

# Theory-driven analysis of ecological data: a practical handbook

us

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# Chapter 1

## About Bookdown

This is a *sample* book written in **Markdown**. You can use anything that Pandoc’s Markdown supports; for example, a math equation  $a^2 + b^2 = c^2$ .

### 1.1 Usage

Each **bookdown** chapter is an `.Rmd` file, and each `.Rmd` file can contain one (and only one) chapter. A chapter *must* start with a first-level heading: `# A good chapter`, and can contain one (and only one) first-level heading.

Use second-level and higher headings within chapters like: `## A short section` or `### An even shorter section`.

The `index.Rmd` file is required, and is also your first book chapter. It will be the homepage when you render the book.

### 1.2 Render book

You can render the HTML version of this example book without changing anything:

1. Find the **Build** pane in the RStudio IDE, and
2. Click on **Build Book**, then select your output format, or select “All formats” if you’d like to use multiple formats from the same book source files.

Or build the book from the R console:

```
bookdown::render_book()
```

To render this example to PDF as a `bookdown::pdf_book`, you'll need to install XeLaTeX. You are recommended to install TinyTeX (which includes XeLaTeX): <https://yihui.org/tinytex/>.

## 1.3 Preview book

As you work, you may start a local server to live preview this HTML book. This preview will update as you edit the book when you save individual `.Rmd` files. You can start the server in a work session by using the RStudio add-in “Preview book”, or from the R console:

```
bookdown::serve_book()
```

## 1.4 Here are some useful things for writing the book using bookdown

All chapters start with a first-level heading followed by your chapter title, like the line above. There should be only one first-level heading (`#`) per `.Rmd` file.

### 1.4.1 A section

All chapter sections start with a second-level (`##`) or higher heading followed by your section title, like the sections above and below here. You can have as many as you want within a chapter.

#### An unnumbered section

Chapters and sections are numbered by default. To un-number a heading, add a `{.unnumbered}` or the shorter `{-}` at the end of the heading, like in this section.

## 1.5 Cross-references

Cross-references make it easier for your readers to find and link to elements in your book.

### 1.5.1 Chapters and sub-chapters

There are two steps to cross-reference any heading:

1. Label the heading: `# Hello world {#nice-label}`.
  - Leave the label off if you like the automated heading generated based on your heading title: for example, `# Hello world = # Hello world {#hello-world}`.
  - To label an un-numbered heading, use: `# Hello world {-#nice-label}` or `{# Hello world .unnumbered}`.

2. Next, reference the labeled heading anywhere in the text using `\@ref(nice-label)`; for example, please see Chapter 1.5.
  - If you prefer text as the link instead of a numbered reference use: any text you want can go here.

## 1.5.2 Captioned figures and tables

Figures and tables *with captions* can also be cross-referenced from elsewhere in your book using `\@ref(fig:chunk-label)` and `\@ref(tab:chunk-label)`, respectively.

See Figure 1.1.

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

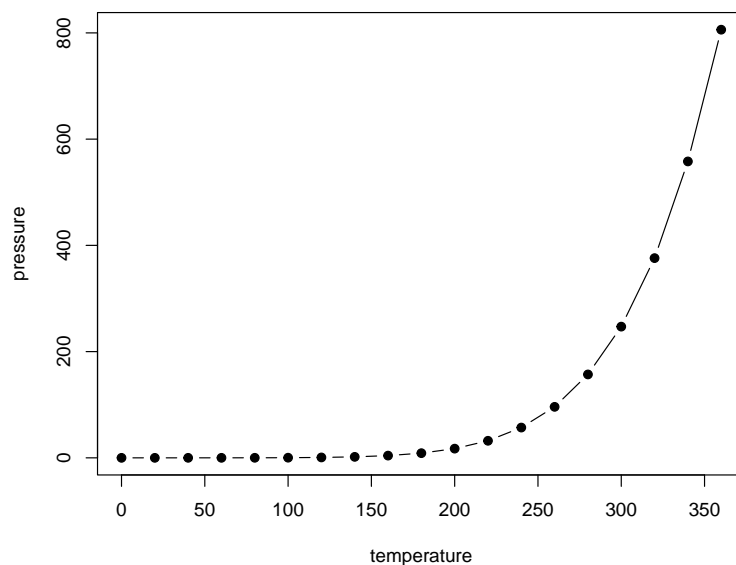


Figure 1.1: Here is a nice figure!

