Occupancy and abundance (N-mixture) examples (in review)

Ecology and Evolution
Open Access

ORIGINAL RESEARCH | Open Access

One size does not fit all: Customizing MCMC methods for hierarchical models using NIMBLE

Lauren C. Ponisio, Perry de Valpine, Nicholas Michaud, Daniel Turek

First published:14 February 2020 | https://doi.org/10.1002/ece3.6053

For each example, we compare:

Sampling over latent states (conventional)

- JAGS
- nimble with default samplers
- nimble with JAGS-like samplers
- nimble with block samplers
  - Random-walk blocking (RWB)
  - Automated factor slice-sampler (AFSS)

Marginalizing over latent-states (nimble-only)

- nimble with default samplers
- nimble with JAGS-like samplers
- nimble with block samplers
  - RWB
  - AFSS

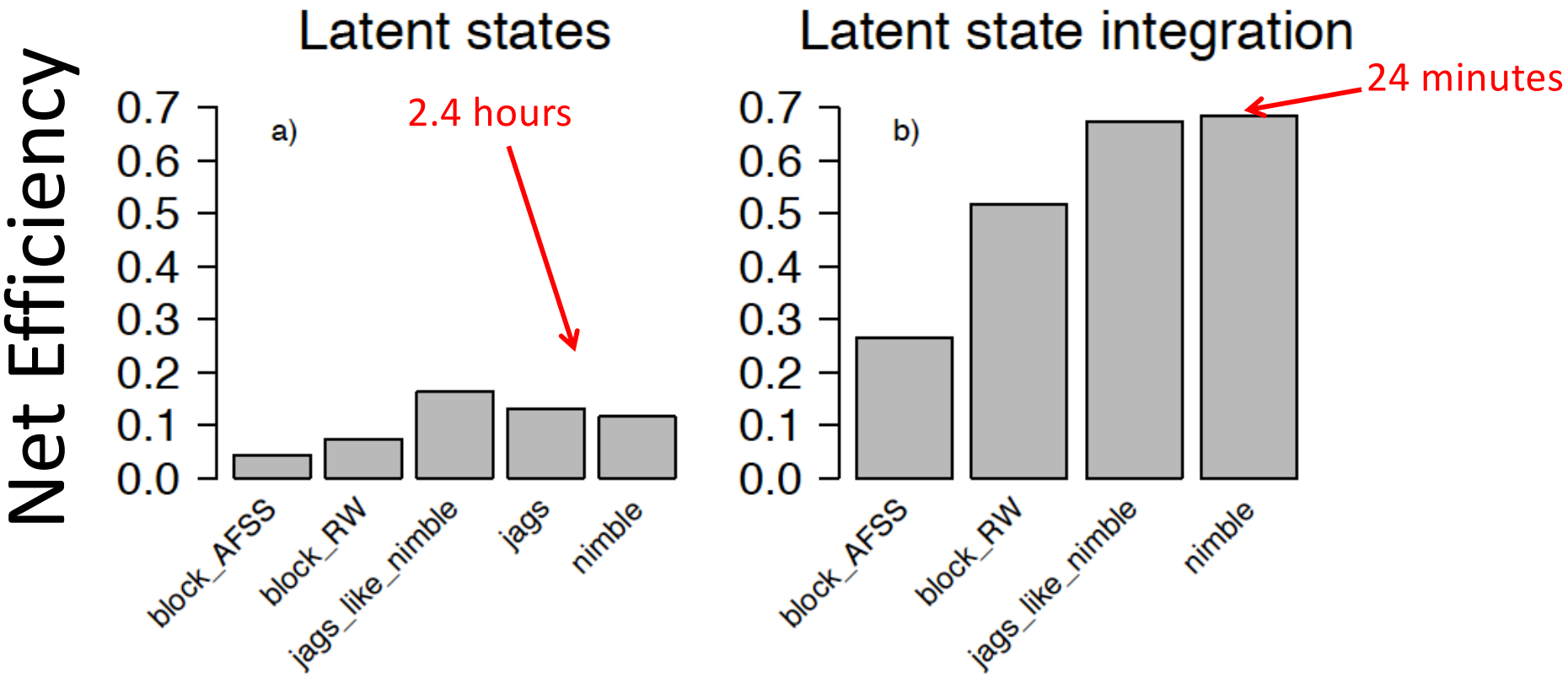
Multi-species single-season occupancy model

- From Zipkin, Royle, Dawon and Bates. 2010. Multi-species occurrence models to evaluate the effects of conservation and management actions. *Biological Conservation* 143: 479–484
- 70 forest sites (Maryland, Blue Ridge Mountains)
- 58 bird species
- 3-4 visits at each site
- 5 parameters for occupancy probability
- 2 parameters for detection probability
- 6 parameters follow prior distributions across species
  - ➔ 6 random effects, each with 58 values.
- Marginalization: Sum over occupancy latent state using “occupancy” distribution.

