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ABSTRACT

This is meant to be a learning tool for LaTeX and knitr. The examples should be straightforward. Good luck!

RÉSUMÉ

Usually the french version of the abstract goes here, but it is included here to show how accents might be added to text and how non-numbered sections work.

1 INTRODUCTION

The purpose of this document is to show how knitr and LaTeX work together to make a PDF file from code. When reading this PDF document, you should also look at the code files to compare. Start with example.Rnw and maindoc.Rnw. This introduction and most of the rest of the document can be found in maindoc.Rnw. LaTeX allows you to write commands into the text. For example the command `\fishname` = Arrowtooth Flounder and `\sciencename` = *Atheresthes stomias*. These are defined in example.Rnw and can be used throughout the document, and in any of the appendices without further modification.

2 BUILDING THIS DOCUMENT

Before building this document, you need to install a couple of things which allow for the rendering of *knitr* code in the document for example purposes. Open Rgui and do the following:

```
install.packages("devtools")
devtools::install_github("thell/knitliteral")
```

To build this document, open a command line and enter **buildtex.bat**. When you run buildtex.bat two things happen:

1. Rscript calls knitr which goes through and *knits* your *example.Rnw* file, which means it runs all the R code it finds, stores figures in the *knitr-cache* directory, and creates a TeX file which LaTeX can then understand. It also creates a file called knitrOutput.log which contains all output and errors encountered during the knitting procedure. That is where to first look when there are problems compiling your document. Here is the line in buildtex.bat that does this:

```
Rscript -e "library(knitr);knit('./example.Rnw')" 1> knitrOutput.log 2>&1
```

2. LaTeX runs through the newly-created TeX file (*example.tex*) and calls *bibtex* to find the references and make the bibliography. There are three output formats of the document: .ps, .dvi, and .pdf. The .ps and .dvi formats require special viewers (Yap and GhostView respectively) and do not incorporate the reference links that are so convinient in the .pdf file. During development of very complex documents, you can leave the last part of this call out to avoid PDF generation, and put it back in when ready to complete the document.

```
@latex -synctex=1 "example.tex" && bibtex "example" && latex "example.tex"
  && latex "example.tex" && dvips "example.dvi" && ps2pdf "example.ps"
```

Some LaTeX packages may have to be installed. If so, the package manager dialog will open. You must choose to install from internet, then make sure to select *ctan* using *HTTP* protocol from *BC*. The default settings will most likely not work.

2.1 THE KNITTING PROCESS

When *knitr* is called, it parses the *example.Rnw* file, looking for special parenthesis characters which are called *R code chunks*. The chunks begin with a set of parentheses and equals sign `<< >>=` and end with the *at* symbol `@`. Anything between them is an R code chunk which will be evaluated by *knitr*. Inside the beginning parentheses, you can define many *chunk options*. The official page listing these options is here: Knitr chunk options. In this document the file *example.Rnw* holds one chunk which loads the R environment, and *maindoc.Rnw* holds the figure chunks (one for each figure) which each hold simple commands to plot some examples. For example, figure 3 is called like this (without the eval=FALSE):

```
<<fig.height=9, fig.width=8, eval=FALSE>>=
half.torus()
@
```

2.1.1 Running R code directly in text

One should always write calculated values or data by using a reference to the R objects instead of typing the numbers in as text. This way, if something changes you don't have to read and verify every number in your document, they will be updated automatically by *knitr*.

Here's how you write some values by reference from your R environment inside LaTeX text block: For example to get the mean of x you would use the command: `$\Sexpr{mean(x)}$` which in this case evaluates to 19.8623508. The `$\Sexpr{}$` construct represents an S-expression, where S was the predecessor to R. For some reason it hasn't yet been changed to `$\Rexpr{}$`. In this example, the values for the x vector were read in from *example.r* at the beginning of the knitting process and is accessible throughout the document. You can call simple R commands using the `$\Sexpr{}$` command inside LaTeX. You can do more than one command by separating with a semicolon, for example the command `$\Sexpr{z=x+y;mean(z)}$` evaluates to 68.3410075 for the x and y values loaded from *example.r*.