Don't miss Table 1.1.

```
knitr::kable(  
  head(pressure, 10), caption = 'Here is a nice table!',  
  booktabs = TRUE  
)
```

Table 1.1: Here is a nice table!

temperature	pressure
0	0.0002
20	0.0012
40	0.0060
60	0.0300
80	0.0900
100	0.2700
120	0.7500
140	1.8500
160	4.2000
180	8.8000

## 1.6 Parts

You can add parts to organize one or more book chapters together. Parts can be inserted at the top of an .Rmd file, before the first-level chapter heading in that same file.

Add a numbered part: `# (PART) Act one {-}` (followed by `# A chapter`)

Add an unnumbered part: `# (PART\*) Act one {-}` (followed by `# A chapter`)

Add an appendix as a special kind of un-numbered part: `# (APPENDIX) Other stuff {-}` (followed by `# A chapter`). Chapters in an appendix are prepended with letters instead of numbers.

## 1.7 Footnotes and citations

### 1.7.1 Footnotes

Footnotes are put inside the square brackets after a caret `^[]`. Like this one <sup>1</sup>.

### 1.7.2 Citations

Reference items in your bibliography file(s) using `@key`.

For example, we are using the **bookdown** package [Xie, 2023] (check out the last code chunk in index.Rmd to see how this citation key was added) in this sample book, which was built on top of R Markdown and **knitr** [Xie, 2015] (this citation was added manually in an external file book.bib). Note that the .bib files need to be listed in the index.Rmd with the YAML `bibliography` key.

---

<sup>1</sup>This is a footnote.



The RStudio Visual Markdown Editor can also make it easier to insert citations: <https://rstudio.github.io/visual-markdown-editing/#/citations>

## 1.8 Blocks

### 1.8.1 Equations

Here is an equation.

$$f(k) = \binom{n}{k} p^k (1-p)^{n-k} \quad (1.1)$$

You may refer to using `\@ref{eq:binom}`, like see Equation (1.1).

### 1.8.2 Theorems and proofs

Labeled theorems can be referenced in text using `\@ref{thm:tri}`, for example, check out this smart theorem 1.1.

**Theorem 1.1.** *For a right triangle, if  $c$  denotes the length of the hypotenuse and  $a$  and  $b$  denote the lengths of the **other** two sides, we have*

$$a^2 + b^2 = c^2$$

Read more here <https://bookdown.org/yihui/bookdown/markdown-extensions-by-bookdown.html>.

### 1.8.3 Callout blocks

The R Markdown Cookbook provides more help on how to use custom blocks to design your own callouts: <https://bookdown.org/yihui/rmarkdown-cookbook/custom-blocks.html>

## 1.9 Sharing your book

### 1.9.1 Publishing

HTML books can be published online, see: <https://bookdown.org/yihui/bookdown/publishing.html>

### 1.9.2 404 pages

By default, users will be directed to a 404 page if they try to access a webpage that cannot be found. If you'd like to customize your 404 page instead of using the default, you may add either a `_404.Rmd` or `_404.md` file to your project root and use code and/or Markdown syntax.

### 1.9.3 Metadata for sharing

Bookdown HTML books will provide HTML metadata for social sharing on platforms like Twitter, Facebook, and LinkedIn, using information you provide in the `index.Rmd` YAML. To setup, set the `url` for your book and the path to your `cover-image` file. Your book's `title` and `description` are also used.

This `gitbook` uses the same social sharing data across all chapters in your book—all links shared will look the same.

Specify your book's source repository on GitHub using the `edit` key under the configuration options in the `_output.yml` file, which allows users to suggest an edit by linking to a chapter's source file.

Read more about the features of this output format here:

<https://pkgs.rstudio.com/bookdown/reference/gitbook.html>

Or use:

```
?bookdown::gitbook
```

## Chapter 2

# Preamble

Who is the textbook for?



## Chapter 3

# Background (more fancy title needed)

### 3.1 Modelling in ecology

#### 3.1.1 A quick history

#### 3.1.2 Specificities of ecology

Variability + time\*space + local interactions + observations through both experiments and field studies + open systems Formalisation,simplifications often used in ecology, assumptions, ...