Black-and-white warbler (*Mniotilta varia*)

https://commons.wikimedia.org/wiki/File:Black-and-white_Warbler_2.jpg

Multi-species single-season occupancy model



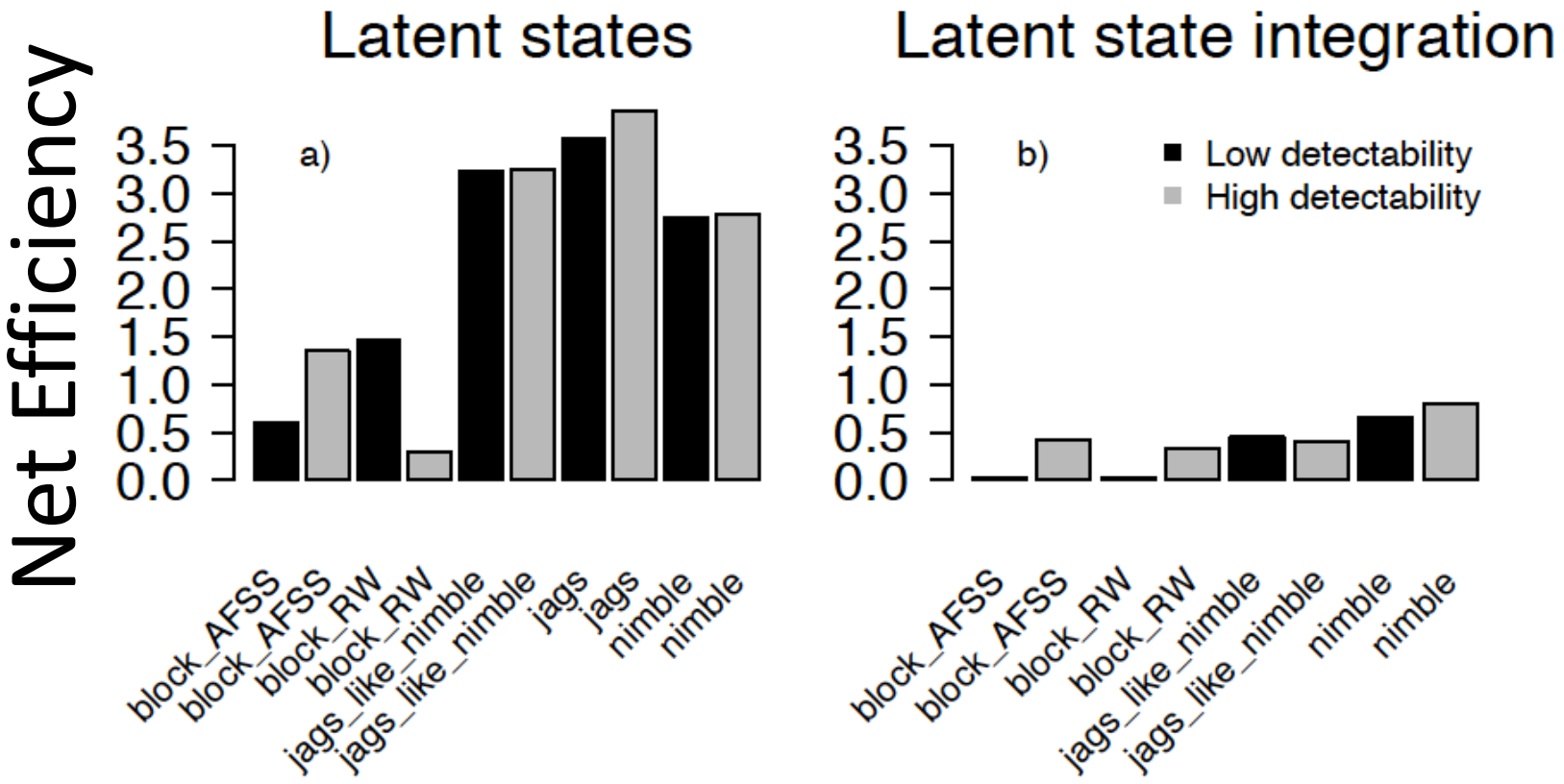
MCMC method

Single-species multi-season (dynamic) occupancy model

- Simulated data modified from Kéry & Schaub (2012, Bayesian Population Analysis).
- 100 sites
- 15 years
- 5 visits per site per year

