Olivier Gimenez

Bayesian Analysis of Capture-Recapture Data with Hidden Markov Models – Theory and Case Studies in R

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Welcome

Welcome to the website of the book *Bayesian Analysis of Capture-Recapture Data with Hidden Markov Models – Theory and Case Studies in R* by Olivier Gimenez[1]. Note that the book is also available in PDF format[2].

I'm currently writing this book, and I welcome any feedback or requests for content here[3].

Many thanks!

Last updated: August 25, 2021

[1] https://www.linkedin.com/in/keith-mcnulty/

[2] https://github.com/oliviergimenez/banana-book/raw/master/docs/bayesHMMcapturerecapture.pdf

[3] https://github.com/oliviergimenez/banana-book/issues

Preface

The HMM framework has gained much attention in the ecological literature over the last decade, and has been suggested as a general modelling framework for the demography of plant and animal populations. In particular, HMMs are increasingly used to analyse capture-recapture data and estimate key population parameters (e.g., survival, dispersal, recruitment or abundance) with applications all fields of ecology. In parallel, Bayesian statistics is relatively well established and fast growing in ecology and related disciplines, because it resonates with scientific reasoning and allows accommodating uncertainty smoothly. The popularity of Bayesian statistics also comes from the availability of free pieces of software (WinBUGS, OpenBUGS, JAGS, Stan, nimble) that allow practitioners to code their own analyses.

However, to my knowledge, a full Bayesian treatment of HMMs applied to capture-recapture data is yet to be proposed in a book. This is what I propose with this book. Besides, the popular software solutions come with computational limitations when ecologists have to deal with complex models and/or big data. I will use Nimble that is seen by many as the future of ecological data modelling because it extends the BUGS language for writing new functions and distributions, and provides samplers that can deal with discrete latent states in contrast with Stan.

In this book, I will cover both the theory of HMMs for capture-recapture data, and the applications of these models to empower practitioners to fit their models with confidence. An important part of the book will consist in case studies presented in a tutorial style to abide by the "learning by doing" philosophy.

Why read this book

Structure of the book

Blabla.

Software information and conventions

This book uses primarily the R package **nimble**, so you need to at least install R and the **nimble** package.

The R session information when compiling this book is shown below:

```
sessionInfo()
## R version 4.1.0 (2021-05-18)
## Platform: x86_64-apple-darwin17.0 (64-bit)
## Running under: macOS Catalina 10.15.7
##
## Matrix products: default
## BLAS:   /System/Library/Frameworks/Accelerate.framework/Versions/A/Frameworks/vecLib.framew
## LAPACK: /Library/Frameworks/R.framework/Versions/4.1/Resources/lib/libRlapack.dylib
```

[4] http://creativecommons.org/licenses/by-nc-sa/4.0/

```
##
## locale:
## [1] fr_FR.UTF-8/fr_FR.UTF-8/fr_FR.UTF-8/C/C/fr_FR.UTF-8
##
## attached base packages:
## [1] stats     graphics  grDevices utils     datasets
## [6] methods   base
##
## loaded via a namespace (and not attached):
##  [1] Rcpp_1.0.7         rstudioapi_0.13
##  [3] servr_0.23         knitr_1.33
##  [5] xml2_1.3.2         magrittr_2.0.1
##  [7] downlit_0.2.1      R6_2.5.0
##  [9] rlang_0.4.11       fansi_0.5.0
## [11] highr_0.9          stringr_1.4.0
## [13] tools_4.1.0        xfun_0.25
## [15] utf8_1.2.2         jquerylib_0.1.4
## [17] htmltools_0.5.1.1 ellipsis_0.3.2
## [19] yaml_2.2.1         digest_0.6.27
## [21] tibble_3.1.3       lifecycle_1.0.0
## [23] crayon_1.4.1       bookdown_0.23
## [25] later_1.2.0        promises_1.2.0.1
## [27] vctrs_0.3.8        sass_0.4.0
## [29] fs_1.5.0           mime_0.11
## [31] evaluate_0.14      rmarkdown_2.10
## [33] stringi_1.7.3      compiler_4.1.0
## [35] bslib_0.2.5.1      pillar_1.6.2
## [37] jsonlite_1.7.2     httpuv_1.6.1
## [39] pkgconfig_2.0.3
```