#### 3.1.3 Ecological data, uncertainties, sampling

At different organisational scales: individual, population, community, ecosystem and all meta-

#### 3.1.4 Mathematical modelling / computational approaches (lots to discuss here from Game of life type stuff/von Neumann to IBMs/ABMs note: Grimm is not universally representative ;-)) ?

#### 3.1.5 Appendices: Primer on vectors and matrices (multidimensional data)

#### 3.1.6 Appendices: Primer on analysis, dérivées, Taylor series, minimum/maximum...

**3.1.7 Appendices: Removing dimensions, dimensional analysis**

## Chapter 4

# Mathematical (or “process-based”?) modeling

Intro pour expliquer la logique de l’agencement des chapitres

### 4.1 Finite numbers of individuals (stochastic models)

#### 4.1.1 Stochastic individual-based simulations

#### 4.1.2 Primer on probabilities (random variables, discrete and continuous distributions, PGF and MGF, central limit theorem)

#### 4.1.3 Small populations and branching processes

#### 4.1.4 Markov chains (ergodicity, absorbing states)

#### 4.1.5 Master equations, moment closure?

#### 4.1.6 PDEs, diffusion

#### 4.1.7 Boxes: algo Gillespie + refinements ; generating random numbers according to defined distributions

### 4.2 Large numbers (dynamical systems; and ways to analyse them)

- 4.2.1 Primer on analysis (derivatives, attractors, stability, permanence, jacobian, changes of variables... + analytical approximations: Taylor series, delta method)
- 4.2.2 Difference equations (ex: fibonacci)
- 4.2.3 ODEs (example: malthus and logistic)
- 4.2.4 Stage-structured / physiologically structured / compartment models (R0, Euler-Lotka, reproductive values, eigenvalue-based growth rate...)
- 4.2.5 Boxes: integration schemes (Euler et al.)
- 4.3 Reintroducing stochasticity (dynamical systems with noise)
  - 4.3.1 Environmental stochasticity / demographic stochasticity
- 4.4 Spatial structure
  - 4.4.1 Implicit space and patches
  - 4.4.2 Explicit discrete space (networks and lattices)
  - 4.4.3 Explicit continuous spaces (PDEs)
  - 4.4.4 Models of dispersal and foraging (kernels, brownian motion, Lévy walk, optimal foraging...)
- 4.5 Interactions
  - 4.5.1 Types of interactions and functional responses (in continuous and discrete time)
 

Chemical kinetics to invent functional responses
  - 4.5.2 Lotka-Volterra
  - 4.5.3 Food-web models (niche, cascade, ...)
  - 4.5.4 Network analysis (primer)
  - 4.5.5 Random matrices



## 4.6 Links between ecology and evolution

4.6.1 Historical overview (incl. common processes cf Vel-  
lend etc; globally cf. for example Huneman 2019;  
and maybe ELE special issue 2023)

4.6.2 Timescales

4.6.3 Frameworks (AD, QG, oligomorphic dynamics,  
IBMs)



## Chapter 5

# Linking process-based models to data - the statistical interface

### 5.1 Linking process-based models to data: the statistical interface

5.1.1 How to confront models and data: from qualitative to quantitative (overview of existing lit)

5.1.2 Models on sampling uncertainty, sources of variability (types of error, non-observed states etc?)

5.1.3 Learning and validation

### 5.2 Model fitting

5.2.1 Distances between model predictions and data (least square...)

5.2.2 Likelihood

Bayesian, MCMC, ABC

### 5.3 Model selection

- 5.3.1 Model selection and Information criteria, model averaging/Burnham-Anderson stuff
- 5.3.2 Penalised regression (lasso, ridge, etc.)
- 5.3.3 Machine learning approaches (random forest, neural networks, ...)

# Bibliography

Yihui Xie. *Dynamic Documents with R and knitr*. Chapman and Hall/CRC, Boca Raton, Florida, 2nd edition, 2015. URL <http://yihui.org/knitr/>. ISBN 978-1498716963.

Yihui Xie. *bookdown: Authoring Books and Technical Documents with R Markdown*, 2023. URL <https://github.com/rstudio/bookdown>. R package version 0.35.