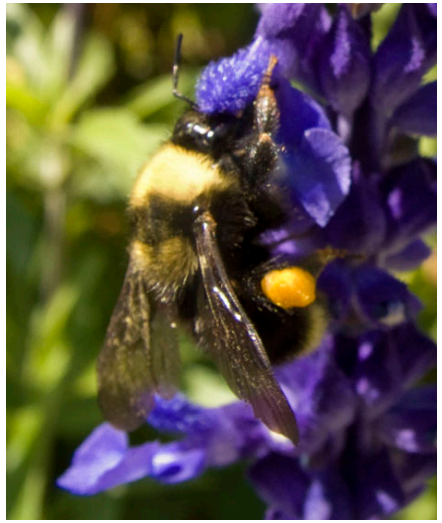
- Persistence (1-extinction) and colonization probabilities follow a prior across years
  - ➔ 2 random effects, each with 14 values.
- Detection probability = 0.27 (low) or 0.73 (high)
- Marginalization: Sum over occupancy latent state and time-series (Hidden Markov Model) using “dynamic occupancy” distribution.

Single-species multi-season (dynamic) occupancy model

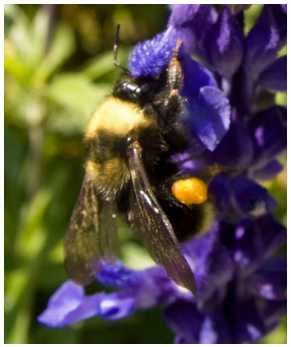


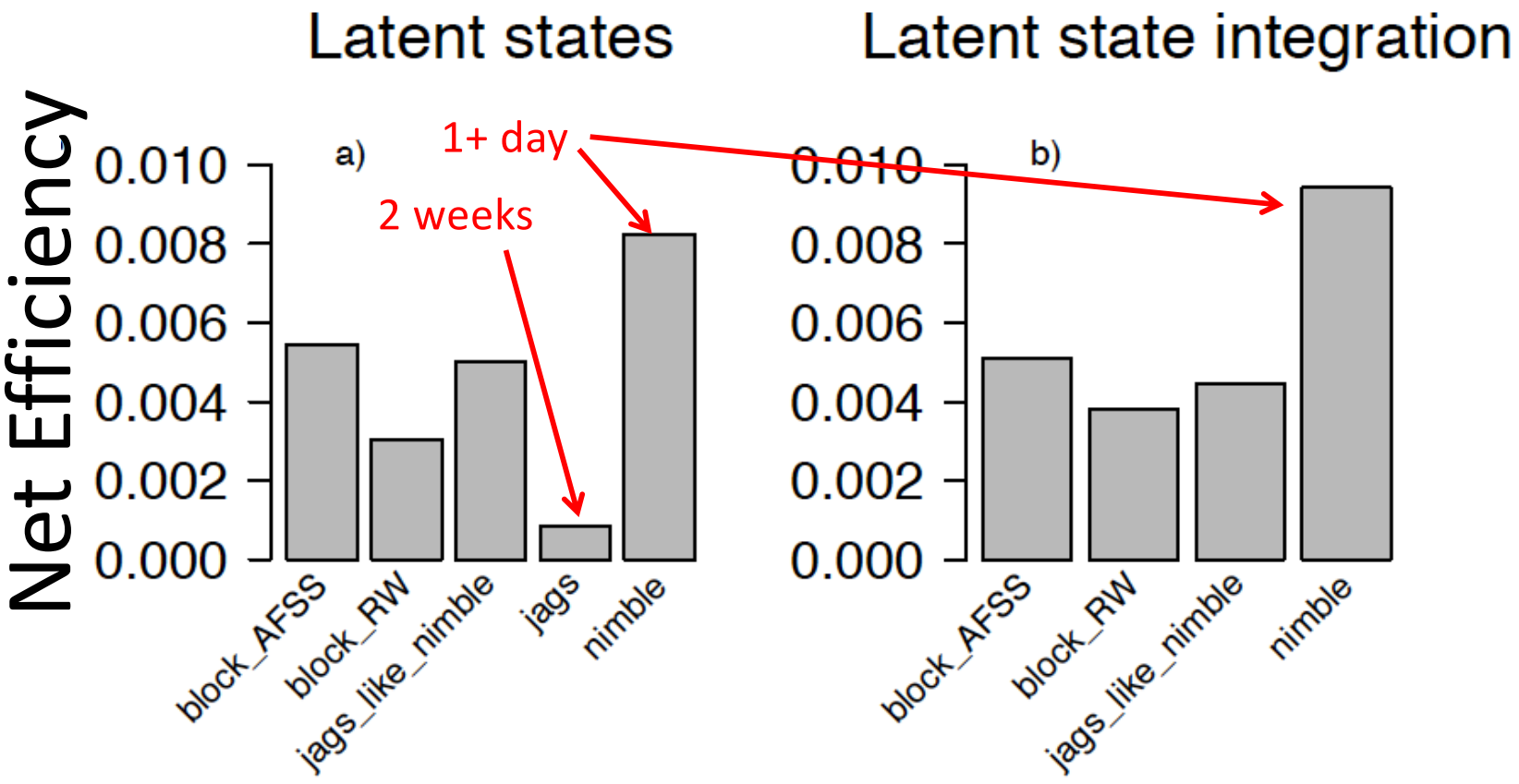
Multi-species multi-season (dynamic) occupancy model

