Estimated malaria epidemiologically effective lifetime of mass LLIN distributions depending on transmission in African countries

Report for African Leaders Malaria Alliance

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Introduction

A recent modelling exercise [1] concluded that the duration of the effective epidemiological lifetime of a mass long lasting insecticide treated net (LLIN) distribution may be more sensitive to the pre-intervention entomological inoculation rate (EIR) than to other parameters such as attrition rate, coverage and net quality. A recent world map of *Plasmodium falciparum* transmission published by the Malaria Atlas Project (MAP) [2] allows exploring how the duration of the effective epidemiological lifetime of a LLIN distribution may vary country by country.

Data

The following data were used:

- MAP [2] grids with *Pf*EIR percentiles 1 to 99 at 5km resolution. The *Pf*EIR is expressed in infectious bites per adult per annum (ibpapa). For each 5 × 5 km grid cell, MAP provides not only an estimated median value, but also the entire posterior distribution of annual *Pf*EIR transmission, giving the probability for each transmission level that it occurs in the grid cell.
- GRUMP population grid at 5 km resolution [3]
- Admin1 administrative area grid at 5 km resolution

Methods

From [1], the following relationship was established for the centre scenario used in [1], with varying EIR:

$$L=\exp(-0.262861 * \log(Pf\mathrm{EIR}) + 2.367012), \qquad \text{(equation 1)}$$

with *L* the effective length of epidemiological protection of a mass distribution round of LLINs, measure from distribution until half of maximum impact. This relationship is shown as the blue line in Figure 5b of [1]. In short, the centre scenario presumes a Tanzanian population structure and mosquito seasonality, 70% (initial) coverage with LLINs achieved by the round, the LLINs interfere with 75% of all mosquito bites, LLIN attrition with a half life of 4 years, medium levels of deterrency, pre- and post prandial killing, insecticide decay with a half life of 1.5 years (approximate value for second generation coated LLINs), and a hole generation rate of 1.8 holes per net per year.

For each world country listed in the Admin1 grid, a population weighted histogram was calculated for each *Pf*EIR percentile. For each country, all 99 histograms were summed and divided by the total to result in a population weighted density (statistical) distribution over the range of possible *Pf*EIR transmission levels. The density distribution can be interpreted as the statistical distribution of the population of a country over the possible transmission levels.
L was calculated for the empirical cumulative distribution function (ECDF) for each country.
Also, for the 90^{th} *Pf*EIR percentile grid, L was calculated directly for each grid cell.

Results
Figure 1 shows a map of Africa with L value for each country corresponding to the 90^{th} percentile. Each number in the map corresponds to the estimated duration applicable for 90% of the population of a country. If a successive round of LLINs is distributed after this time, for 90% of the people this will be before the impact of the previous distribution will have worn off to less than half of its maximum impact. For the remaining 10% of the population in the country, the previous distribution will have lost more impact. This concept can be studied on a country by country basis, by looking at the panels marked **b** in the Appendix. The panels **a** provide the population weighted *Pf*EIR distribution for each country.
Figure 2 shows a map of Africa with the L value for each 5 × 5 km grid cell based on the 90% percentile of the statistical distribution of the annual entomological inoculation rate. Even though the median (50^{th} percentile) is the “best estimate” of the local annual transmission (See Figure 5A of [2]), there generally is considerable uncertainty about this estimate. For the planning of LLIN distributions, it is safer to base it on a higher estimate, *e.g.* the transmission level at the 90^{th} percentile, where with a probability of 90% the transmission is equal or lower than that level. Whereas Figure 1 shows L values averaged for a whole country, Figure 2 gives an idea how the L value may vary geographically within countries, and whether regionally differing strategies should be considered.

Discussion
The results presented here should be interpreted with caution, and the L value should not be taken at its absolute value. Equation 1 was based on one scenario with a specific vector population and seasonality and health system based loosely on Tanzania, an attrition of nets with a four year half life, a coverage of 70%, and other parameter assumptions which may well vary with country and bed net type. A country specific modeling exercise would be required to estimate how equation 1 varies geographically. Moreover, equation 1 is based on the pre-intervention EIR (the EIR before implementation of LLINs), and the model of [2], which gives a higher weight to more recent data and takes time trends into account, provides EIR estimates which are likely influenced by implementation of LLINs. Therefore, pre-intervention EIRs would likely be higher than the EIR mapped in many countries, resulting in a bias for shorter L estimates in countries with successful LLIN programmes.

Acknowledgements
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Reference List

1. Briet OJ, Hardy D, Smith TA: **Importance of factors determining the effective lifetime of a mass, long-lasting, insecticidal net distribution: a sensitivity analysis.** *Malar J* 2012, **11**(1)**:** 20.

2. Gething PW, Patil AP, Smith DL, Guerra CA, Elyazar IR, Johnston GL, Tatem AJ, Hay SI: **A new world malaria map: Plasmodium falciparum endemicity in 2010.** *Malar J* 2011, **10:378.** 378.

3. **Global Rural Urban Mapping Project (GRUMP) alpha: Gridded Population of the World, version 2, with urban reallocation (GPW-UR)**

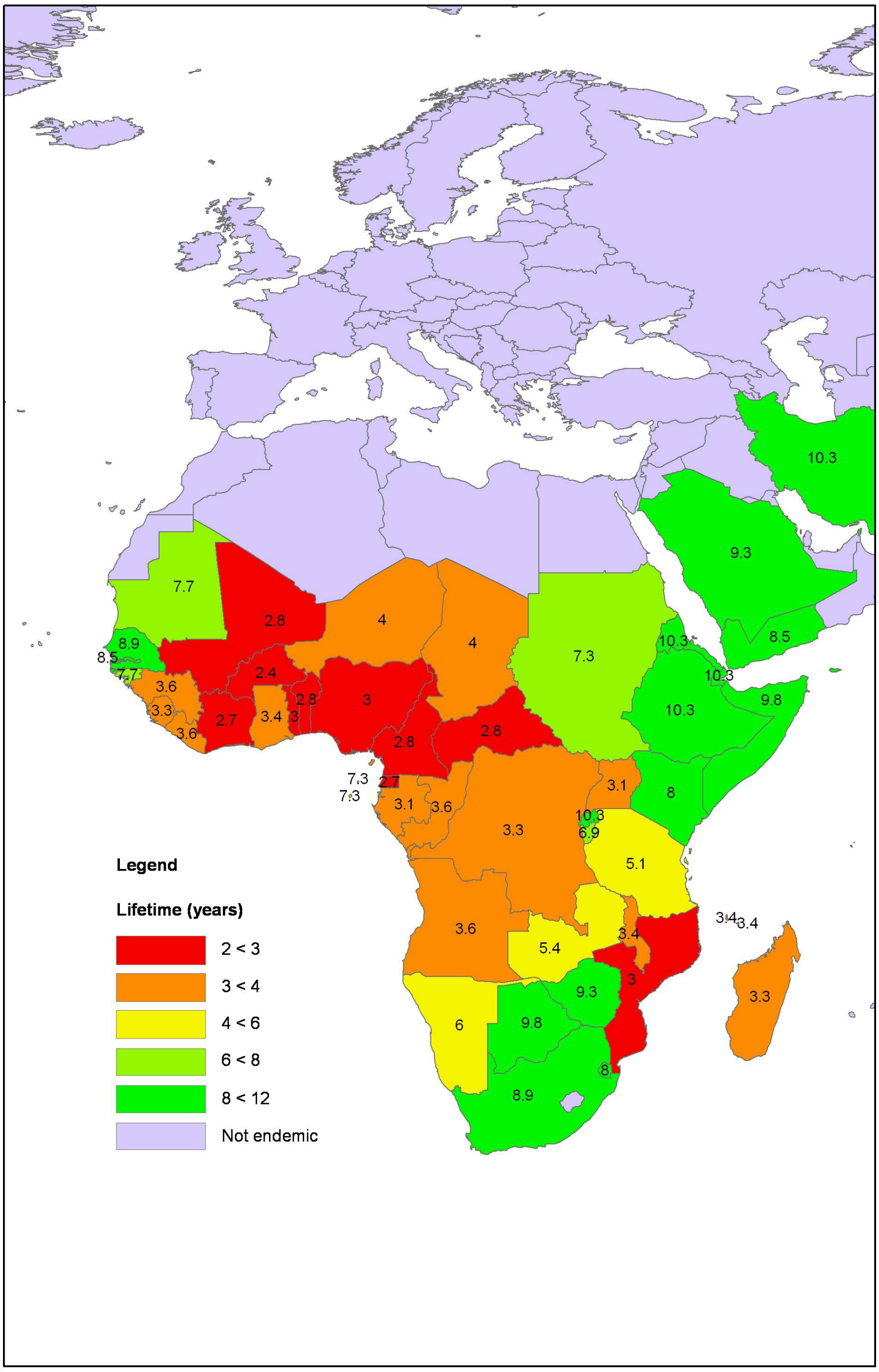

Figure 1 Estimated duration of the effective epidemiological lifetime of a mass long lasting insecticide treated net distribution based on the population weighted annual entomological inoculation rate, per country. Each number corresponds to the estimated duration applicable for 90% of the population of a country.