2.2 WHAT TO DO IF THERE'S AN ERROR

If there's an error, the first thing to do is check the *knitrOutput.log* file. This will contain all messages both regular and error which *knitr* outputs. If there was an error during the knitting process, you will find it there. The last lines of the file should say:

```
output file: example.tex

[1] "example.tex"
```

If you see this message and the file *example.tex* exists then the *knitr* part has worked but the LaTeX part of the compilation has failed. The message in the case that LaTeX has failed will be something like *l.132...error message*. In that case, the error happened on line 132 of the *example.tex* file. You will have to look at this file first to see where the error is, then go back to your example.Rnw file and fix it. Sometimes errors earlier on can trigger something later to fail, which makes it very hard to debug. The best advice is to compile after every change to make sure it is still working. A lot of time can be wasted tracking down errors if you haven't compiled in a long time and made many changes, where more than one error may have been introduced. Matching parenthesis errors can be particular insidious.

If there is an error stating:

***** Could not open the file example.pdf*

it means that you still have the PDF open and you need to close it and re-compile. If you have the GhostView viewer, you can keep the postscript (*example.ps*) file open instead while developing. You won't get an error even if it stays open.

3 EQUATIONS IN LATEX

Equations are fairly straightforward, and if organized using the same label prefix (**eq:**), they will be numbered automatically. Here are some example equations from the 2015 Arrowtooth Flounder assessment with added margins for captions:

$$B_y = \sum_{i=1}^{k} C_{y_i} A_i = \sum_{i=1}^{k} B_{y_i} \tag{1}$$

where C_{y_i} is the mean CPUE density (kg/km^2) for species s in stratum i, A_i is the area of stratum i, B_{y_i} is the biomass of Arrowtooth Flounder in stratum i for year y, and k is the number of strata.

CPUE (C_{y_i}) for Arrowtooth Flounder in stratum i for year y was calculated as a density in kg/km^2 by:

$$C_{y_i} = \frac{\sum_{j=1}^{n_{y_i}} \left[\frac{W_{y_i,j}}{D_{y_i,j} w_{y_i,j}} \right]}{n_{y_i}} \tag{2}$$

where $W_{y_i,j}$ is the catch weight in kg for Arrowtooth Flounder in stratum i, year y, and tow j, $D_{y_i,j}$ is the distance travelled in km for tow j in stratum i and year y, $w_{y_i,j}$ is the net opening in km by tow j, stratum i, and year y, and n_{y_i} is the number of tows in stratum i.

The variance of the survey biomass estimate V_y for Arrowtooth Flounder in year y is calculated in kg^2 as follows:

$$V_y = \sum_{i=1}^{k} \left[\frac{\sigma_{y_i}^2 A_i^2}{n_{y_i}} \right] = \sum_{i=1}^{k} V_{y_i} \tag{3}$$

where $\sigma_{y_i}^2$ is the variance of the CPUE in kg^2/km^4 for year y in stratum i, V_{y_i} is the variance of Arrowtooth Flounder in stratum i for year y, where $\sigma_{y_i}^2$ was obtained from bootstrapped samples (see below).

The CV for Arrowtooth Flounder for each year y was calculated as follows:

$$CV_y = \frac{\sqrt{V_y}}{B_y} \tag{4}$$

where CV_y is the CV for year y.

3.0.1 A few more equation tidbits

Here is an example of overline usage: $\overline{R}_{init}$.

Double dashes can be used to make a longer solid line to show value ranges: $0.308y^{-1}$–$0.406y^{-1}$.

Here's how you show a fraction inline: $\frac{B_{2016}}{B_{ReferencePoint}} < 1$.