- From Ponisio, de Valpine, M'Gonigle, and Kremen. 2019. Proximity of restored hedgerows interacts with local floraldiversity and species' traits to shape long-term pollinatormetacommunity dynamics. *Ecology Letters* 22: 1048–1060.
- 31 sites (agricultural, with / without hedgerow habitat restoration, California)
- 10 years
- 49 bee species
- 2-7 surveys per site per year
- 5 covariates for site persistence probability
- 5 covariates for site colonization probability
- 2 covariates for detection probability
- 11 parameters are species-specific following priors across species
  - ➔ 11 random effects, each with 49 values



Multi-species multi-season (dynamic) occupancy model





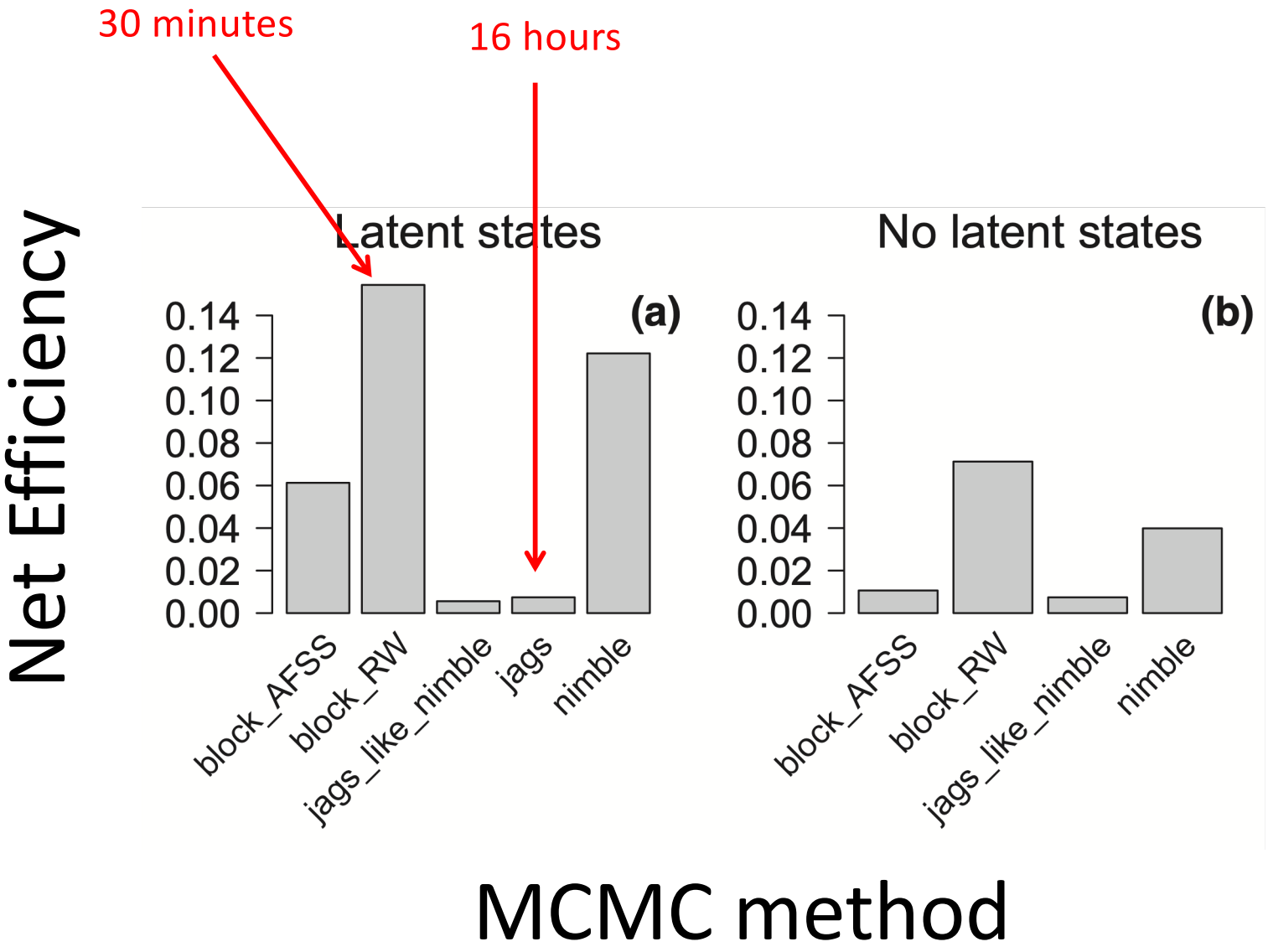
MCMC method

Zero-inflated N-mixture model

- Great tits in Switzerland (Swiss Breeding Bird Survey)
- From Kéry and Royle. 2016. (Applied Hierarchical Modeling in Ecology. Vol I.). 6.11.1
- 267 sites (quadrats)
- Data from 2013
- 2-3 surveys per site
- 8 parameters for abundance