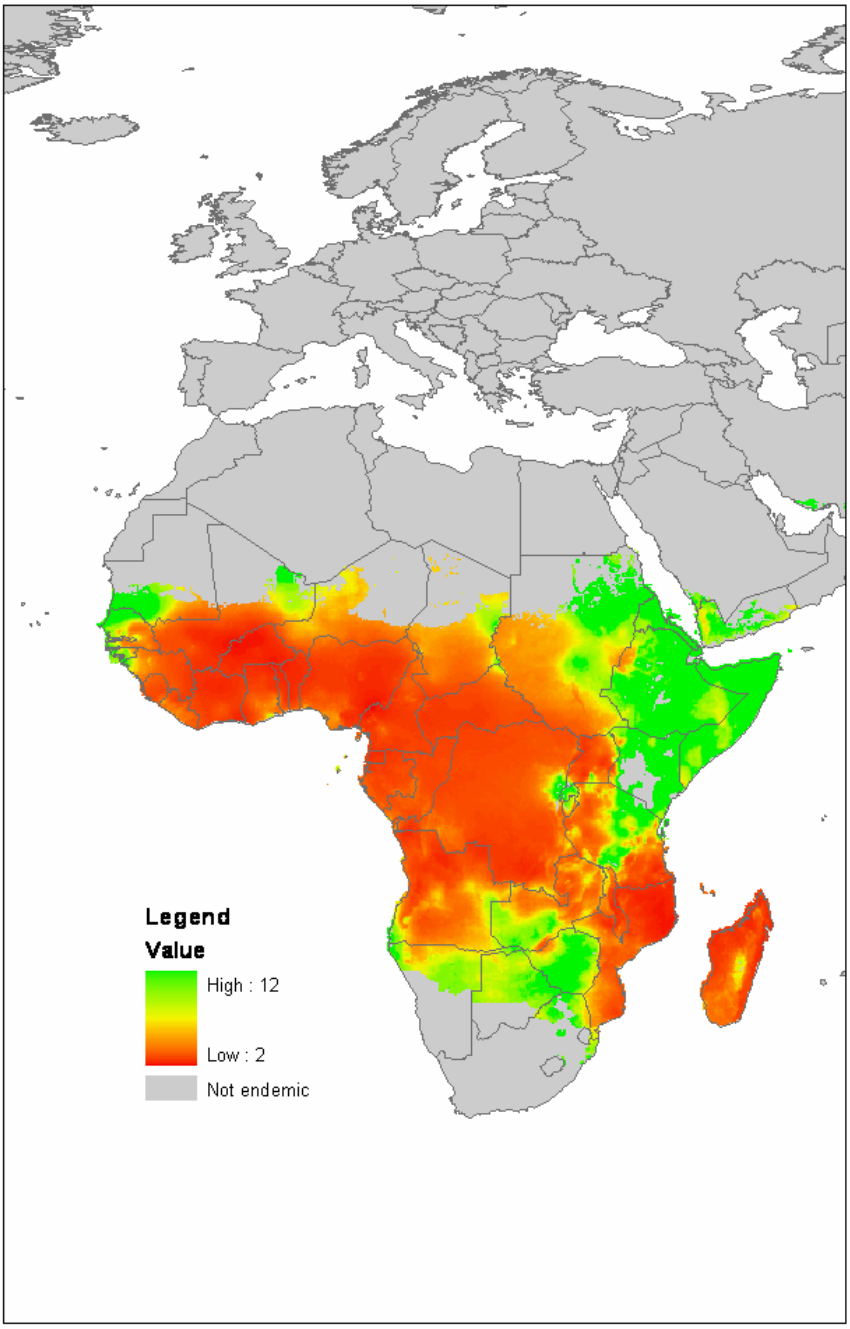

Figure 2 Estimated duration of the effective epidemiological lifetime of a mass long lasting insecticide treated net distribution based on the 90th percentile of the annual entomological inoculation rate

Appendix

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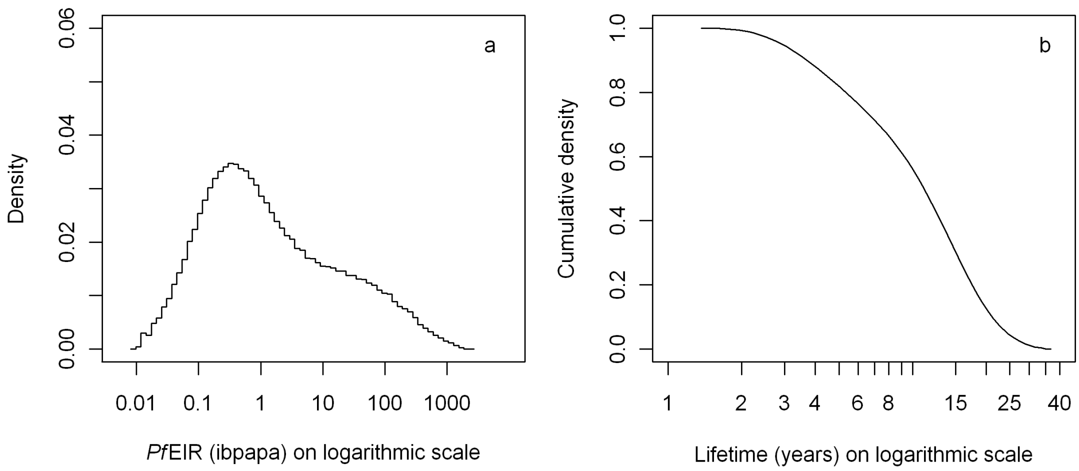

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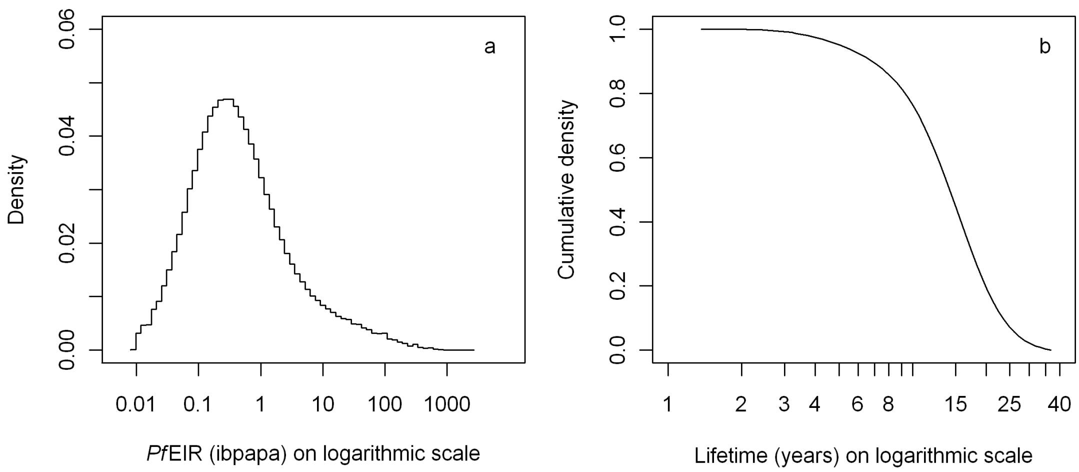

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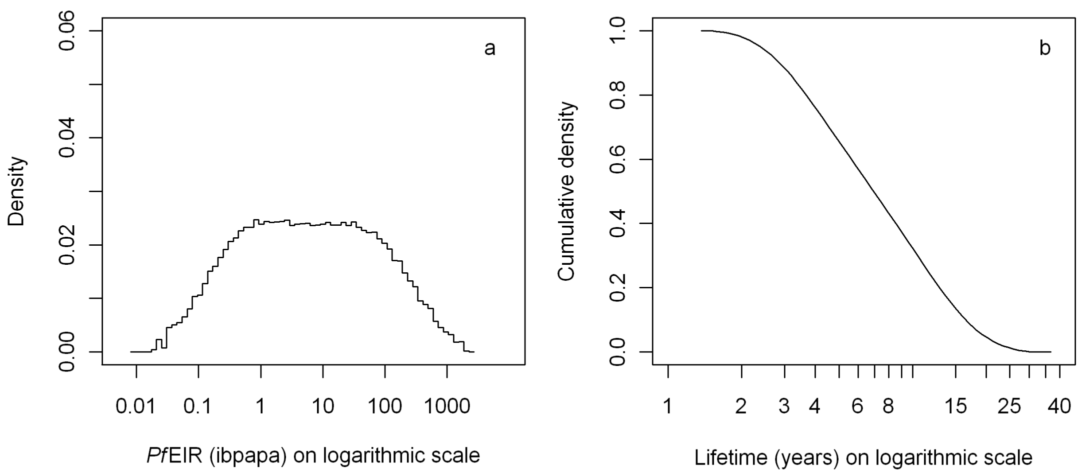

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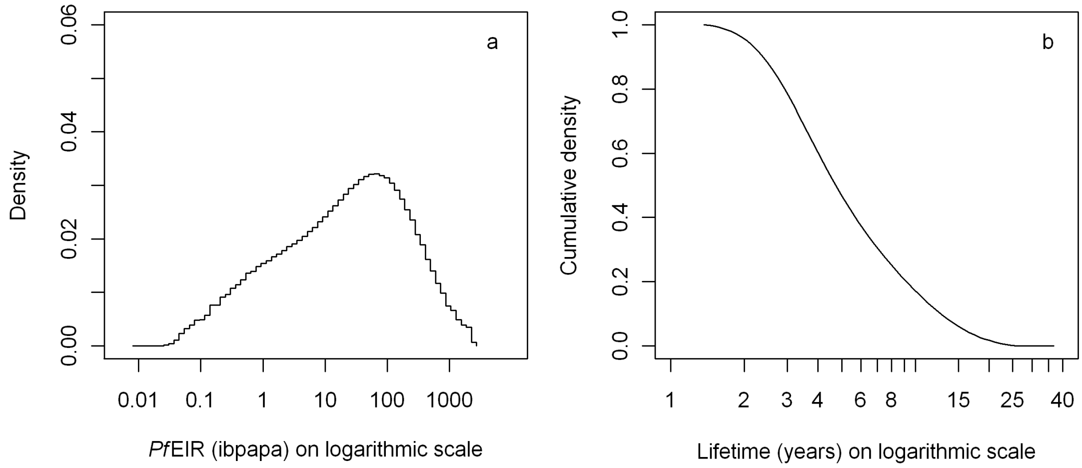

