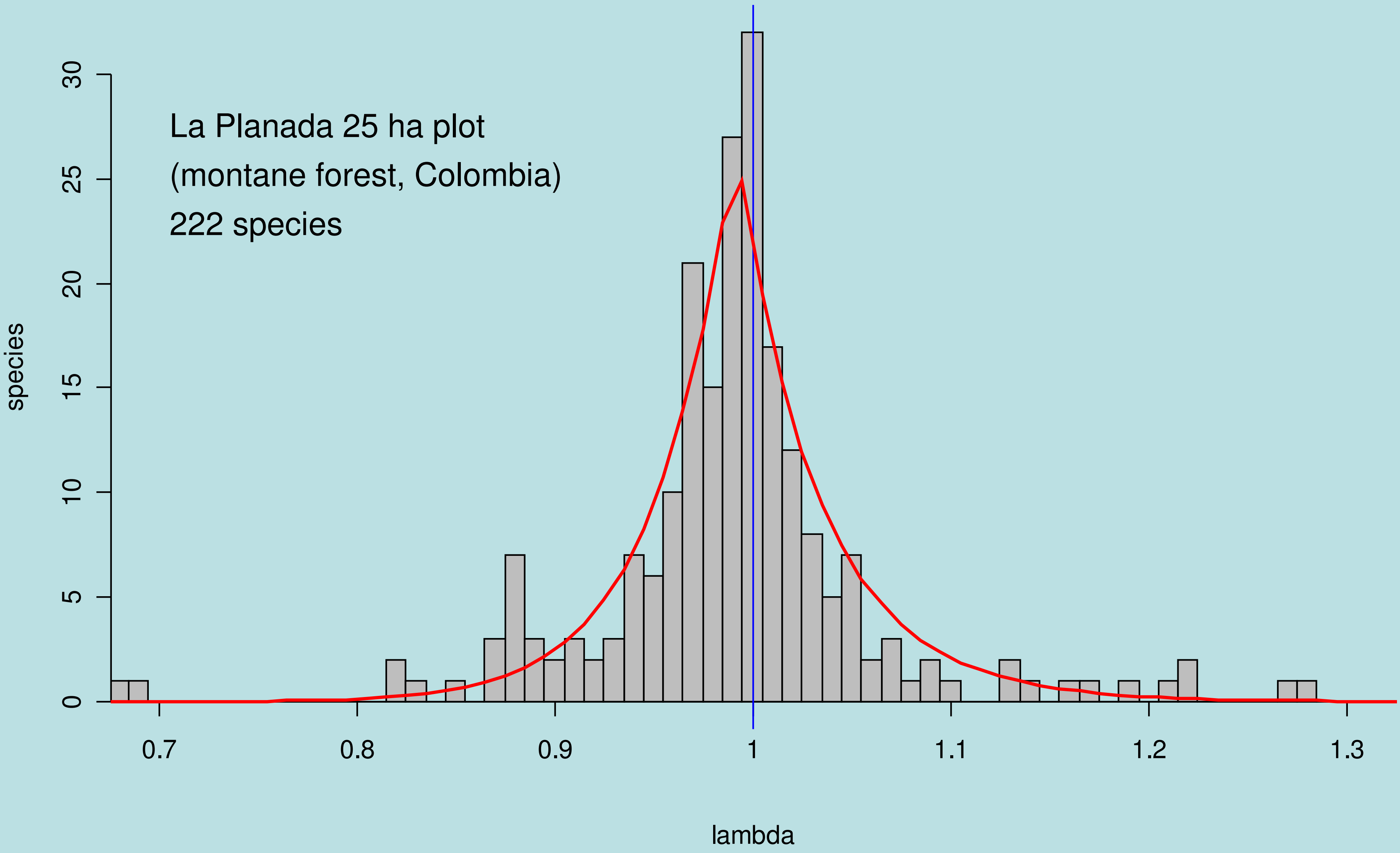
λ varies more in rare species: sampling error



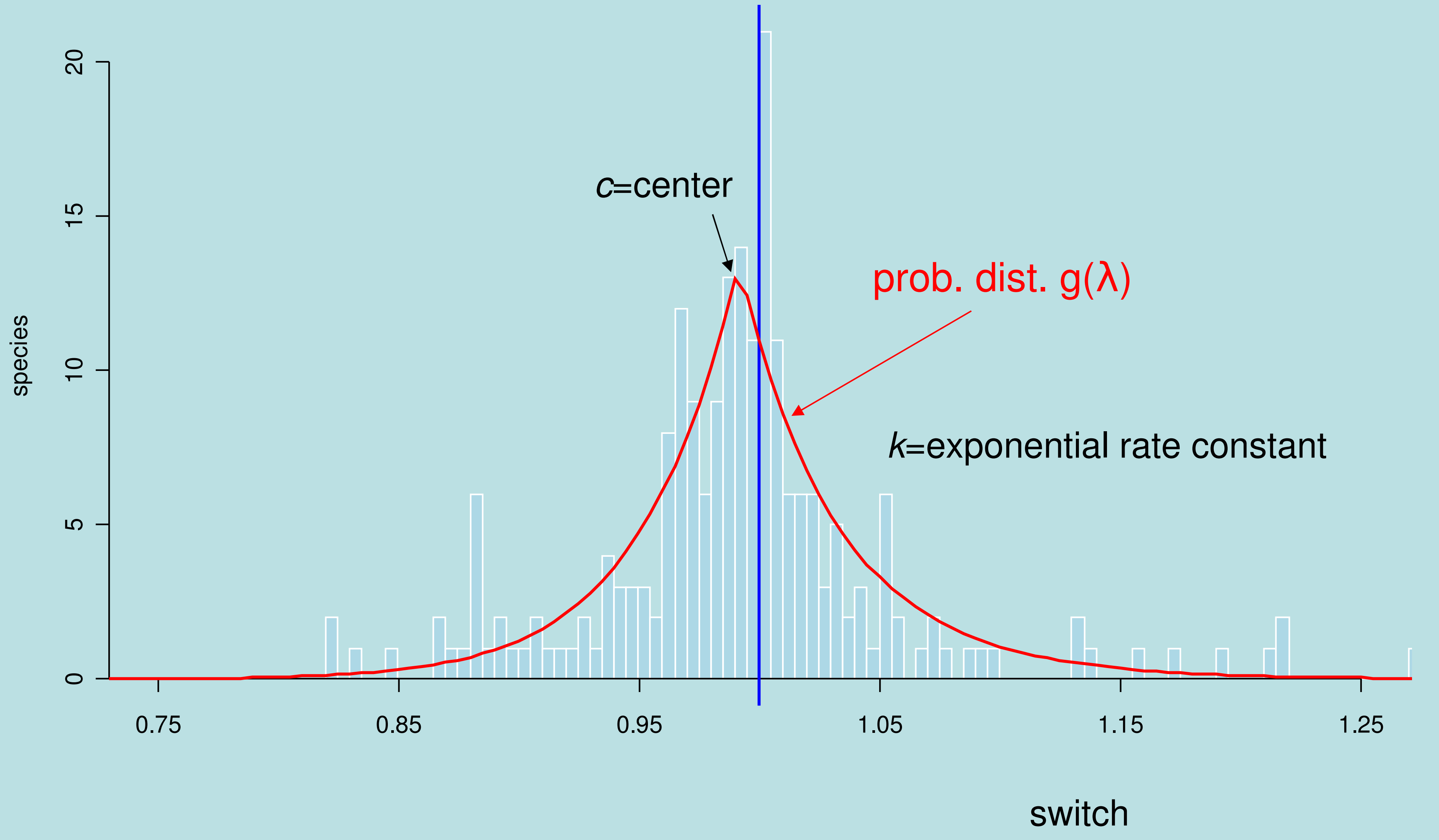
The variance of the distribution of λ reflects the stability of the community