We do not add prompts (`>` and `+`) to R source code in this book, and we comment out the text output with two hashes `##` by default, as you can see from the R session information above. This is for your convenience when you want to copy and run the code (the text output will be ignored since it is commented out). Package names are in bold text (e.g., **nimble**), and inline code and filenames are formatted in a typewriter

font (e.g., `knitr::knit('foo.Rmd')`). Function names are followed by parentheses (e.g., `nimble::nimbleCode()`). The double-colon operator `::` means accessing an object from a package.

Acknowledgments

CNRS. Jean-Do. Roger. Rémi. My students. Chloé, Sarah, Perry, Daniel. Rob Chapman & Hall/CRC. Workshop attendees. Feedback from. FIP radio. Marc Kéry for his support and advice on how to write a book. Proofreading by. My family.

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About the Author

Je m'appelle Olivier Gimenez (https://oliviergimenez.github.io/). Je suis directeur de recherche au CNRS. Après des études universitaires en mathématiques, j'ai fait une thèse en statistiques pour l'écologie. J'ai passé mon Habilitation à Diriger des Recherches en écologie et évolution. Récemment, je suis retourné sur les bancs de l'université pour m'initier à la sociologie.

J'ai écrit des articles scientifiques[5] faisant appel à la statistique bayésienne, et co-écrit avec des collègues britanniques un livre sur les analyses bayésiennes pour l'écologie des populations[6].

Vous pouvez me retrouver sur Twitter (https://twitter.com/oaggimenez), ou bien me contacter via mon adresse email qui s'écrit olivier suivi d'un point puis gimenez, ensuite arobase, puis cefe, suivi d'un point, puis cnrs, suivi d'un point et pour terminer fr.

Tombé dedans quand j'étais petit. Obélix Roger et Astérix JD.

[5] https://oliviergimenez.github.io/publication/papers/
[6] https://oliviergimenez.github.io/publication/books/

Part I

Theory

1

Bayesian statistics & MCMC

You can label chapter and section titles using `{#label}` after them, e.g., we can reference Chapter 1.

Figures and tables with captions will be placed in `figure` and `table` environments, respectively.

```
par(mar = c(4, 4, .1, .1))
plot(pressure, type = 'b', pch = 19)
```

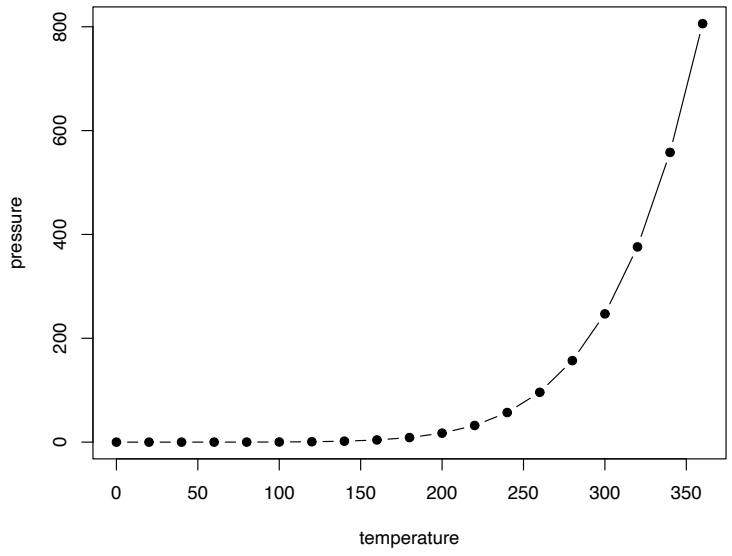

FIGURE 1.1: Here is a nice figure!

Reference a figure by its code chunk label with the `fig:` prefix, e.g., see Figure 1.1. Similarly, you can reference tables generated from `knitr::kable()`, e.g., see Table 1.1.

TABLE 1.1: Here is a nice table!