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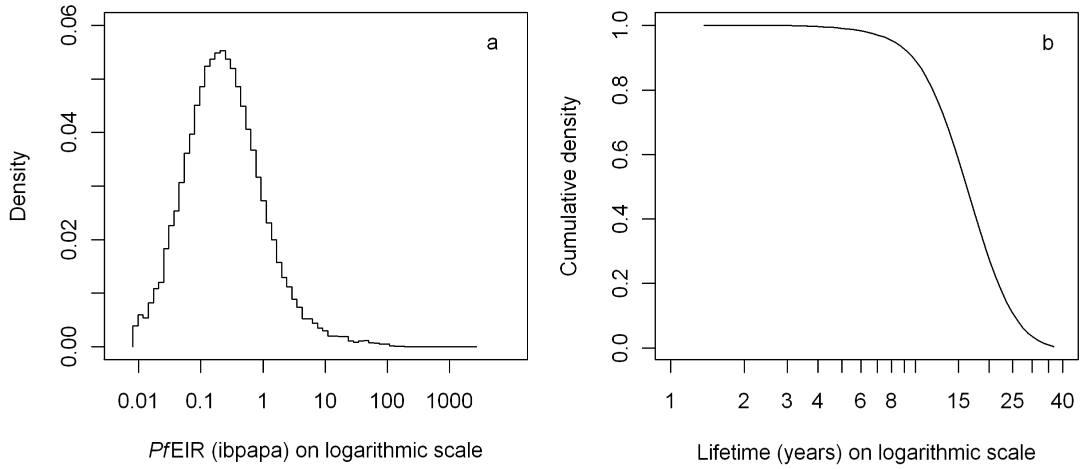

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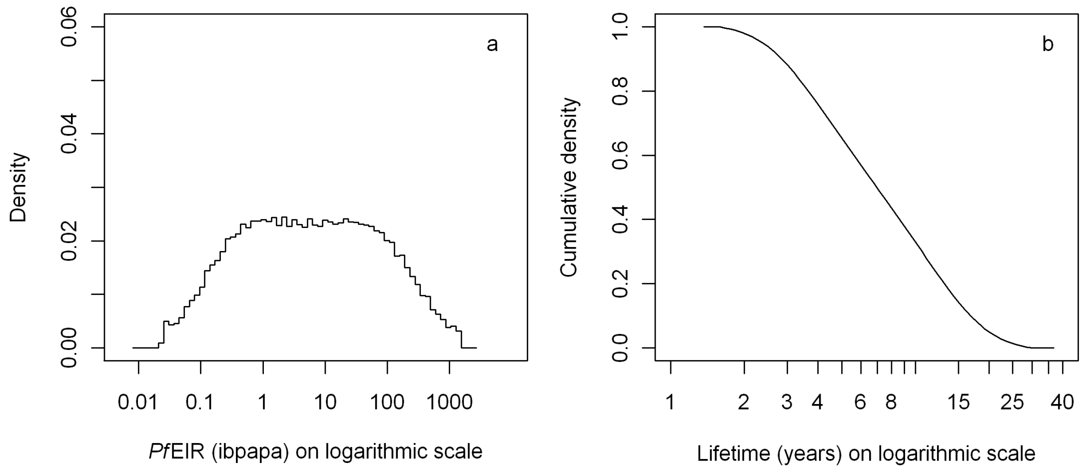

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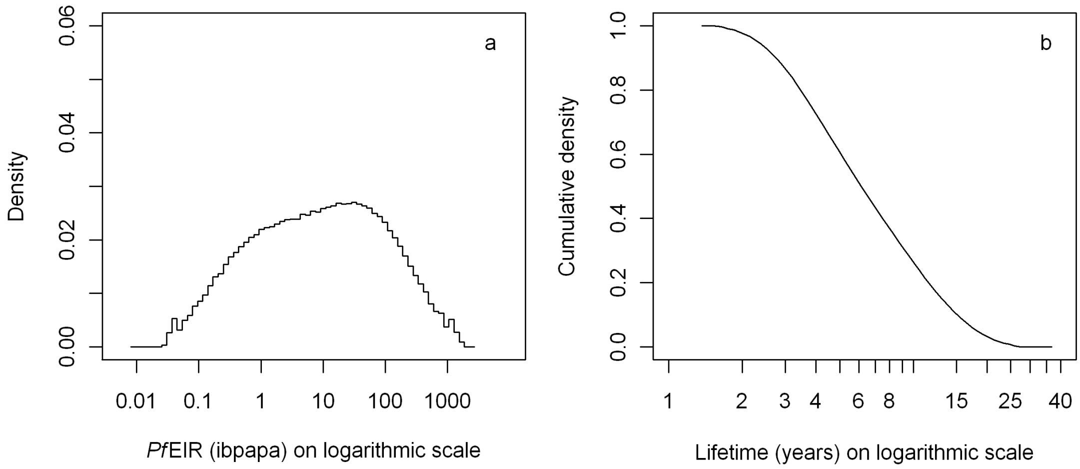

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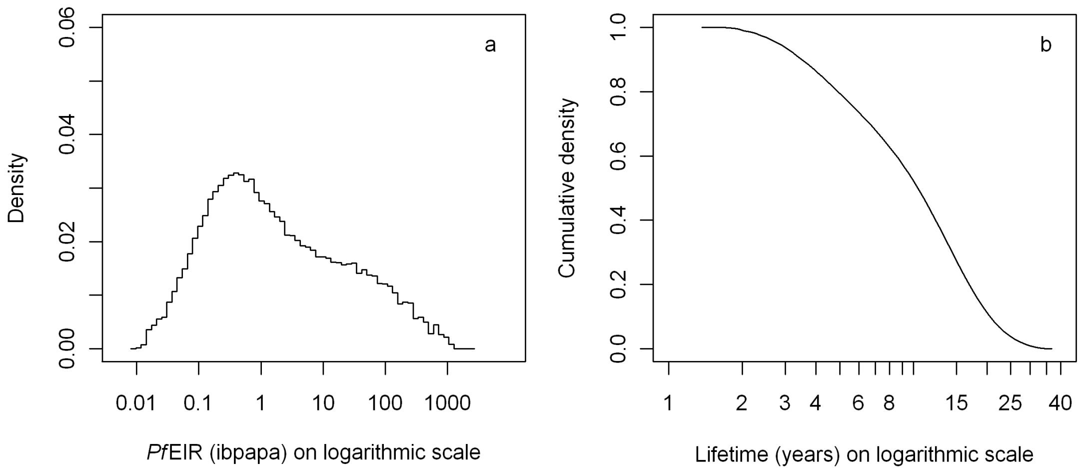

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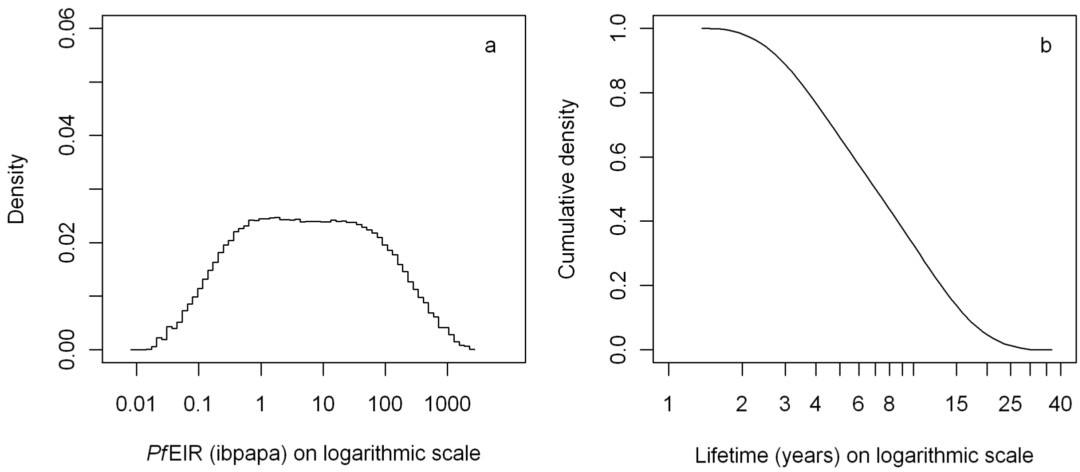

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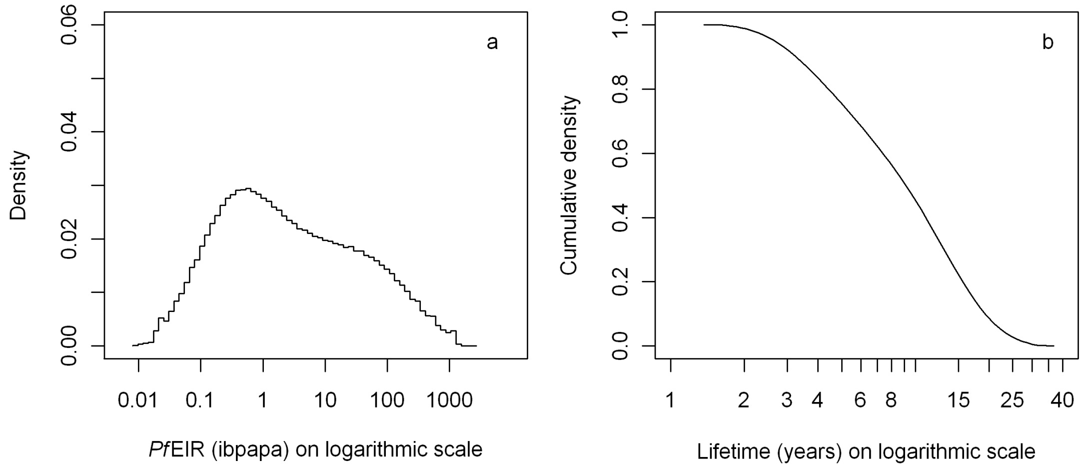