Mission: fit the 'hyperdistribution' of lambda accounting for abundance and stochasticity



community-wide distribution of λ
symmetrical exponential



Calculating the likelihood of observations for all species in a forest

1) Probability of observing growth rate $r=\log(\lambda)$

$$prob(r)=g(r)\sim symExponential(c,k)$$

2) Probability of observing population change, given survival θ and population growth rate λ (time adjusted)

$$prob(N_1|\lambda,N_0,\theta)=f(N_1|\lambda,N_0,\theta)\sim Normal(\lambda,\lambda-\theta^2)$$

3) Likelihood of observations N and θ for species i

$$L(i)=\int f(N_1|r)g(r)dr$$

4) Probability of observations for all species in a forest

$$L_T=\sum_i \log(L(i))$$

Easier to read in R …

L[i] = integrate(dnorm(mean= λ,sd= $\lambda + \theta$) * dsymexp(*c,k*))

1) Probability of observing growth rate r=log(λ)

$$prob(r) = g(r) \sim symExponential(c, k)$$

2) Probability of observing population change, given survival θ and population growth rate λ (time adjusted)

$$prob(N_1|\lambda, N_0, \theta) = f(N_1|\lambda, N_0, \theta) \sim Normal(\lambda, \lambda - \theta^2)$$