4 HOW REFERENCES WORK

4.1 HOW THE BIBLIOGRAPHY WORKS

The bibliography is automatically generated by LaTeX. The file all.bib contains thousands of references and is added to on an ongoing basis. The format of that file is simple and self-explanatory. When you cite a document, you use a *citet* command to get a reference to a paper. For example, `\citet{arf2001}` = Fargo and Starr (2001). You can also click the reference to go to its entry in the bibliography. Press Alt-left arrow to come back to where you were after. The *bibtex* program, which is called up by LaTeX, searches all.bib for this and inserts the correct reference in a file called *example.bbl* which is then used to generate the bibliography. The bibliography is generated at the end of the process, and only those references included in the document by you (and in example.bbl) are included in the bibliography. Here are a bunch more references: Fournier and Archibald (1982), Schnute and Richards (1995); Richards et al. (1997), McAllister and Ianelli (1997); Gavaris and Ianelli (2002). Check the bibliography to see that they are all there. You can use these references anywhere in the document, including in child documents like *maindoc.Rnw* and any appendices.

4.2 HOW THE FIGURE AND TABLE REFERENCES WORK

See Figures 1, 2, 3, and 4. Note that these numbers are clickable and you can go directly to the figure. These are referenced figures.

A figure/table reference works by adding a reference name to a figure/table, then remembering what is was and using a `\ref` command to reference the figure/table. For example in Figure 1, the figure reference code has a label tag like this `\label{fig:example-random-stuff}`. The figure can be referenced anywhere in the latex document by using this syntax: `\ref{fig:example-random-stuff}`. The numbering is taken care of for you and is separate for each type of reference. Here is a list of suggested prefixes to use for different reference types:

1. **sec**: - section
2. **subsec**: - subsection
3. **fig**: - figure
4. **tab**: - table
5. **eq**: - equation
6. **lst**: - code listing
7. **itm**: - enumerated list item (like this list)
8. **chap**: - appendix

4.3 HOW APPENDIX REFERENCES WORK

Appendix references are much like chapters of a book. They can be added or commented out easily at the bottom of *example.Rnw*. This helps with the incremental form of development where you make sure the main document is compiling and then when ready, uncomment the appendix inclusion code and the appendix will be included in the document. Once included, any appendix references will be resolved. To reference an appendix, use this syntax: `\ref{chap:example.1}` which resolves to appendix A. This is also clickable and will take you directly to the appendix.

The code which adds an appendix is *knitr* code because you want the appendix added before the knitting process so that any figures or R expressions are resolved, just like in the main document. This is an example of how appendix code is added:

```
\rfoot{Appendix A -- Example appendix 1}
```

5 SUMMARY

Here's a reference to an appendix:

REFERENCES

Fargo, J. and Starr, P.J. 2001. Turbot Stock Assessment for 2001 and Recommendations for Management in 2002. DFO Can. Sci. Advis. Sec. Advis. Rep. **2001/150**: 70 p. Available from http://www.dfo-mpo.gc.ca/csas/.

Fournier, D. and Archibald, C. 1982. A general theory for analyzing catch at age data. Can. J. Fish. Aquat. Sci. **39(8)**: 1195–1207.

Gavaris, S. and Ianelli, J. 2002. Statistical Issues in Fisheries' Stock Assessments. Scan. J. Stat. **29(2)**: 245–267.

Martell, S.J., Cleary, J. and Haist, V. 2011. Moving towards the sustainable fisheries framework for Pacific herring: data, models, and alternative assumptions; Stock Assessment and Management Advice for the British Columbia Pacific Herring Stocks: 2011 Assessment and 2012 Forecasts. DFO Can. Sci. Advis. Sec. Res. Doc. **2011/nnn**: v + 136–151.

McAllister, M.K. and Ianelli, J. 1997. Bayesian stock assessment using catch-age data and the sampling: importance resampling algorithm. Can. J. Fish. Aquat. Sci. **54(2)**: 284–300.

Richards, L., Schnute, J. and Olsen, N. 1997. Visualizing catch-age analysis: a case study. Can. J. Fish. Aquat. Sci. **54(7)**: 1646–1658.

Schnute, J.T. and Richards, L.J. 1995. The influence of error on population estimates from catch-age models. Can. J. Fish. Aquat. Sci. **52**: 2063–2077.

6 TABLES

Table 1. Estimated and fixed parameters and prior probablilty distributions used in the Reference Case.