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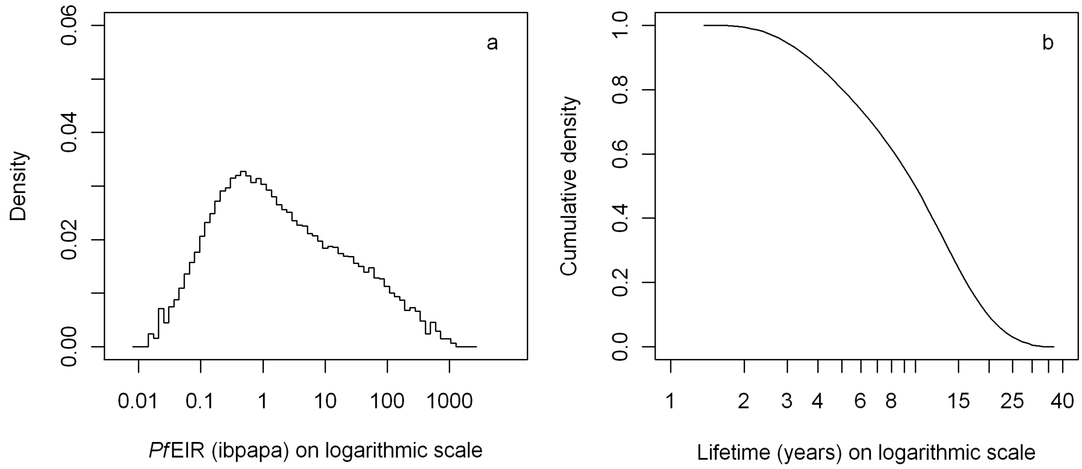

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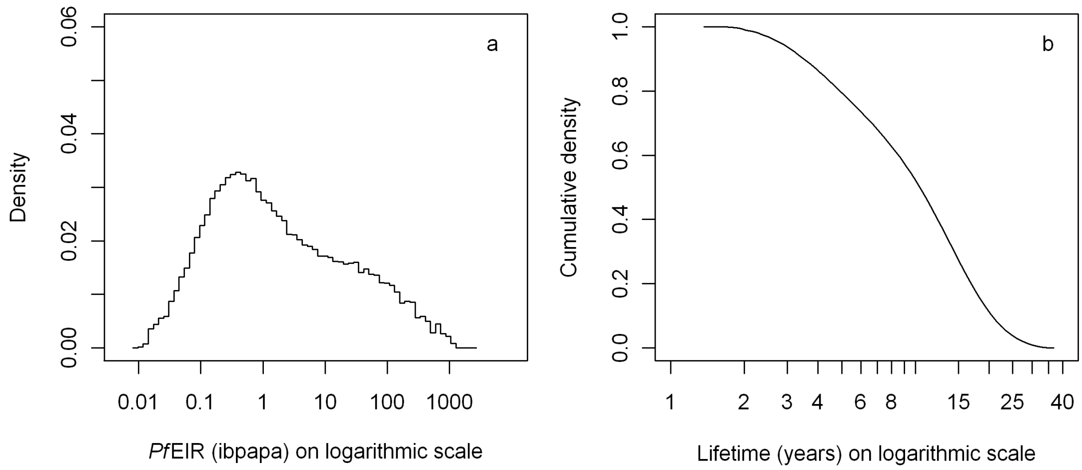

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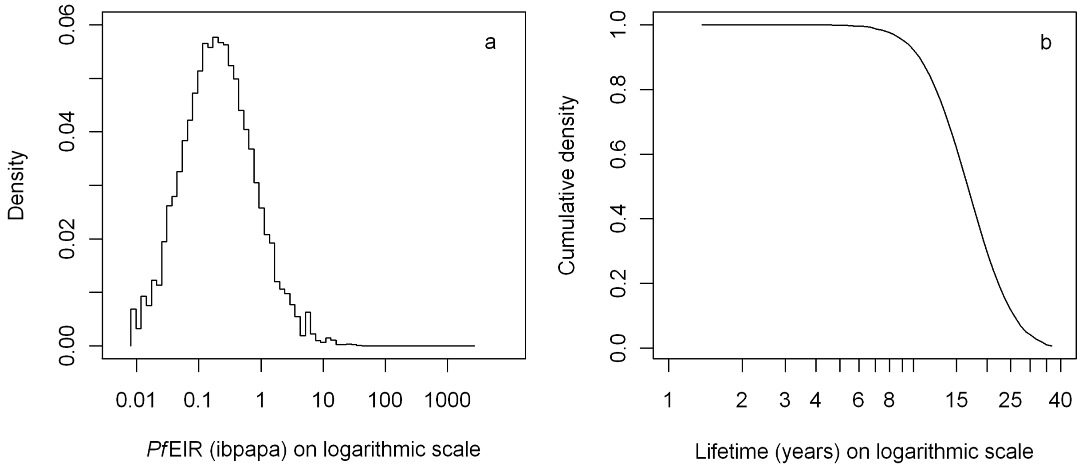

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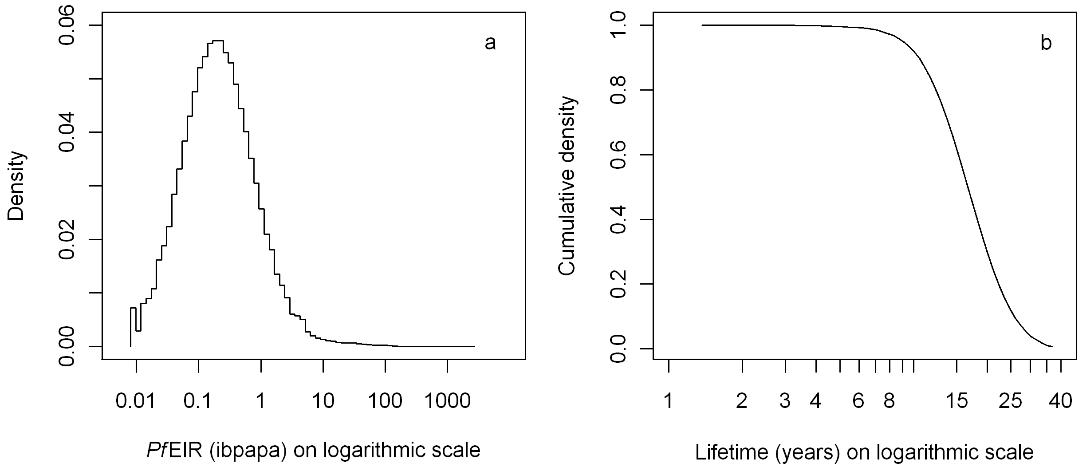

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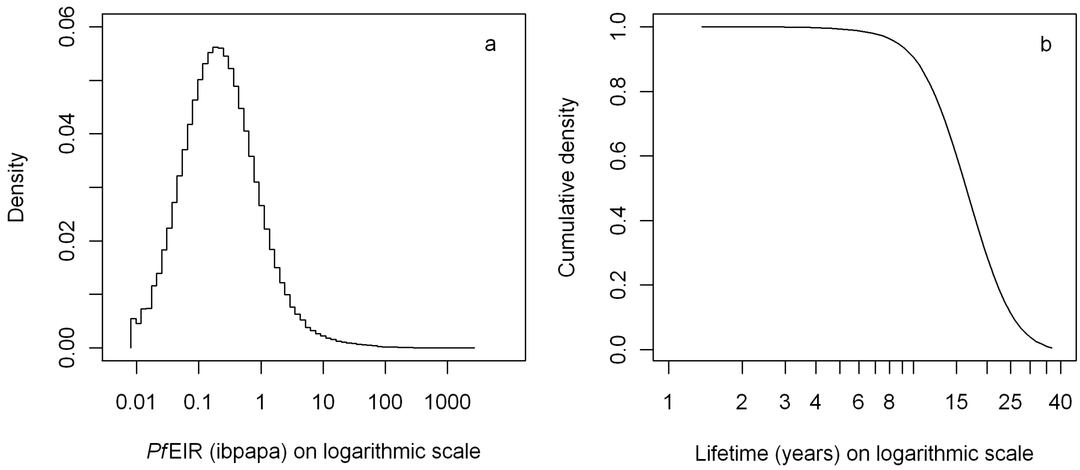

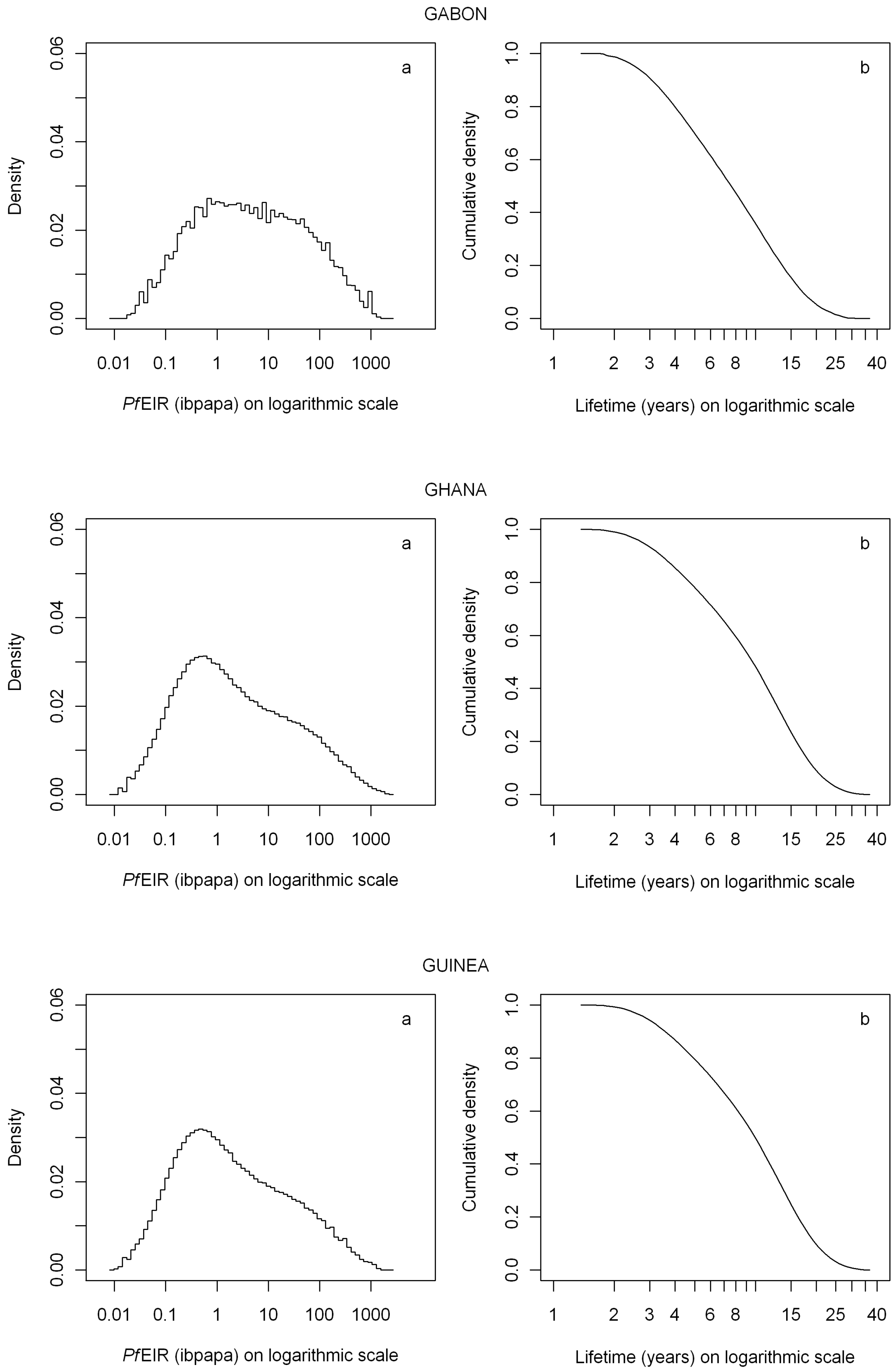
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*Pf*EIR (ibpapa) on logarithmic scale
Lifetime (years) on logarithmic scale