3) Likelihood of observations *N* and θ for species *i*

$$L(i) = \int f(N_1|r) g(r) dr$$

Calculating the likelihood of observations for all species in a forest

1) Probability of observing any growth rate $r = \log(\lambda)$

$$prob(r) = g(r) \sim symExponential(c, k)$$

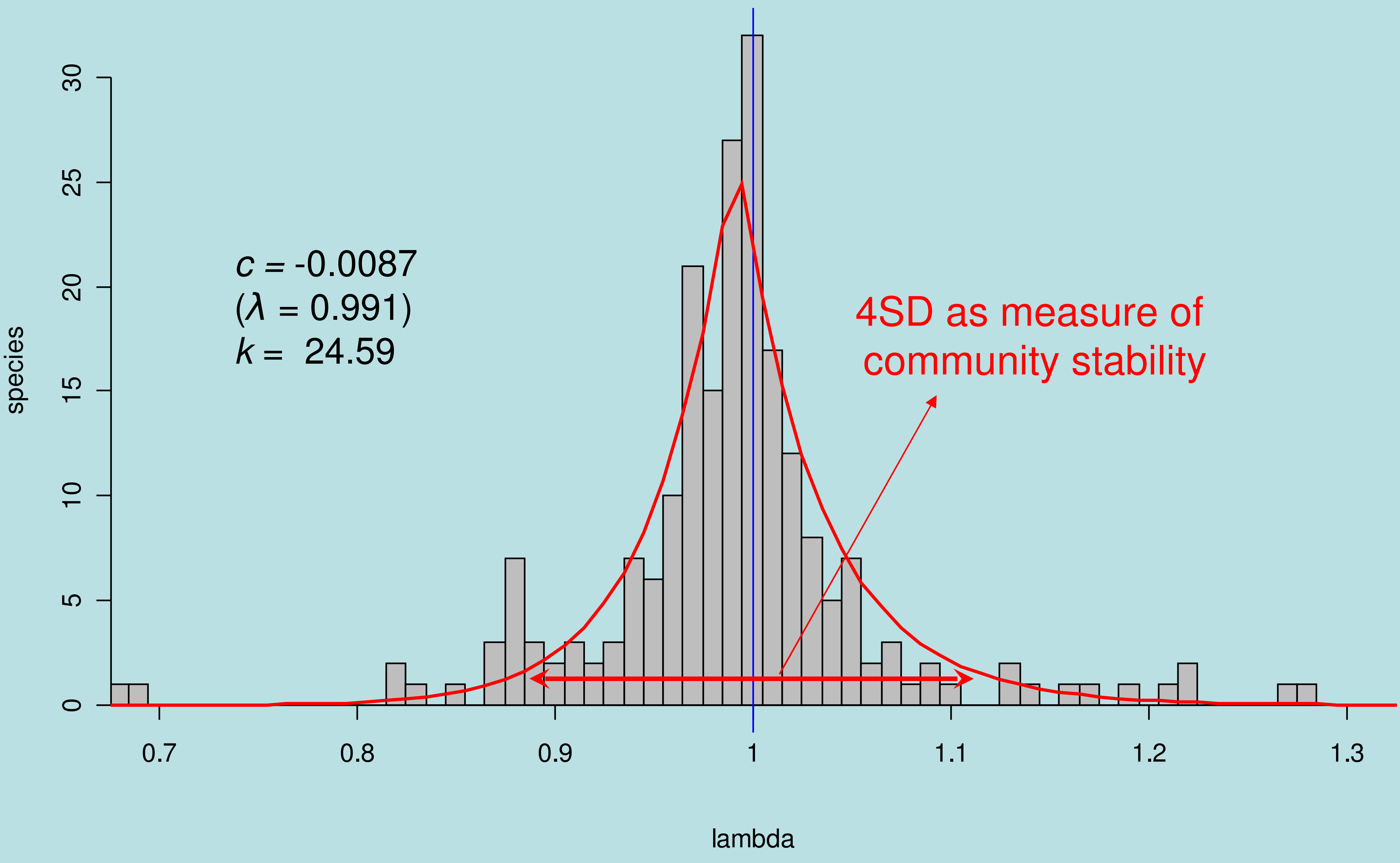
……

4) Probability of observations for all species in a forest

$$L_T = \sum_i \log\left(L(i)\right)$$

L_T is a function of c, k only – find c, k to maximize L