- 14 parameters for detection
- Random effects for
  - Site (abundance) (267 values)
  - Site (detection) (267 values)
  - Survey-by-visit (detection) (267 x (2-3)) values
- Marginalization: Sum over latent true abundance (N).

https://commons.wikimedia.org/wiki/File:Great_tit_side-on.jpg

Zero-inflated N-mixture model



Good MCMC strategies are problem-specific.

There is no one-size-fits-all solution.

Efficient Estimation of Large-Scale Spatial Capture-Recapture Models

Daniel Turek, Cyril Milleret, Torbjørn Ergon, Henrik Brøseth, Perry de Valpine

doi: https://doi.org/10.1101/2020.05.07.081182

Ecology and Evolution

Open Access

ORIGINAL RESEARCH | Open Access

A local evaluation of the individual state-space to scale up Bayesian spatial capture–recapture

Cyril Milleret, Pierre Dupont, Christophe Bonenfant, Henrik Brøseth, Øystein Flagstad, Chris Sutherland, Richard Bischof

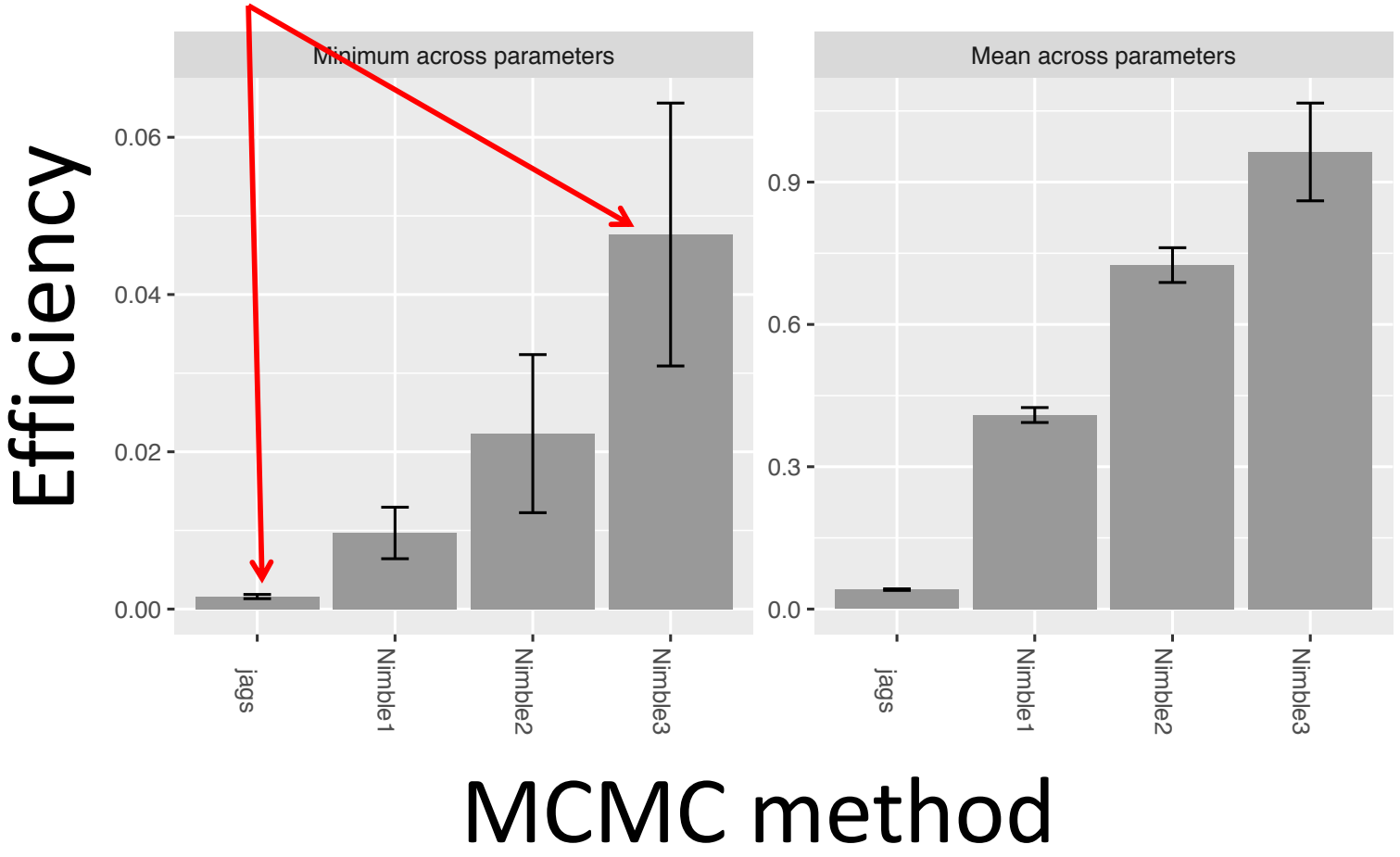
First published:18 December 2018 | https://doi.org/10.1002/ece3.4751 | Citations: 1