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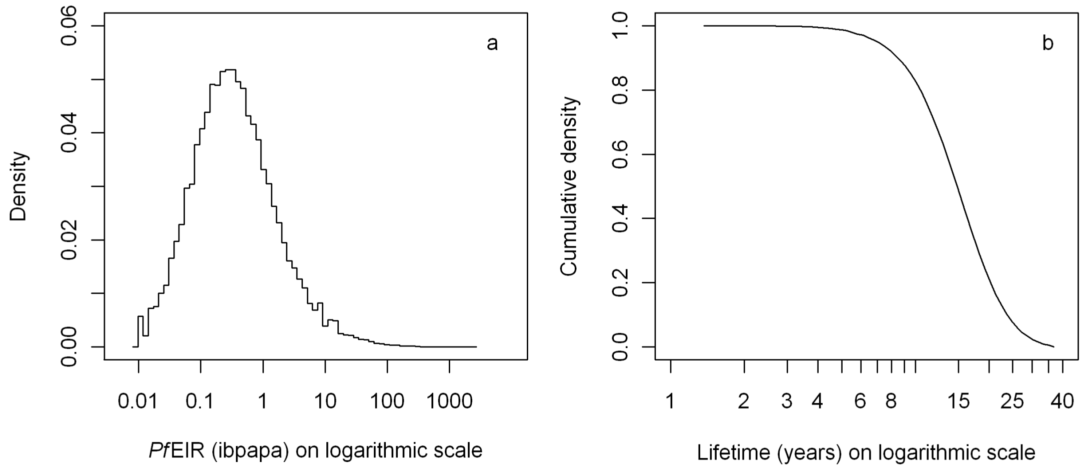

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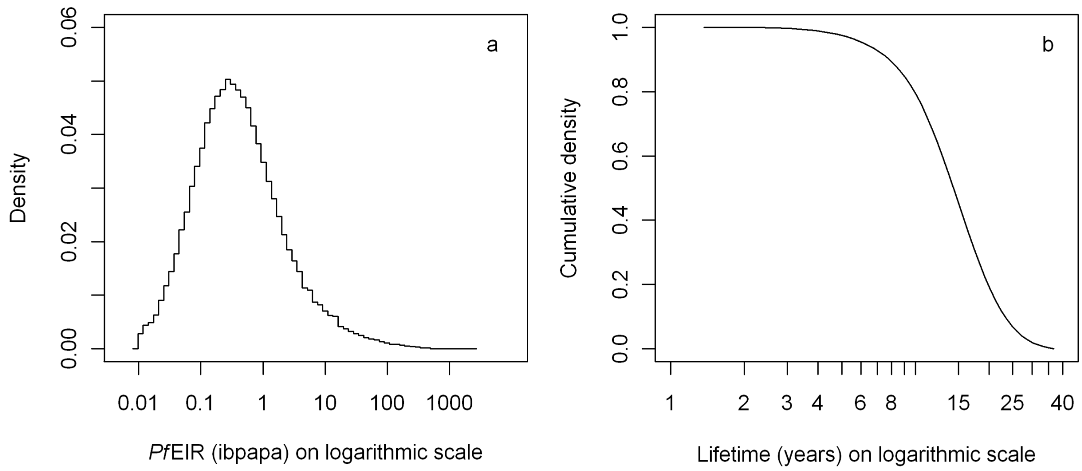

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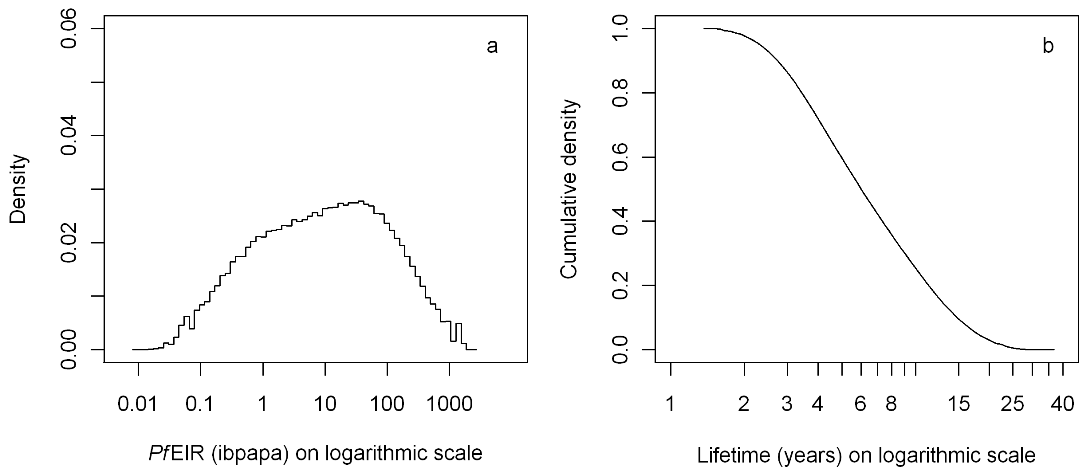