The distribution of population changes
La Planada, Colombia

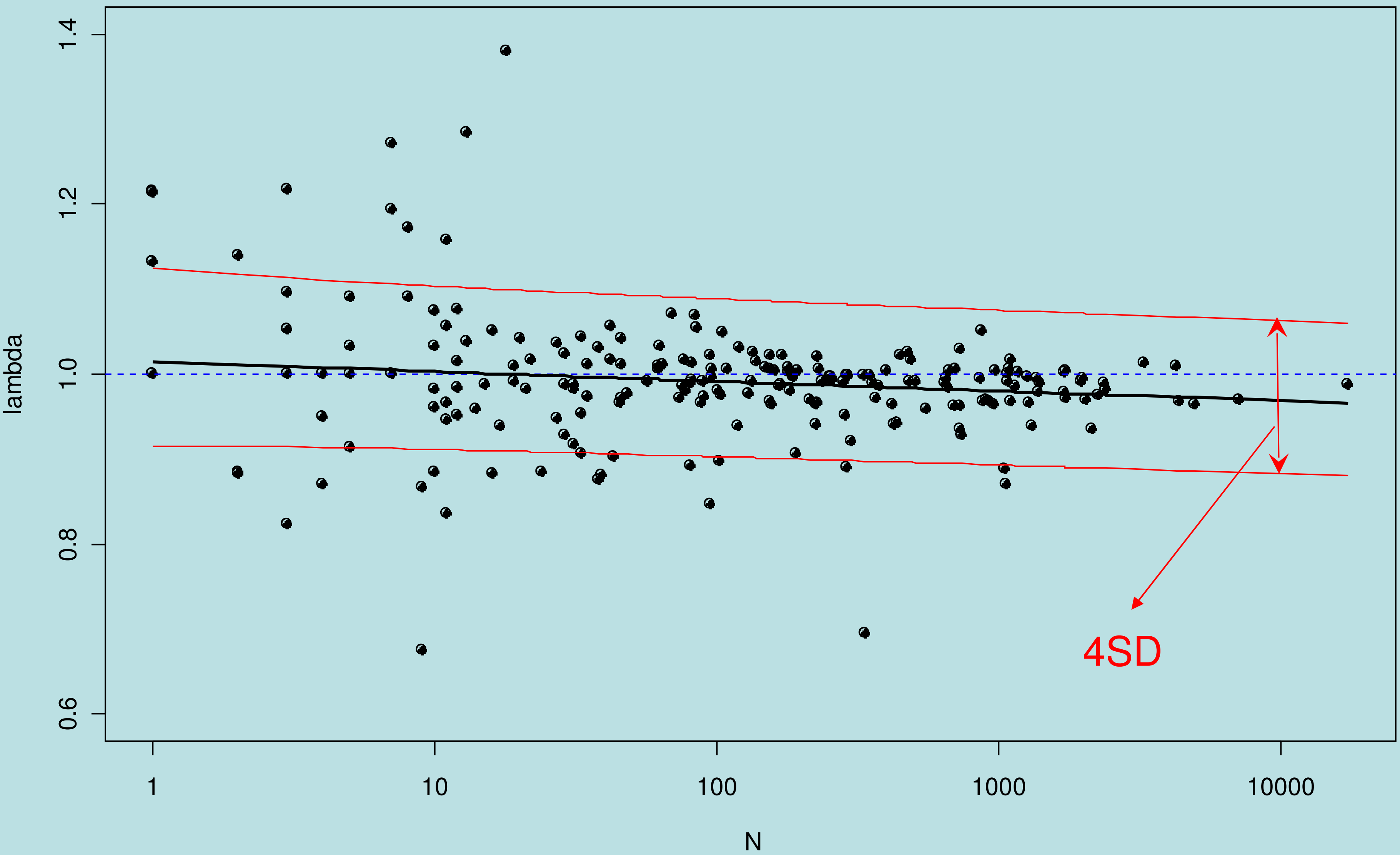


Testing difference in rate species
4-parameter model

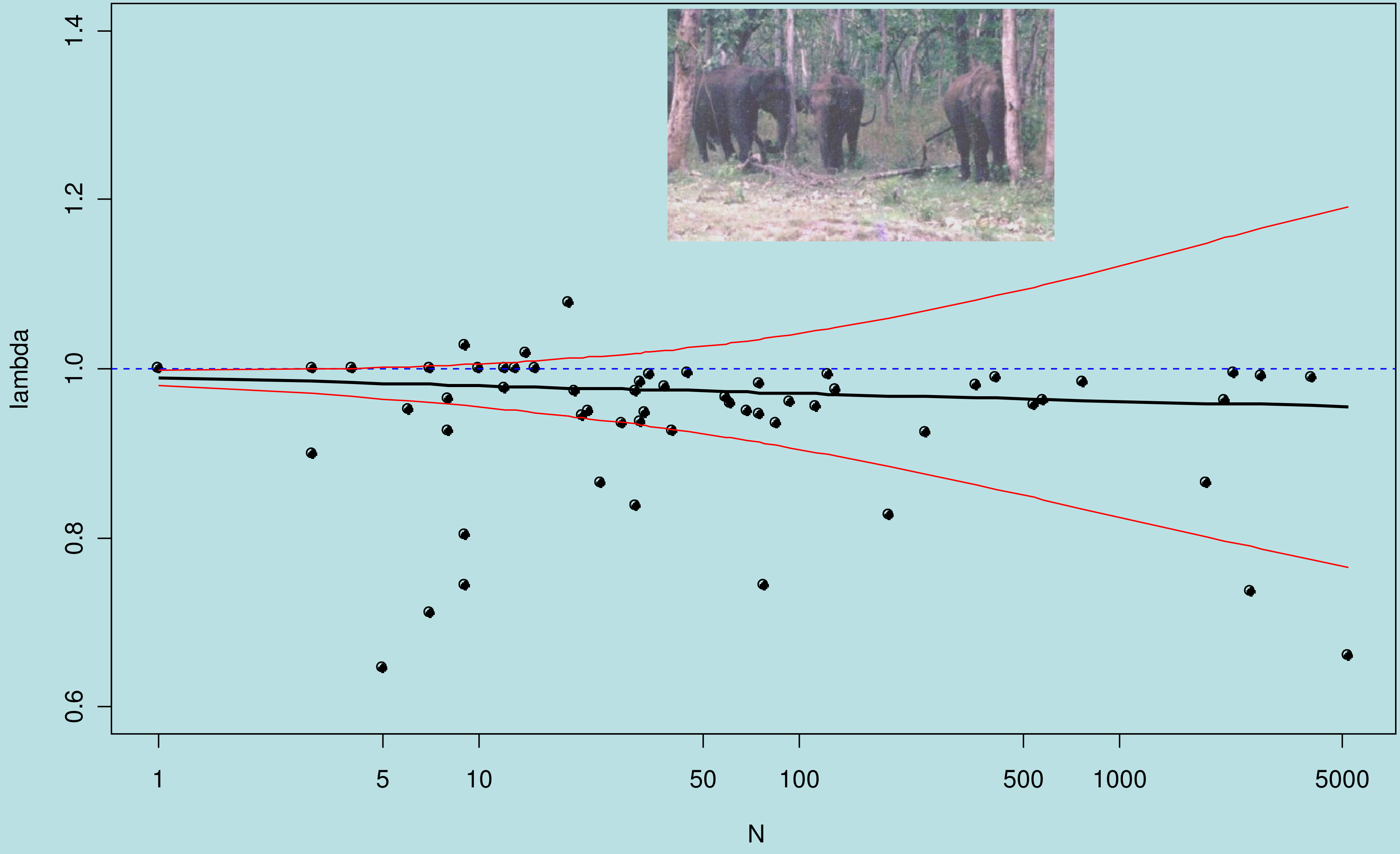
distribution of r=log(λ) allowing variation with abundance

$$g(r) \sim symExponential\left[c_o + c\ln(N_0), k_o + \frac{k}{N_0^{\ 2}}\right]$$

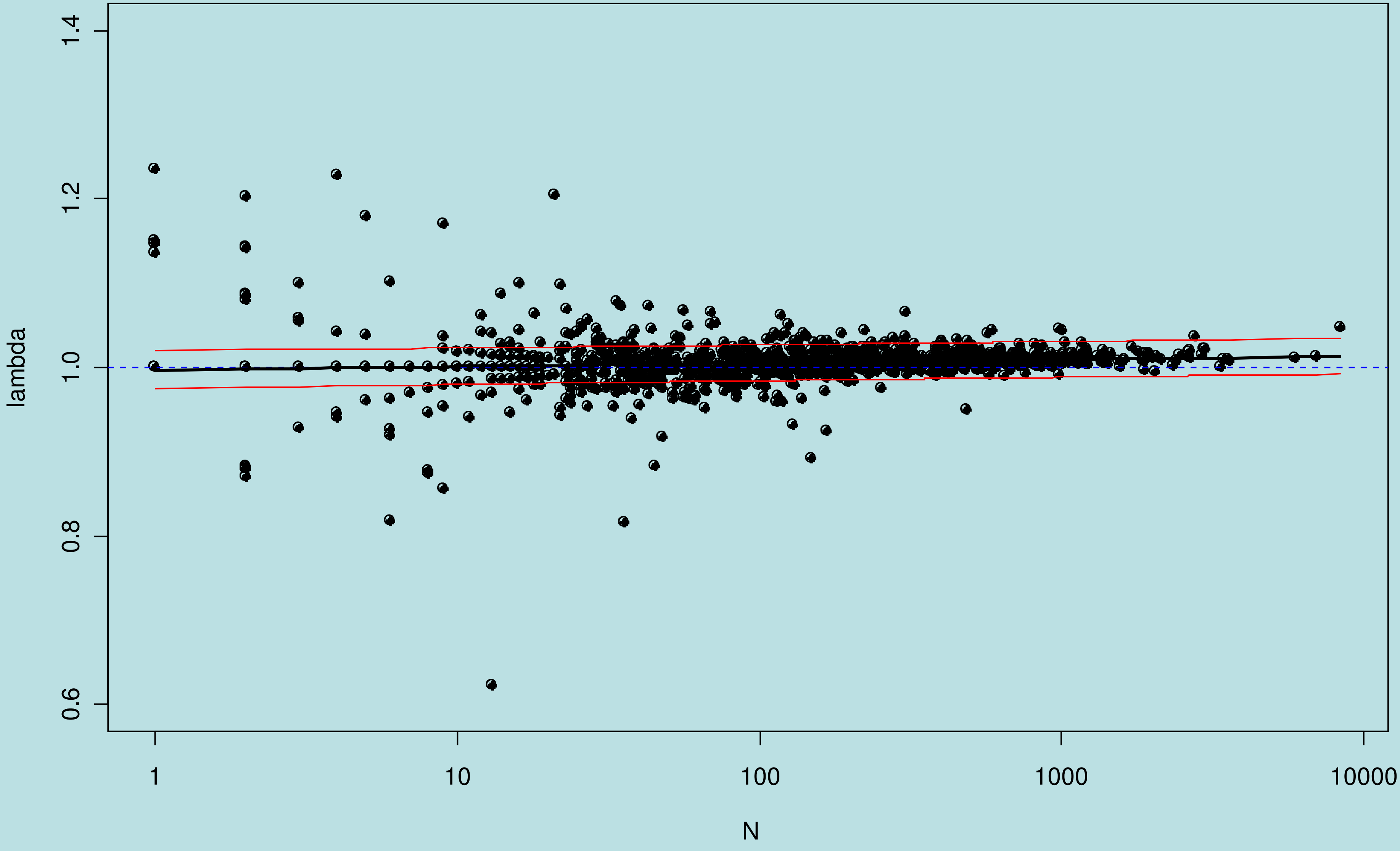
Population changes as a function of abundance
La Planada, Colombia