Parameter	**Number estimated**	**Bounds [low,high]**	**Prior (Mean, SD) (single value=fixed)**
Log recruitment ($\ln(R_0)$)	1	[-2,6]	Uniform
Steepness (h)	1	[0.2,1]	Beta($\alpha = 13.4$,$\beta = 2.40$)
Log natural mortality ($\ln(M)$)	1	[-5,0]	Normal($\ln(0.2)$,0.2)
Log mean recruitment ($\ln(\overline{R})$)	1	[-2,6]	Uniform
Log initial recruitment ($\ln(\overline{R}_{init})$)	1	[-2,6]	Uniform
Variance ratio (ρ)	0	Fixed	0.059
Inverse total variance (ϑ^2)	0	Fixed	1.471
Survey age at 50% selectivity ($\hat{a}_k$)	3	[0,1]	None
Fishery age at 50% selectivity ($\hat{a}_k$)	1	[0,1]	None
Survey SD of logistic selectivity ($\hat{\gamma}_k$)	3	[0,Inf)	None
Fishery SD of logistic selectivity ($\hat{\gamma}_k$)	1	[0,Inf)	None
Survey catchability (q_k)	4	None	Normal(0.5,1.0)
Log fishing mortality values ($\Gamma_{k,t}$)	19	[-30,3]	[-30,3]
Log recruitment deviations (ω_t)	19	None	Normal(0,τ)
Initial log recruitment deviations ($\omega_{init,t}$)	19	None	Normal(0,τ)

Table 2. Example using xtable with some pseudo-random seeded numbers. The function get.align makes the left column justified left and the rest justified right which is how most tables giving values are shown.

ID	$R_{s=1}$	$R_{s=2}$	$R_{s=3}$	$R_{s=4}$	$\overline{R}$	σ
1	1.52	11.57	12.54	16.04	10.42	6.23
2	5.19	12.18	5.18	6.16	7.18	3.37
3	11.12	16.99	11.56	19.04	14.68	3.94
4	5.87	7.55	1.58	19.49	8.62	7.67
5	14.75	8.27	15.46	5.33	10.95	4.96
6	1.58	6.21	2.02	15.79	6.40	6.60
7	15.16	3.91	3.79	8.43	7.82	5.35
8	13.65	6.07	5.13	1.70	6.64	5.04
9	19.58	14.46	10.44	13.04	14.38	3.85
10	16.18	3.30	15.46	4.54	9.87	6.89
11	12.75	8.52	8.08	18.19	11.88	4.70
12	10.49	7.17	16.04	5.64	9.83	4.60
13	5.80	17.18	11.04	13.30	11.83	4.75
14	4.09	13.79	16.24	2.37	9.12	6.91
15	6.30	9.46	4.25	17.04	9.26	5.61
16	17.23	3.48	12.21	12.05	11.24	5.71
17	3.71	1.65	2.14	9.24	4.18	3.48
18	4.15	4.07	16.51	1.54	6.57	6.74
19	19.46	16.45	18.98	5.80	15.17	6.39
20	18.94	3.53	19.74	19.90	15.53	8.01

Table 3. Sensitivity cases and their parameters.

Scenario	Description	Parameters
1	Reference Case	See Table 1
2	Decrease σ to 0.1	$\vartheta^2 = 1.538$; $\rho = 0.015$
3	Estimate Total Variance	ϑ^2 estimated; $\rho = 0.059$
4	Increase τ to 1.0	$\vartheta^2 = 0.962$; $\rho = 0.038$
5	Decrease τ to 0.6	$\vartheta^2 = 2.500$; $\rho = 0.100$
6	Decrease mean of h prior to 0.72	h = Beta($\alpha = 12.7$, $\beta = 5.0$)
7	Decrease SD of $\ln(M)$ prior to 0.05	$\ln(M)$ = Normal($\ln(0.2)$, 0.05)
8	Increase SD of $\ln(M)$ prior to 0.25	$\ln(M)$ = Normal($\ln(0.2)$, 0.25)
9	Increase mean of $\ln(M)$ prior to ln(1.0)	$\ln(M)$ = Normal($\ln(0.3)$, 0.20)
10	Increase mean of $\ln(q_k)$ prior to ln(1.0)	$\ln(q_k)$ = Normal($\ln(1.0)$, 1.0)
11	Increase SD of $\ln(q_k)$ prior to 1.5	$\ln(q_k)$ = Normal($\ln(0.5)$, 1.5)
12	Selectivity Ogive = Maturity Ogive	$\hat{a}$ = 4.99 yrs; $\hat{\gamma}$ = 1.27 yrs
13	Age-at-50%-harvest set to 6 yrs	$\hat{a}$ = 6.00 yrs; $\hat{\gamma}$ = 1.00 yrs