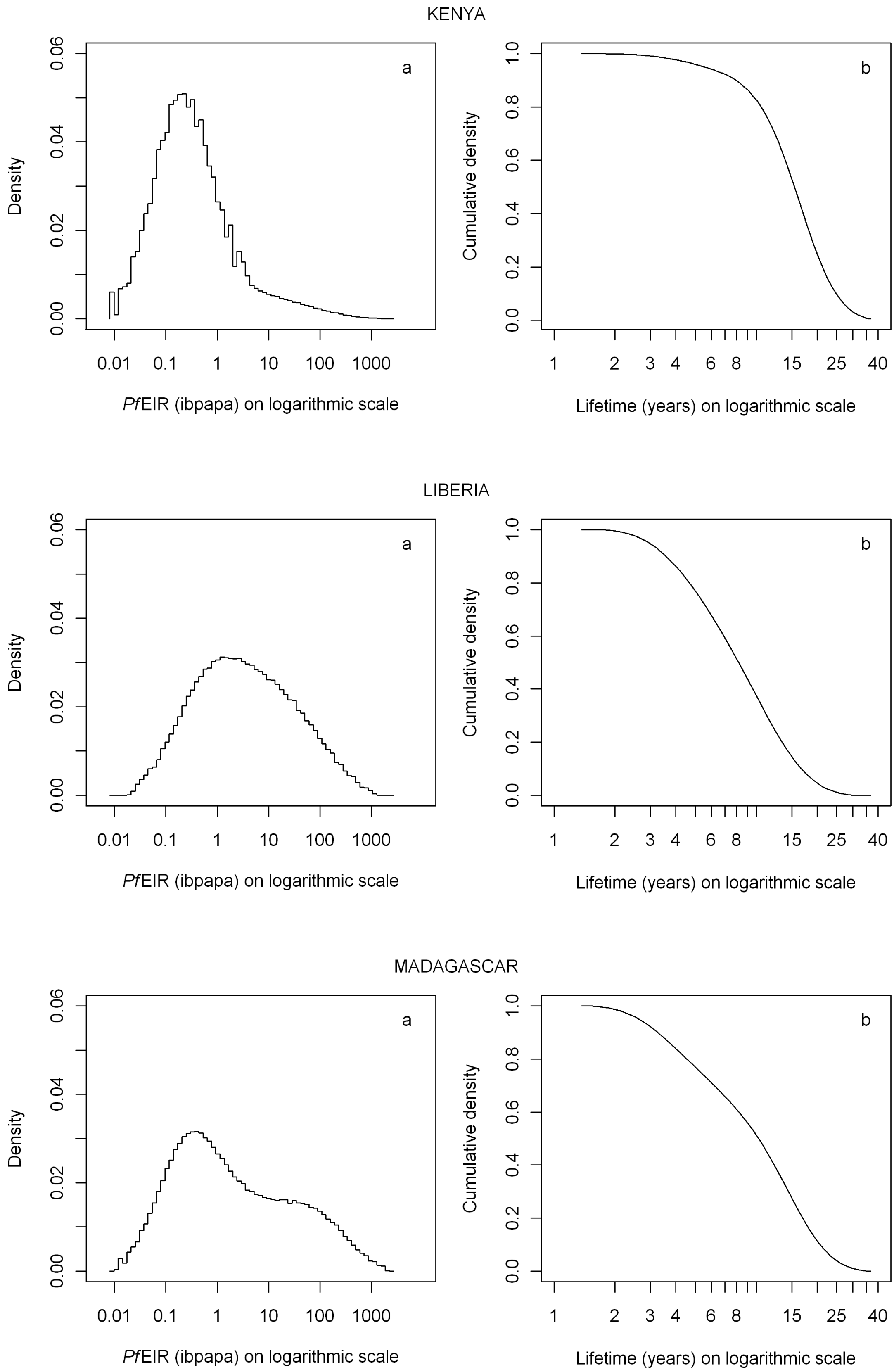
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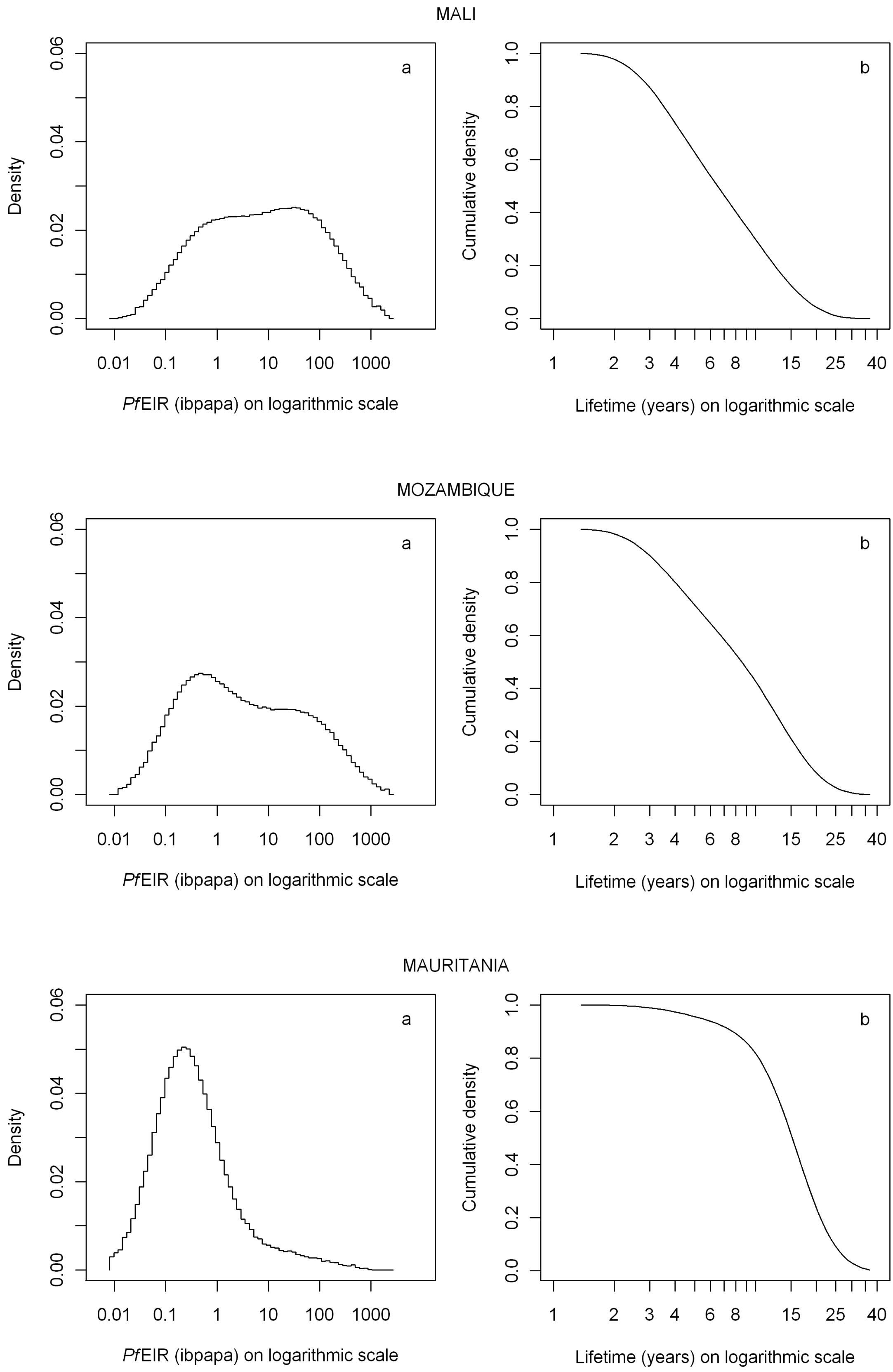
Lifetime (years) on logarithmic scale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*Pf*EIR (ibpapa) on logarithmic scale
Lifetime (years) on logarithmic scale
MOZAMBIQUE
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*Pf*EIR (ibpapa) on logarithmic scale
Lifetime (years) on logarithmic scale
MAURITANIA
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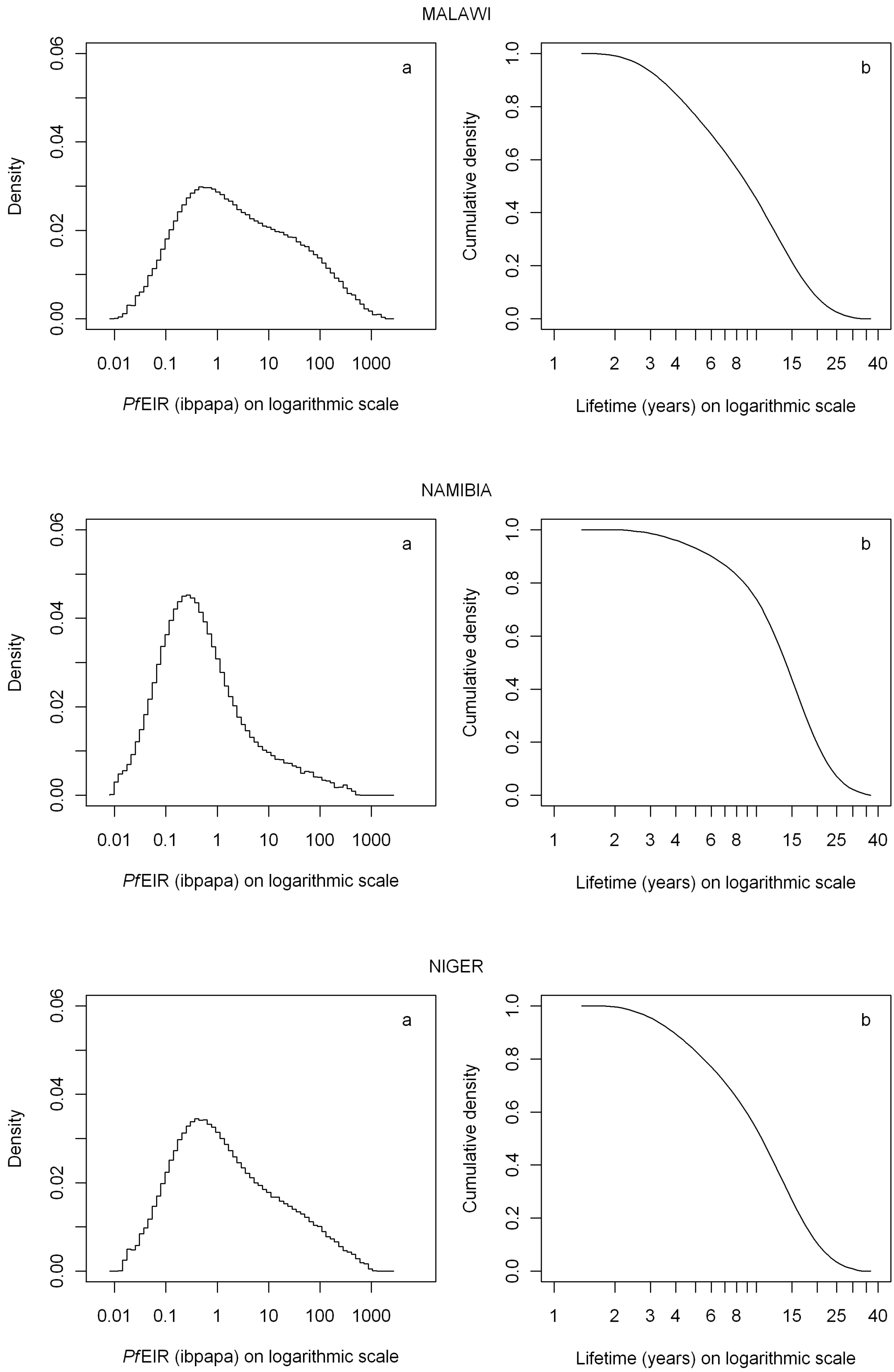
*Pf*EIR (ibpapa) on logarithmic scale
Lifetime (years) on logarithmic scale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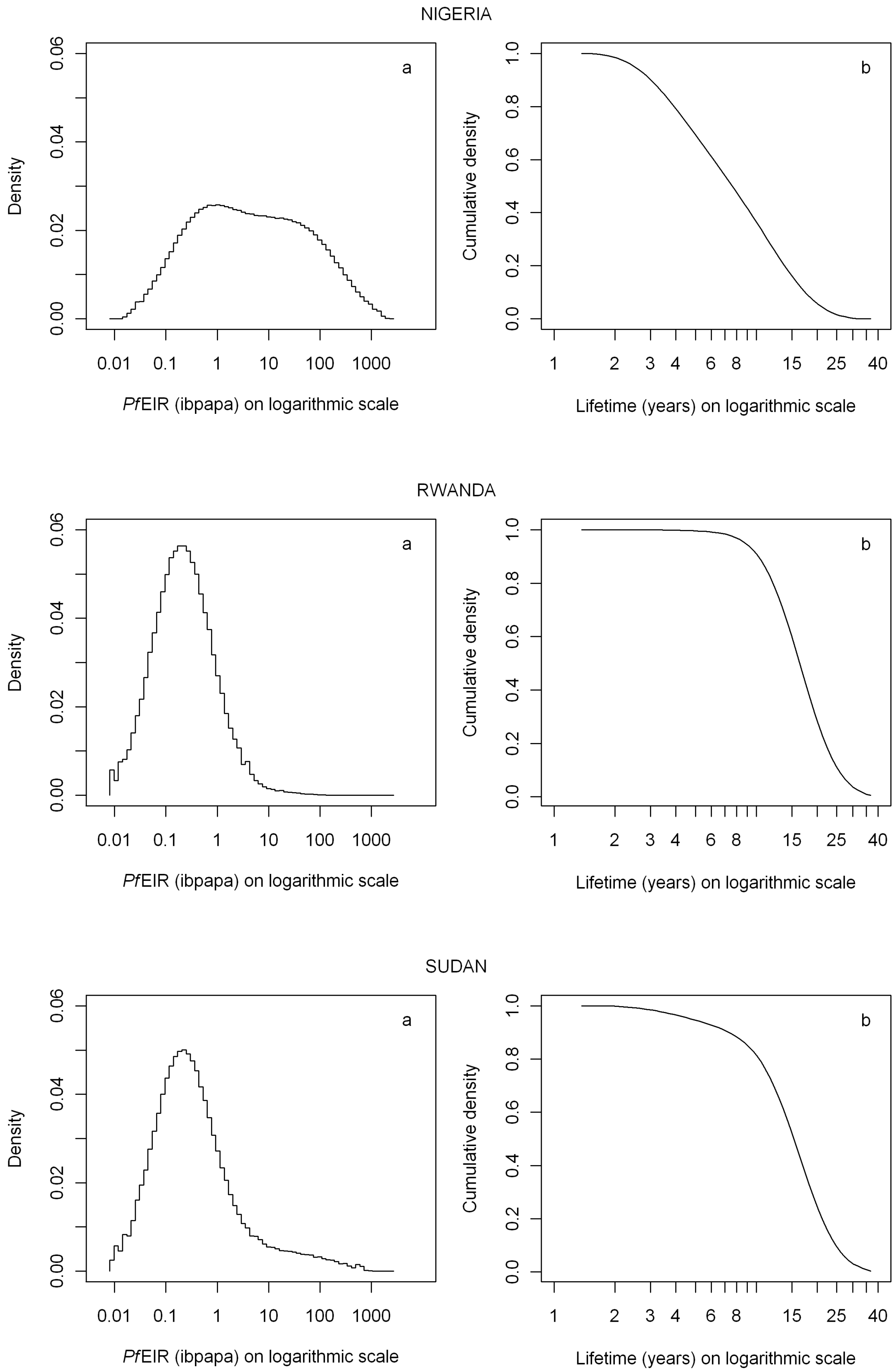
Lifetime (years) on logarithmic scale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Lifetime (years) on logarithmic scale