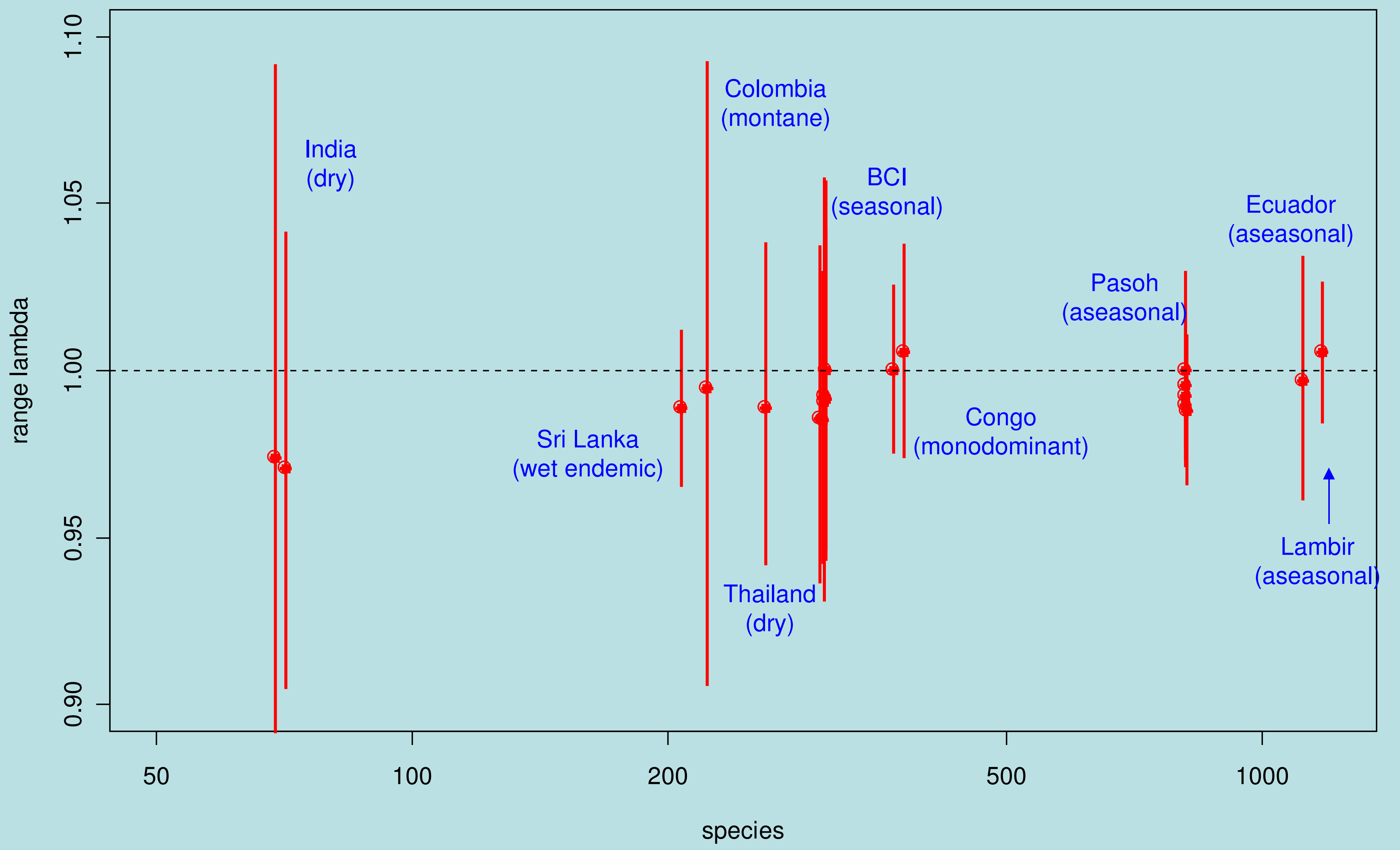
Population changes as a function of abundance
Mudumalai, India
(dry deciduous, elephant-dominated, 71 species)