Open-population multi-season spatial capture-recapture example

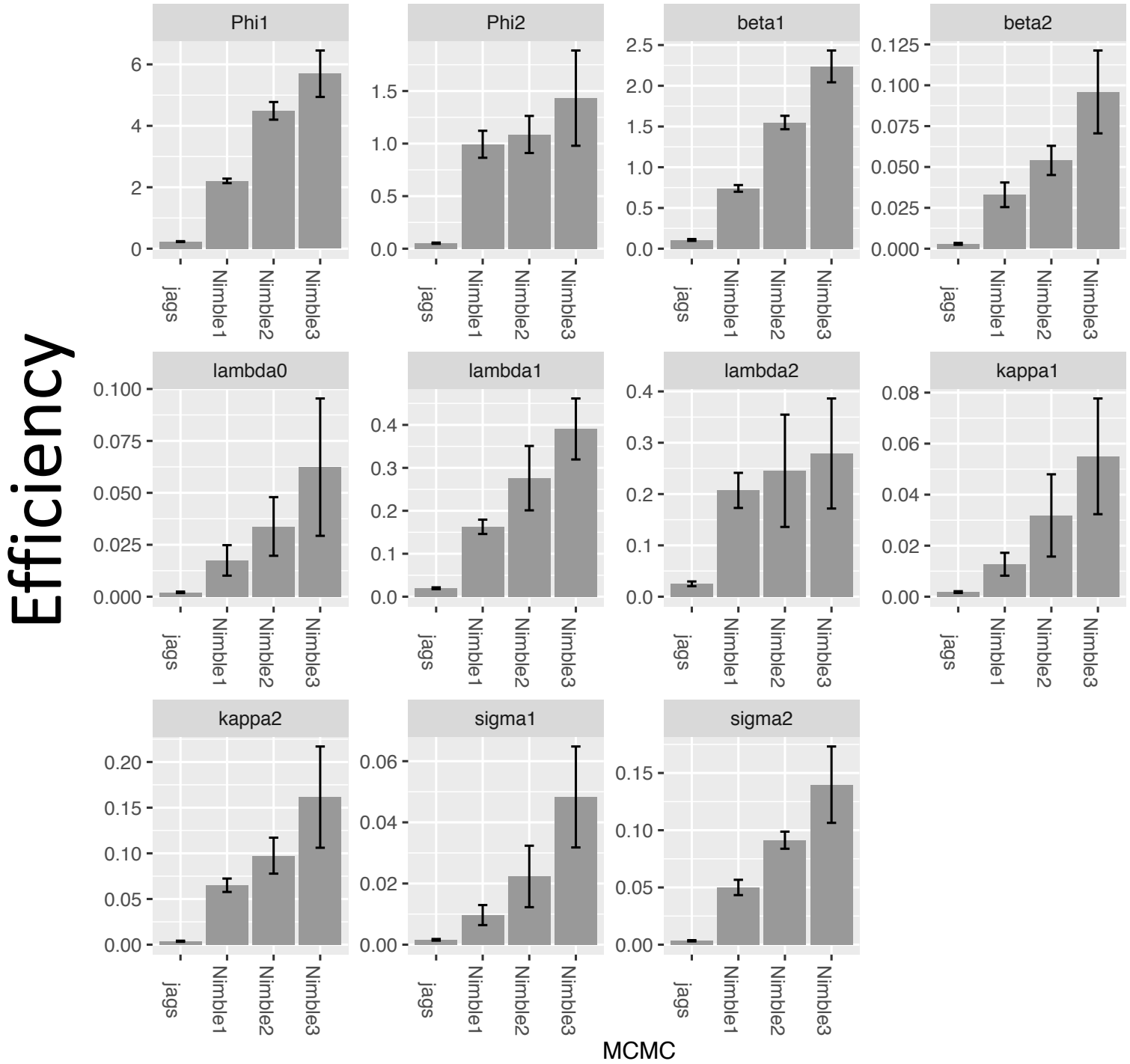
- From Torbjørn Ergon and Beth Gardner (2014). “Separating mortality and emigration: modelling space use, dispersal and survival with robust-design spatial capturerecapture data”. *Methods in Ecology and Evolution* 5: 1327–1336.
- Field voles (*Microtus agrestis*)
- 192 traps
- 4 primary trapping periods (21-23 days)
- 3-5 secondary trap checks (12 hours)
- Survival, dispersal of activity centers, and detection modeled.
- NIMBLE customizations:
  - Nimble1: Block sampling, marginalize over latent states
  - Nimble2: Rewrite (equivalent) activity-center distribution
  - Nimble3: Custom functions to achieve only local trap calculations