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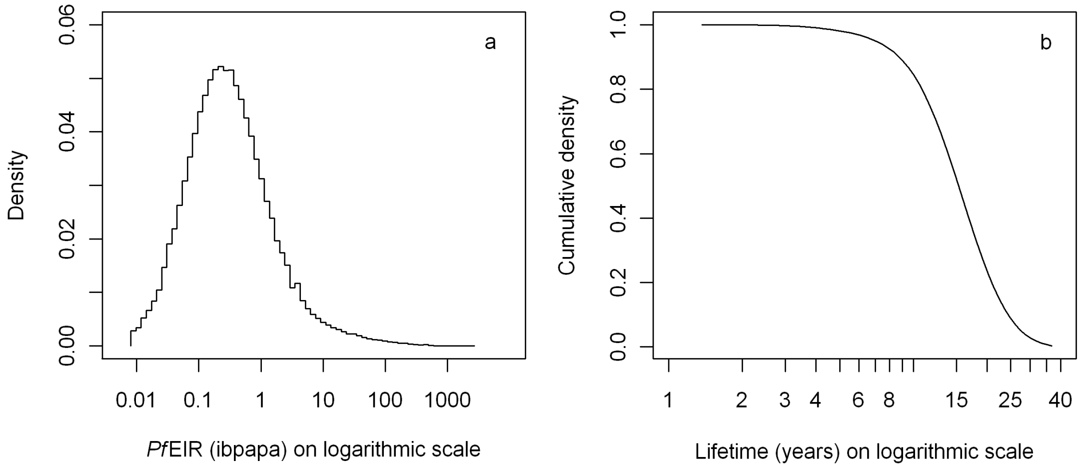

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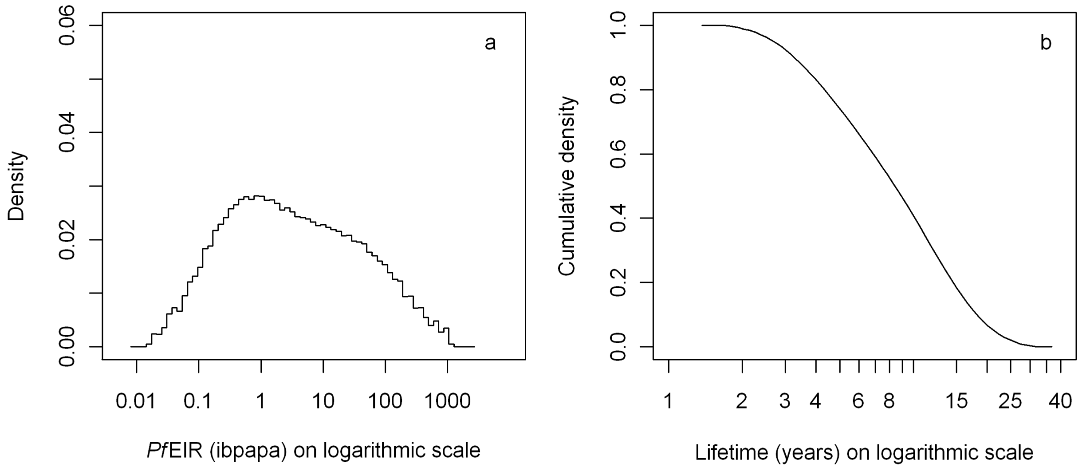

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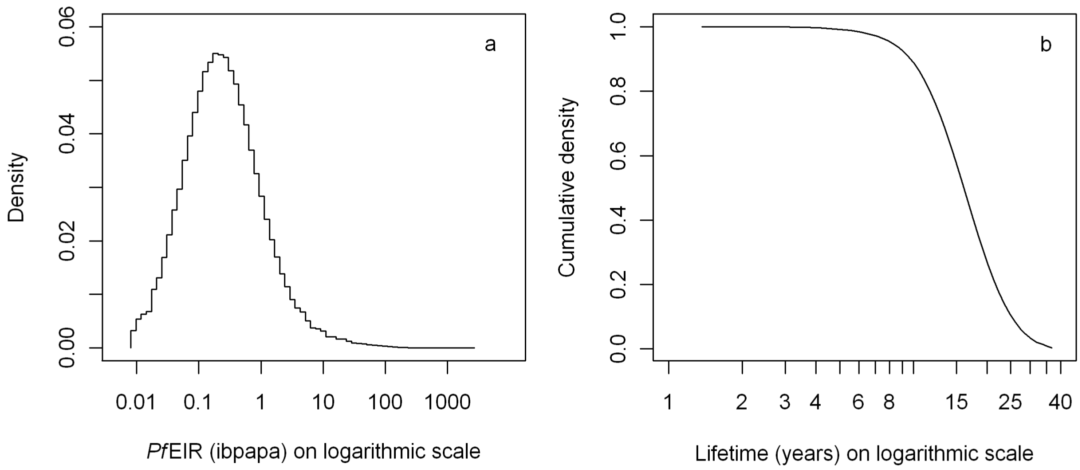

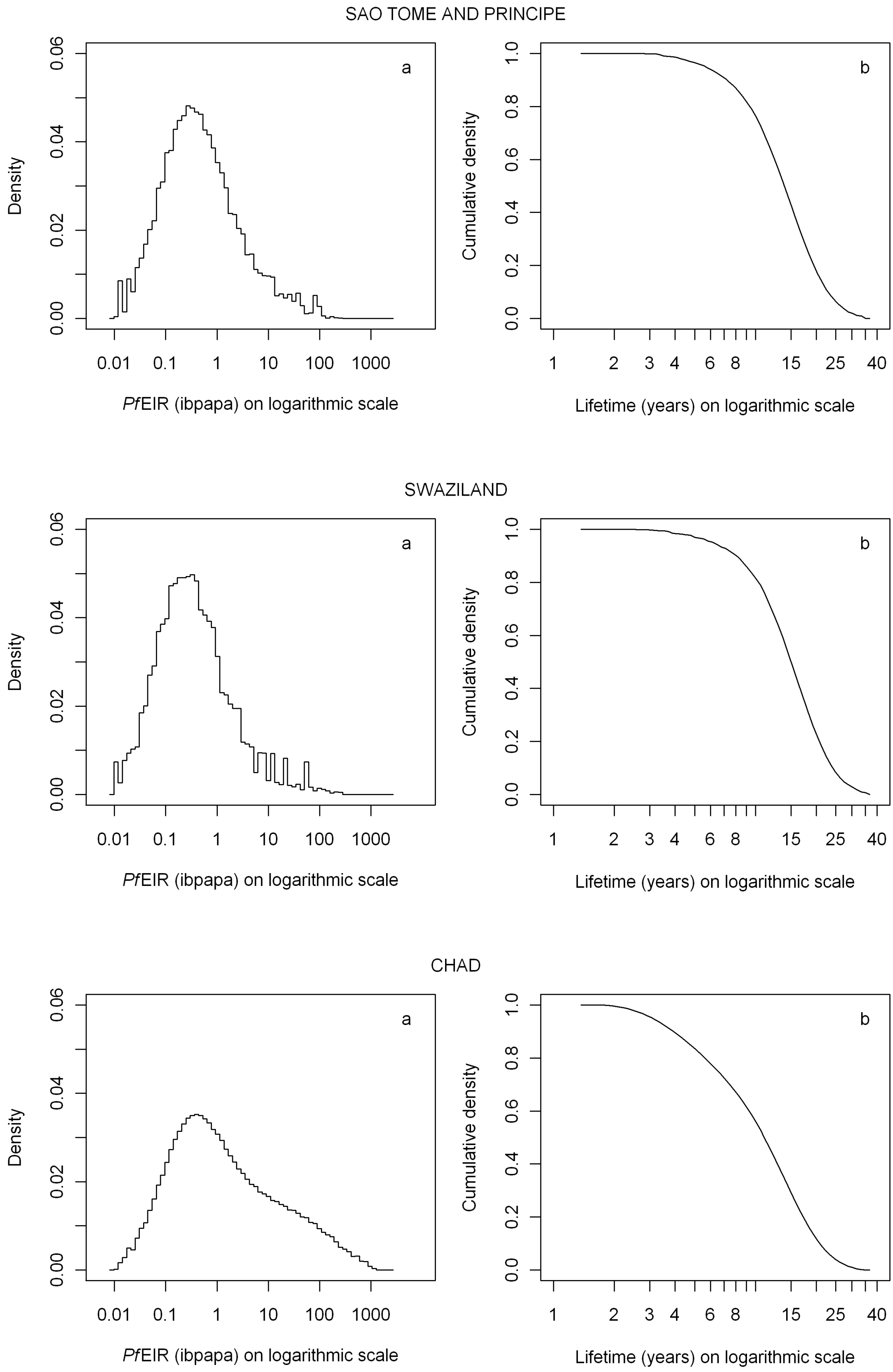
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Lifetime (years) on logarithmic scale