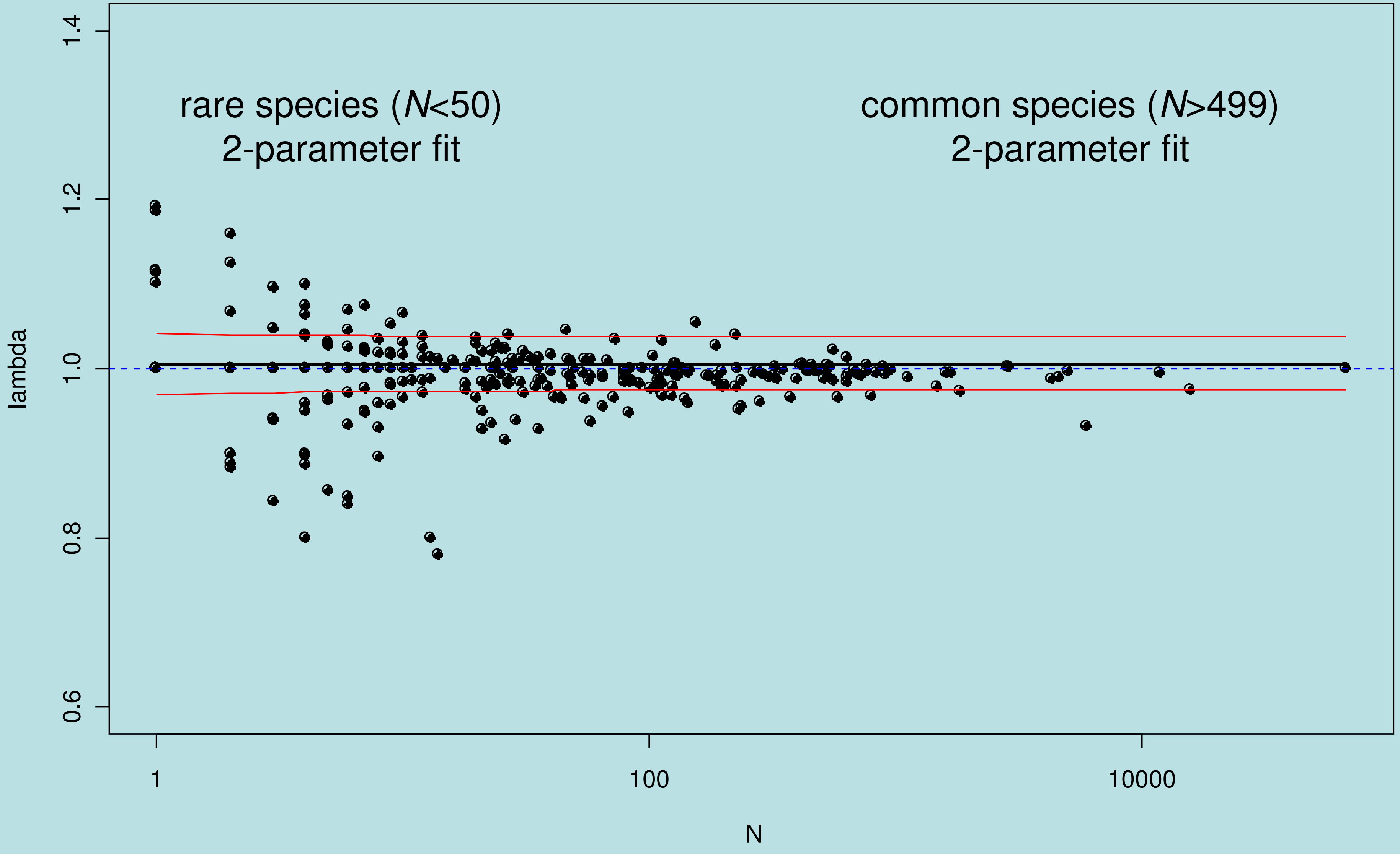
Population changes as a function of abundance
Lambir, Malayia
(dipterocarp-dominated, aseasonal, 1180 species)