Open-population multi-season spatial capture-recapture example

~25 times more efficient than JAGS



Open-population multi-season spatial capture-recapture example



Closed-population single-season spatial capture-recapture example

Closed-population single-season spatial capture-recapture example

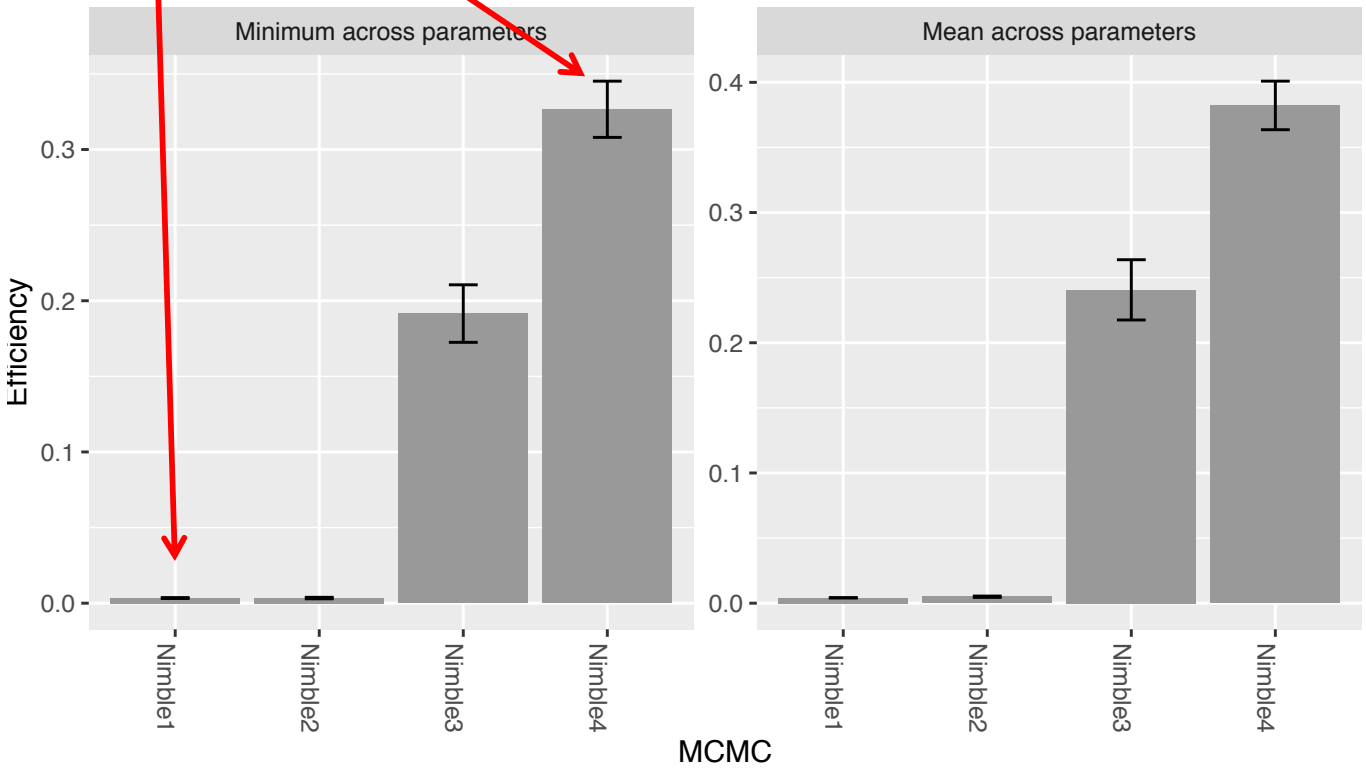
- Wolverines (Gulo gulo) in Norway
- Data from Milleret, Dupont, Bonenfont, Brøseth, Flagstad, Sutherland, and Bischof. 2019. A local evaluation of the individual state-space to scale up Bayesian spatial capture-recapture. *Ecology and Evolution* 9:352–363
- Data originally from Norwegian Institute for Nature Research (NINA) and RovQuant (NMBU)
- January-May 2012
- 196 female wolverines detected
- 453 detections
- Spatial area of >200,000 square km
- >10000 detectors
- Data augmentation to estimate total population size.
- A subset of data from a much larger study.
- JAGS without local trap calculations ran for 30 days before crashing.
- NIMBLE customizations:
  - Nimble1: Vectorize some calculations and improve “ones trick”
  - Nimble2: Joint sampling of x and y coordinates of activity centers
  - Nimble3: Custom functions to restrict likelihood calculations to local traps
  - Nimble4: Turn off unnecessary calculations for individuals “not in the model”.