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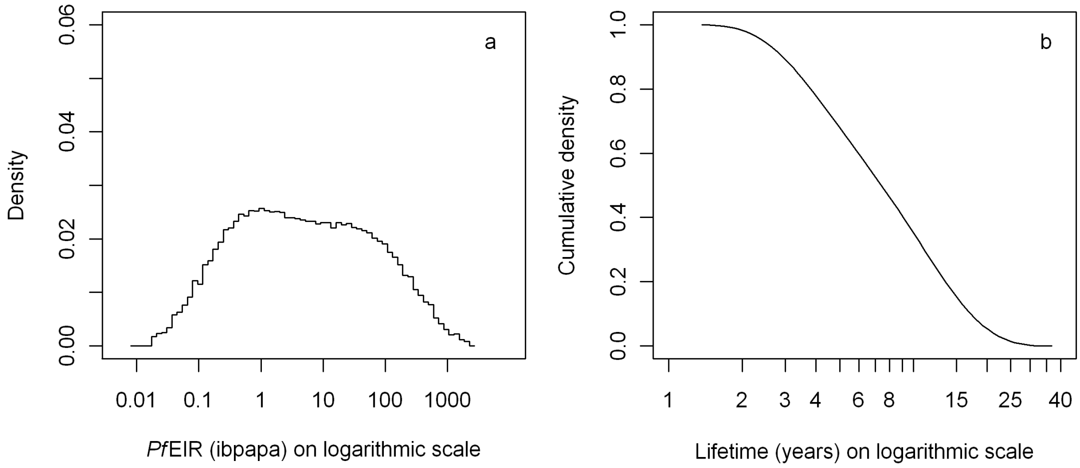

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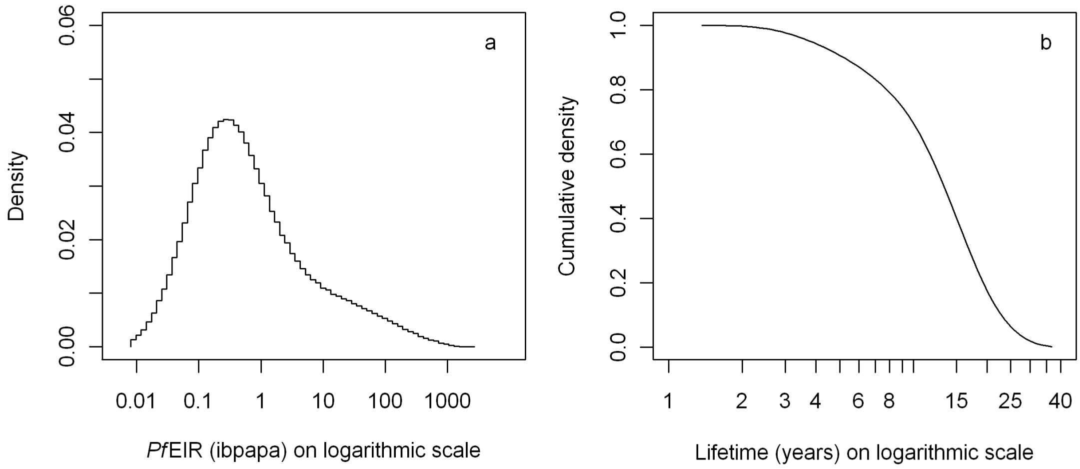

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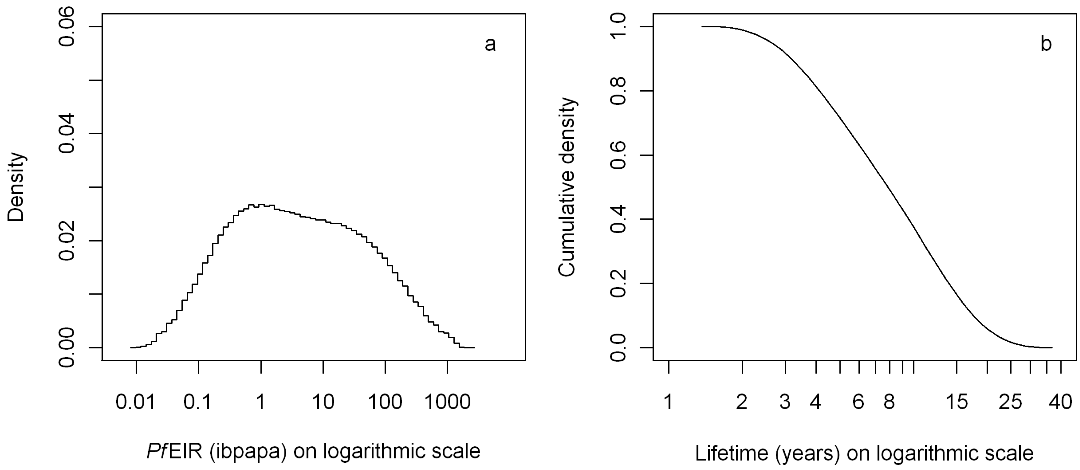

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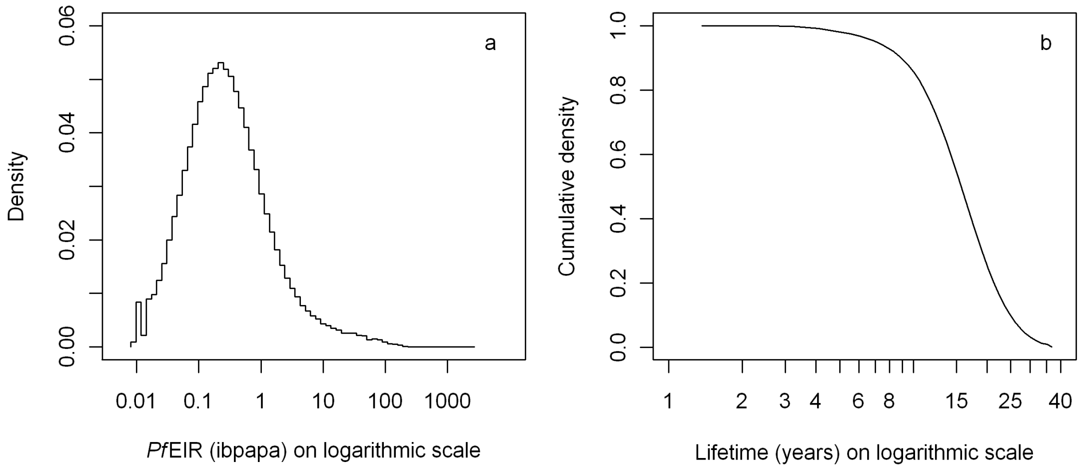

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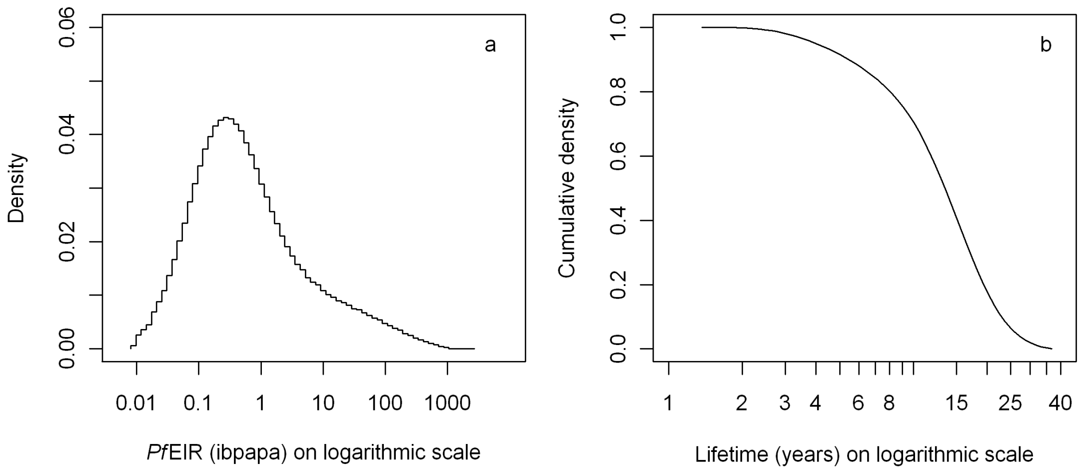

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