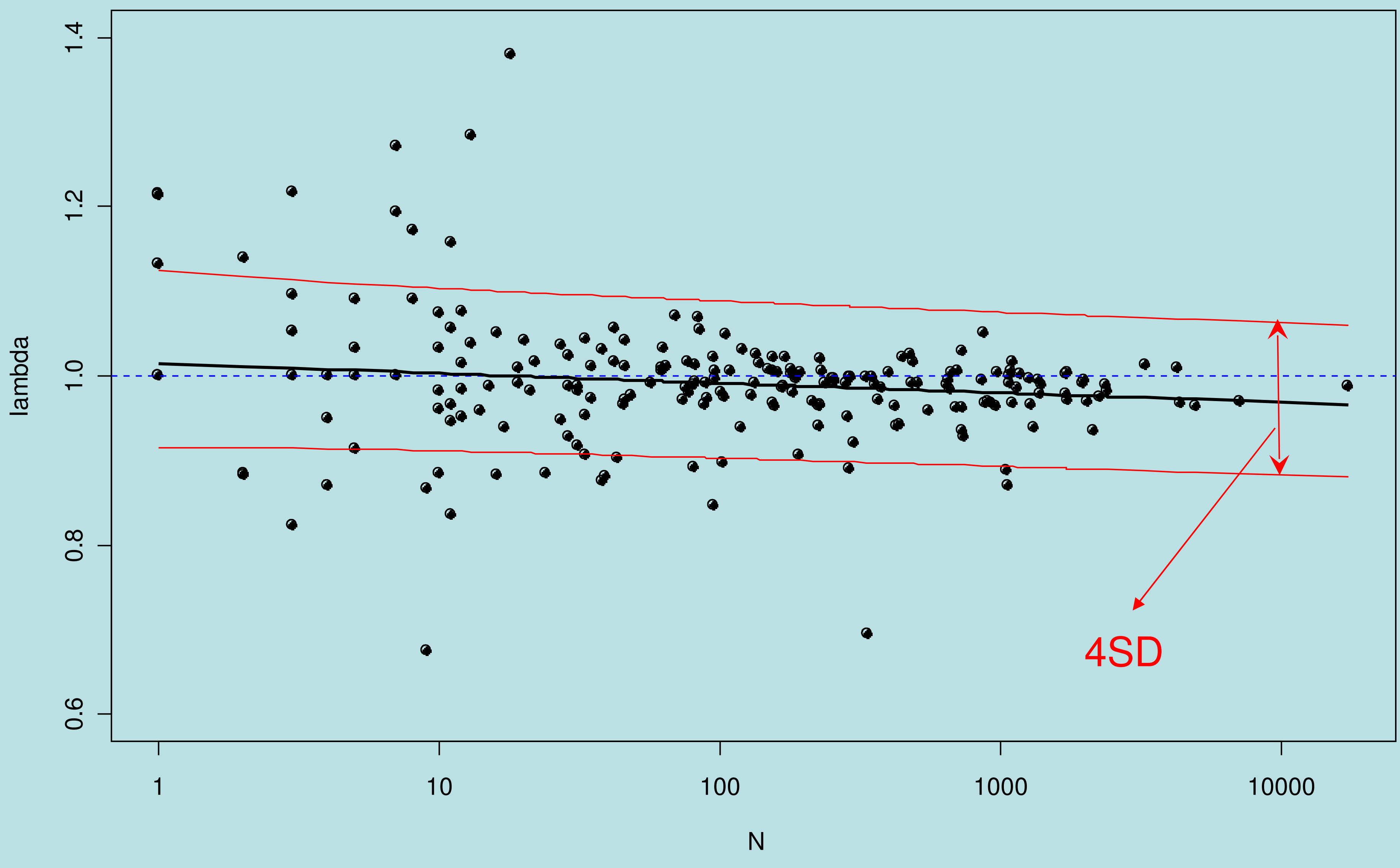
Stability-diversity



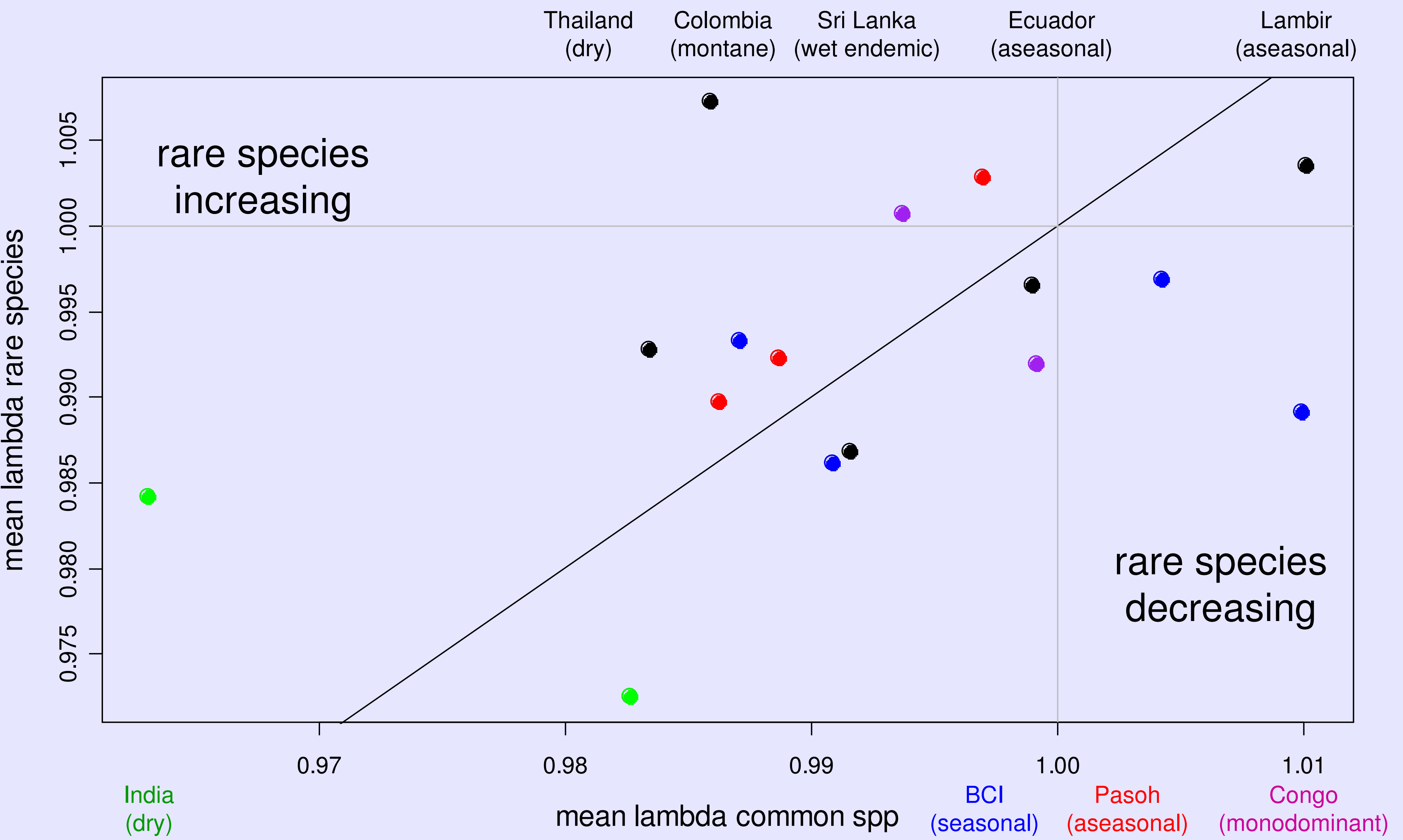
Population changes as a function of abundance
Ituri, Congo
(monodominant caesalpinoid, 368 species)