Sepal.Length	Sepal.Width	Petal.Length	Petal.Width	Species
5.1	3.5	1.4	0.2	setosa
4.9	3.0	1.4	0.2	setosa
4.7	3.2	1.3	0.2	setosa
4.6	3.1	1.5	0.2	setosa
5.0	3.6	1.4	0.2	setosa
5.4	3.9	1.7	0.4	setosa
4.6	3.4	1.4	0.3	setosa
5.0	3.4	1.5	0.2	setosa
4.4	2.9	1.4	0.2	setosa
4.9	3.1	1.5	0.1	setosa
5.4	3.7	1.5	0.2	setosa
4.8	3.4	1.6	0.2	setosa
4.8	3.0	1.4	0.1	setosa
4.3	3.0	1.1	0.1	setosa
5.8	4.0	1.2	0.2	setosa
5.7	4.4	1.5	0.4	setosa
5.4	3.9	1.3	0.4	setosa
5.1	3.5	1.4	0.3	setosa
5.7	3.8	1.7	0.3	setosa
5.1	3.8	1.5	0.3	setosa

```
knitr::kable(
  head(iris, 20), caption = 'Here is a nice table!',
  booktabs = TRUE
)
```

You can write citations, too. For example, we are using the **bookdown** package [**?**] in this sample book, which was built on top of R Markdown and **knitr** [**?**].

2

Introduction to Nimble

3

Hidden Markov models

Heller and Pogaru [2021]

4

Survival

5

Transition

6

Covariates

7

Uncertainty in state assignment

8

Abundance

9

Hidden semi-Markov models

10

Hidden states

11

Speed up MCMC

Part II

Case studies

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Actuarial senescence

Choquet et al. [2011], Péron et al. [2016]

13

Individual heterogeneity

Cubaynes et al. [2010], Gimenez and Choquet [2010], and Turek et al. [2021]

14

Life-history tradeoffs

Morano et al. [2013], Shefferson et al. [2003], and Cruz-Flores et al.

15

Breeding dynamics

Pradel et al. [2012], Desprez et al. [2011], Desprez et al. [2013], and Pacoureau et al. [2019]

16

Robust design

Karamanlidis et al. [2015], Santostasi et al. [2016], Gibson et al. [2018], and Rankin et al. [2016]

17

Stopover duration

Guérin et al. [2017]

18

Disease dynamics

Marescot et al. [2018] and Santoro et al. [2014]

19

Sex uncertainty

Pradel et al. [2008] and Genovart et al. [2012]

20

Dependence among individuals

Culina et al. [2013] and Cubaynes et al. [2021]

21

Individual and temporal variability

Grosbois et al. [2008], Cubaynes et al. [2012], Gimenez et al. [2006], and Bonner et al. [2010]

22

Cause-specific mortalities

Fernández-Chacón et al. [2016] and Ruette et al. [2015]

23

Prevalence

[Santostasi et al., 2019]

FAQ

Below is the *complete* list of frequently asked questions (FAQ). Yes, there is only one question here. Personally I do not like FAQs. They often mean surprises, and surprises are not good for software users.

1. Q: Will **bookdown** have the features X, Y, and Z?

   A: The short answer is no, but if you have asked yourself three times "do I really need them" and the answer is still "yes", please feel free to file a feature request to https://github.com/rstudio/bookdown/issues.

   Users asking for more features often come from the LaTeX world. If that is the case for you, the answer to this question is yes, because Pandoc's Markdown supports raw LaTeX code. Whenever you feel Markdown cannot do the job for you, you always have the option to apply some raw LaTeX code in your Markdown document. For example, you can create glossaries using the **glossaries** package, or embed a complicated LaTeX table, as long as you know the LaTeX syntax. However, please keep in mind that the LaTeX content is not portable. It will only work for LaTeX/PDF output, and will be ignored in other types of output. Depending on the request, we may port a few more LaTeX features into **bookdown** in the future, but our general philosophy is that Markdown should be kept as simple as possible.

The most challenging thing in the world is not to learn fancy technologies, but control your own wild heart.

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