Table 4. Sensitivity cases for q_k; posterior quantiles.

Index	**Sensitivity 10**			**Sensitivity 11**		
$\mathbf{q_k}$	**2.5%**	**50%**	**97.5%**	**2.5%**	**50%**	**97.5%**
QCSSS	0.081	0.158	0.508	0.029	0.083	0.226
HSMAS	0.079	0.121	0.155	0.035	0.081	0.136
HSSS	0.070	0.118	0.200	0.027	0.067	0.136
WCVISS	0.061	0.104	0.172	0.022	0.059	0.118

7 FIGURES

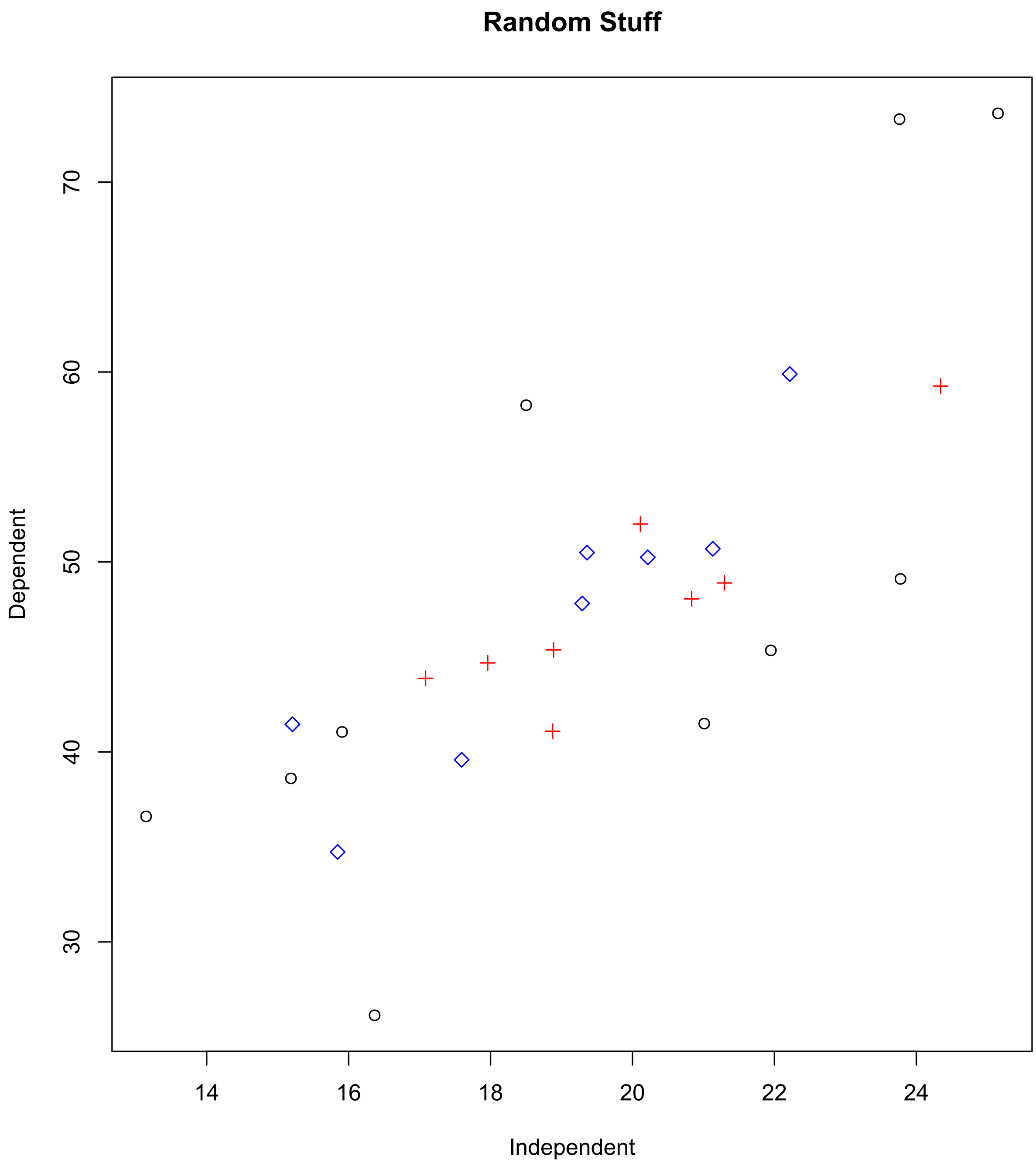

Figure 1. Random points example... Degrees are represented in LaTeX like this 0.1° and superscript like this km^2)

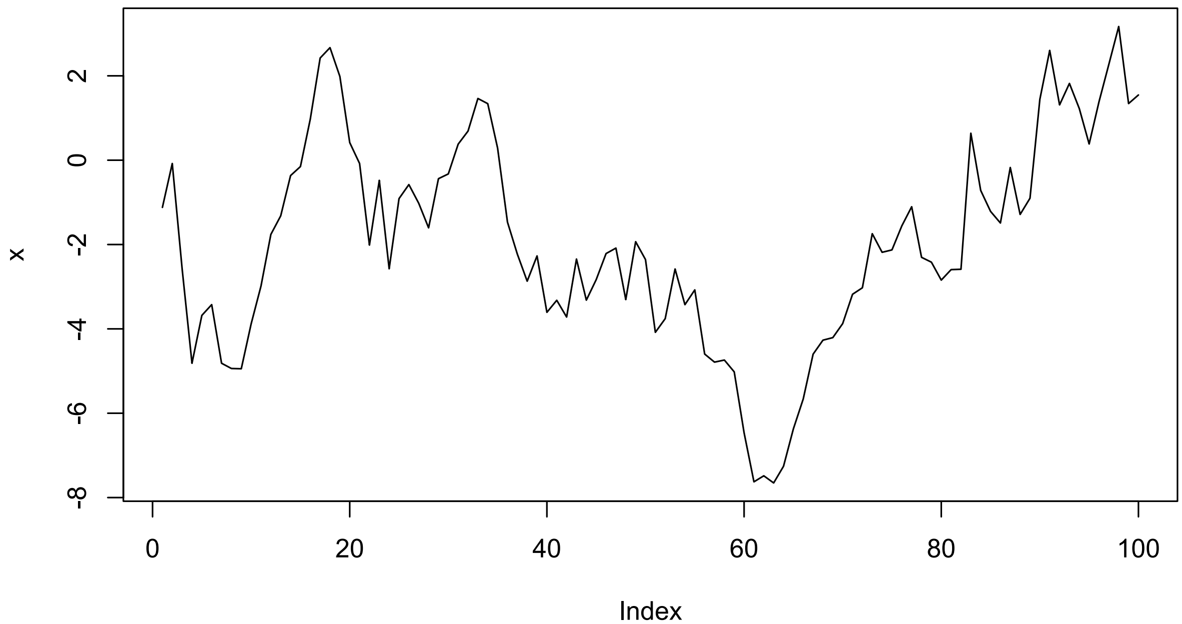

Figure 2. Brownian motion example..