Population changes as a function of abundance
La Planada, Colombia

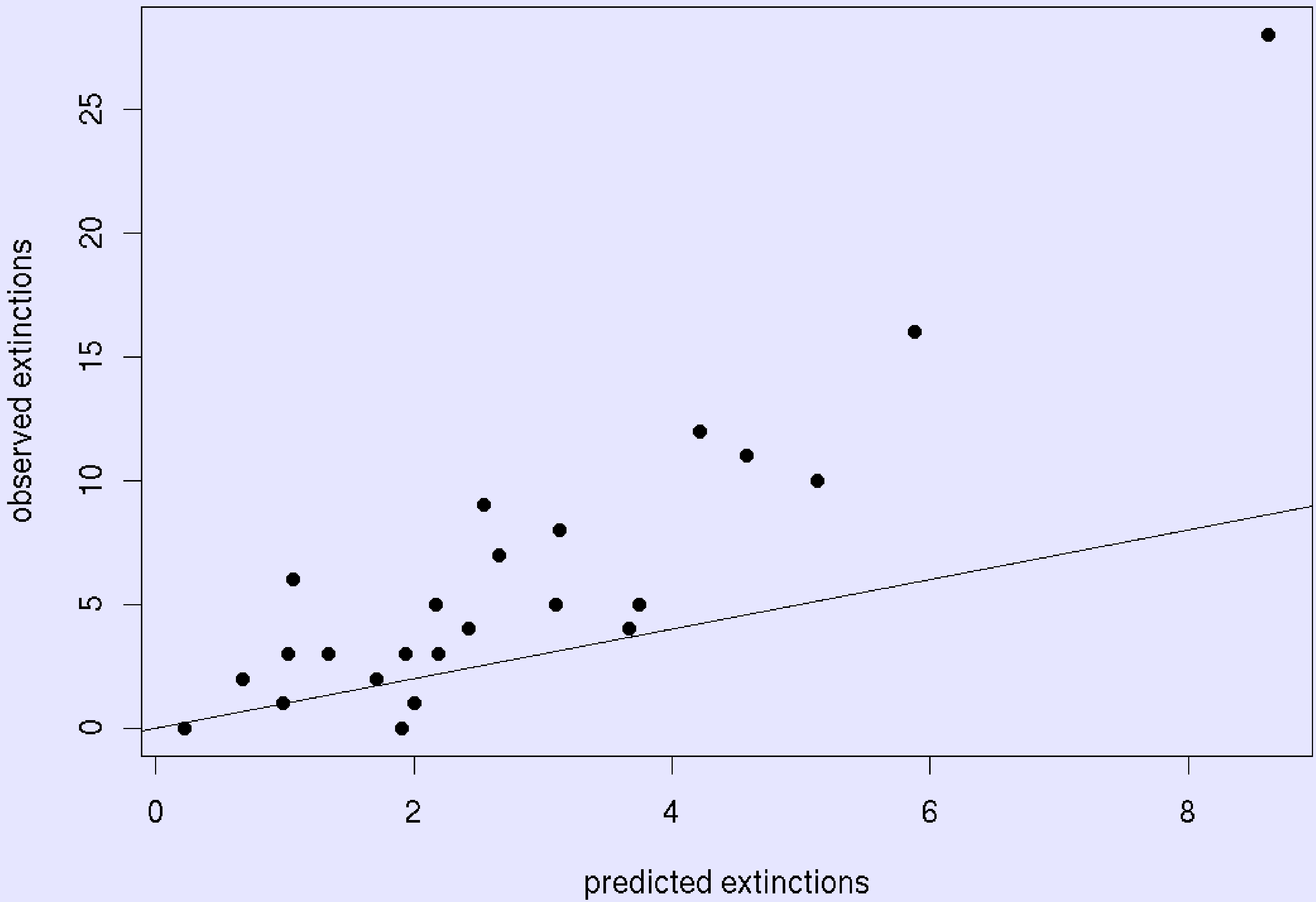


rare species recovery



site	N۰	deaths	births	species	extinct	input	singleton
BCI	۲۳۴۲۶۱	۲۵۹۴۵	۳۳۰۲۹	۳۰۰	۲	۱	۲۲
	۲۴۱۳۴۵	۳۷۰۹۷	۳۹۲۹۷	۳۰۱	۶	۹	۲۱
	۲۴۳۵۴۵	۳۶۶۱۰	۲۱۶۹۵	۲۹۸	۴	۵	۱۷
	۲۲۸۶۳۰	۳۶۵۷۷	۲۱۴۱۸	۲۹۷	۴	۵	۲۳
	۲۱۳۴۷۱	۳۱۳۴۴	۲۵۹۴۰	۲۹۶	۵	۷	۲۲
Pasoh	۳۳۵۳۵۲	۱۴۲۶۴	۵۷۰۹	۸۱۴	۱	۱	۲۴
	۳۲۶۷۹۷	۲۷۵۵۲	۳۹۰۱۷	۸۱۴	۷	۳	۲۷
	۳۳۸۲۶۲	۳۵۱۹۳	۱۳۷۰۱	۸۱۸	۰	۲	۱۸
Mudumalai	۲۵۵۵۴	۸۳۶۸	۴۶۰	۷۲	۱	۳	۸
	۱۷۶۴۶	۳۰۲۶	۶۹۰	۷۰	۱	۶	۷
	۱۵۳۱۰	۱۱۶۱	۳۹۶۰	۶۵	۵	۰	۴
Lambir	۳۳۰۱۰۴	۲۱۲۹۱	۳۸۷۰۷	۱۱۷۹	۶	۳	۲۴
HKK	۷۸۴۴۸	۲۳۰۲۷	۱۶۸۴۱	۲۹۰	۷	۱۰	۲۵
Sinharaja	۲۰۵۱۰۵	۲۱۸۲۴	۹۶۹۶	۲۰۶	۰	۲	۷
Yasuni	۱۴۴۹۳۹	۲۲۵۵۸	۲۰۶۱۸	۱۱۱۴	۴۵	۲۸	۶۹
La Planada	۱۱۲۲۹۳	۳۰۰۲۰	۲۳۰۷۳	۲۲۰	۲۰	۰	۱۰
Edoro	۱۶۱۸۱۸	۱۶۴۷۰	۸۹۶۶	۳۷۳	۱۴	۱۱	۵۰
Lenda	۱۳۶۲۳۵	۱۳۴۴۲	۱۰۴۵۳	۳۶۰	۱۰	۸	۳۶

Observed extinctions vs. extinctions predicted due to stochastic death



In sum

All forests are changing more than neutral expectation:
--communities are not stable

In some forests, there are considerable changes:
--a few species are declining dramatically

Rare species show no tendency to increase