https://commons.wikimedia.org/wiki/File:Wolverine_01.jpg

Closed-population single-season spatial capture-recapture example

~100 times increase in efficiency

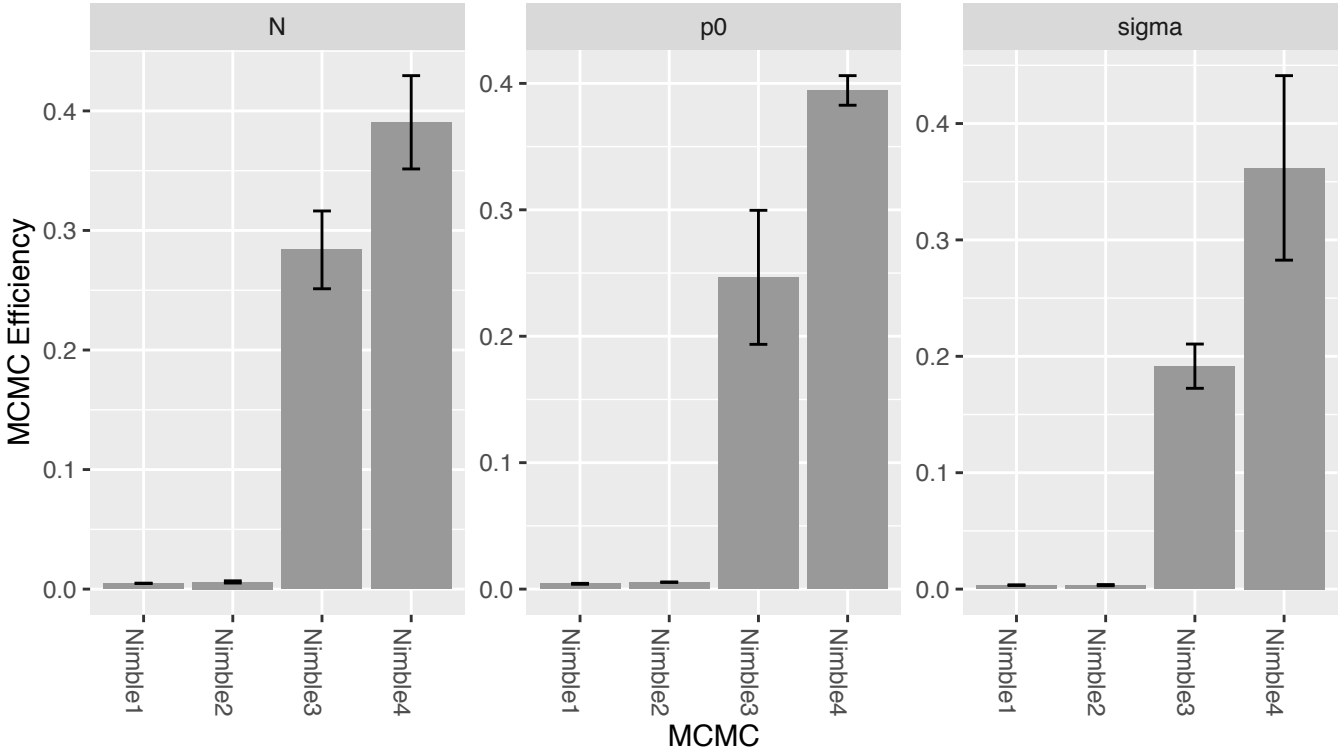
Net Efficiency



MCMC method

Closed-population single-season spatial capture-recapture example

Net Efficiency



MCMC method

Problem-specific customizations for painfully slow problems can sometimes yield huge performance gains.