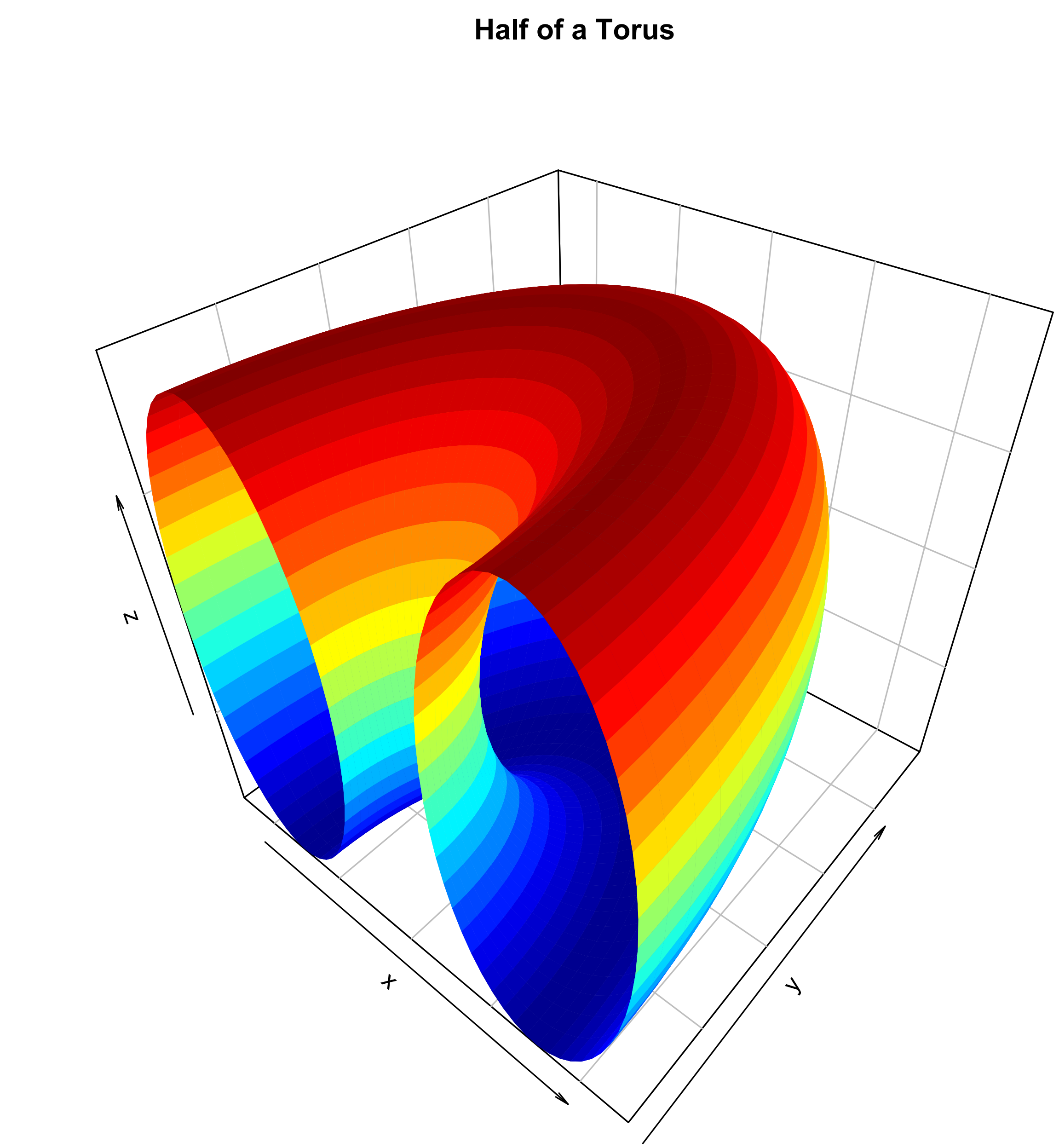

Figure 3. Half torus example..

