SPI-IPM Code Manual

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Contents

About this manual

Briefly on the need for/value of standardized data and analyses.

Why IPMs are popular and what they are suitable for (Kéry and Schaub, 2011; Plard et al., 2019).

Overview over workflow, code repository & contents of manual (Figure 1).

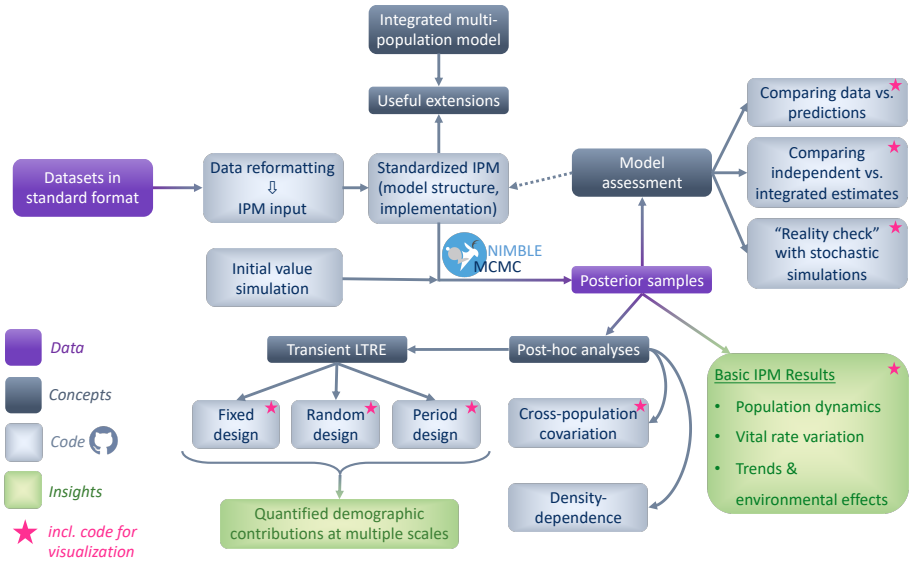

Figure 1: Schematic representation of the SPI-IPM workflow.

In no way complete: great if user's analyses/adaptations become part.

How to cite.

Chapter 1

Preparing SPI-Birds data for Bayesian analysis

Quick recap of SPI-Birds standard format and overview over data types used in IPM (+ how they relate, incl. diagram).

1.1 Nest count data

1.2 Clutch size data

1.2.1 Nest level

1.2.2 Population level

1.3 Fledgling count data

1.3.1 Nest level

1.3.2 Population level

1.4 Mark-recapture data

1.4.1 Individual capture histories

1.4.2 M-array

1.5 Immigrant count data

1.6 Auxiliary data on the sampling process

1.6.1 Nest survey sampling effort

1.6.2 Capture probability proxies

Chapter 2

IPM Construction

2.1 Open population model with 2 age classes

2.2 Data likelihoods

2.2.1 Nest count data likelihood

2.2.2 Clutch size data likelihoods

2.2.3 Fledgling count data likelihoods

2.2.4 Mark-recapture data likelihood

2.2.5 Immigrant count data likelihood

2.3 Priors and constraints

Chapter 3

Modelling temporal variation

3.1 Random year variation

3.2 Temporal covariates

3.2.1 Continuous variables

3.2.2 Categorical variables

3.2.3 Imputation of missing covariate values

3.3 Notes on covariate selection

Chapter 4

IPM Implementation

4.1 Efficient implementation using NIMBLE

We use the fantastic **nimble** package (de Valpine et al., 2017)!

4.2 Simulation of initial values

4.3 Test runs and full runs: chains, iterations, burn-in, and thinning

4.4 Trouble-shooting implementation issues

Chapter 5

Model Assessment

5.1 Assessing chain convergence

5.2 Plotting data vs. predictions

5.3 Comparing estimates from integrated vs. independent analyses

5.4 "Reality check" using stochastic simulations

5.5 Other approaches

Running for additional years and comparing to non-included data, PPCs, etc.

Chapter 6

Visualizing and interpreting direct IPM outputs

6.1 Population trajectories

6.2 Within-population variation in vital rates

6.2.1 Age-class-specific averages

6.2.2 Year-by-year variation

6.3 Between-population variation in vital rates

6.3.1 Population-specific averages

6.3.2 Year-by-year variation

6.4 Covariate effects

Chapter 7

Follow-up Analyses

7.1 Testing for time-trends

7.2 Testing for density-dependence

7.3 Investigating cross-population covariation

7.4 Quantifying demographic contributions to short term population dynamics

7.4.1 Year-by-year variation in population growth rate (random design LTRE)

7.4.2 Year-to-year differences in population growth rate (fixed design LTRE)

7.5 Quantifying demographic contributions to long-term population trends

7.5.1 Differences in population trajectories between time periods (period design LTRE)

7.5.2 Differences in population trajectories between locations (period design LTRE with time-by-space substitution)

Chapter 8

Useful extensions and outlook

8.1 Adapting the population model for your species/population

8.1.1 Accounting for multiple broods per bird per year

8.1.2 Altering age structure

8.1.3 Individual heterogeneity beyond age: sex, traits, and more

8.2 Including additional data and informative priors

8.2.1 Including partially observed age information

8.2.2 Making the most of auxiliary knowledge about immigrants/dispersers

8.2.3 Letting published values help with estimation when data is sparse

8.3 Building on the multi-population perspective

8.3.1 Joint analysis of data from several populations

8.3.2 Modelling cross-population covariation

8.3.3 Estimating hyper-parameters in large-scale analyses

8.3.4 Unlocking the secrets of dispersal

Bibliography

de Valpine, P., Turek, D., Paciorek, C. J., Anderson-Bergman, C., Lang, D. T., and Bodik, R. (2017). Programming with models: writing statistical algorithms for general model structures with nimble. *Journal of Computational and Graphical Statistics*, 26(2):403–413.

Kéry, M. and Schaub, M. (2011). *Bayesian population analysis using WinBUGS: a hierarchical perspective*. Academic Press.

Plard, F., Fay, R., Kéry, M., Cohas, A., and Schaub, M. (2019). Integrated population models: powerful methods to embed individual processes in population dynamics models. *Ecology*, page e02715.