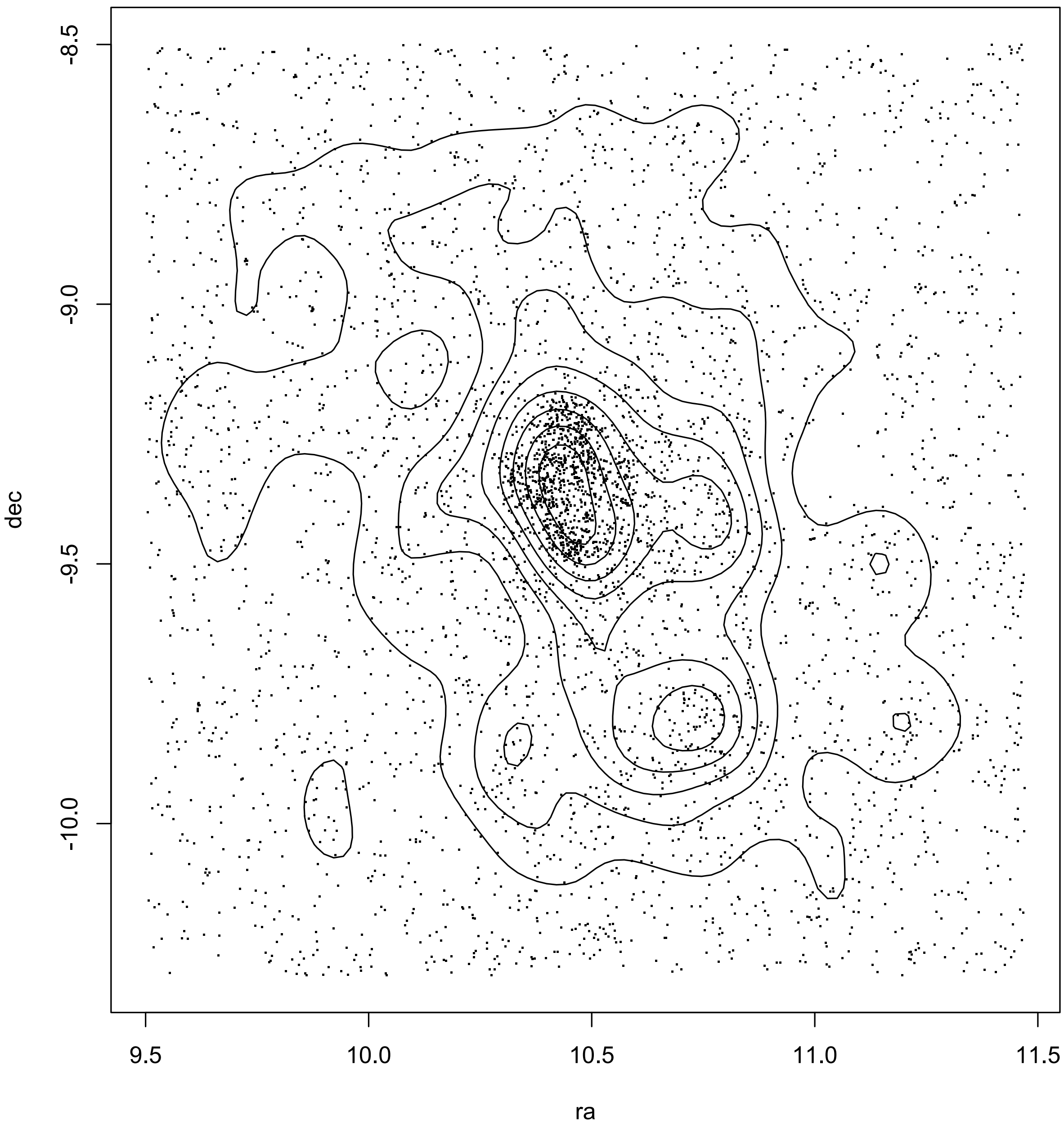

Figure 4. Galaxy example

A EXAMPLE APPENDIX 1

A.1 INTRODUCTION

Stock Assessment modelling was done using the Integrated Statistical Catch Age Model (iSCAM), developed by S. Martell (Martell et al. (2011)). iSCAM is written in AD Model Builder and the source code and documentation for the original iSCAM is available at https://github.com/smartell/iSCAM. Code for the version used in this assessment can be found at https://github.com/cgrandin/iSCAM. iSCAM uses a statistical catch-at-age model implemented in a Bayesian estimation framework.

Running of iSCAM and compilation of results figures was streamlined using the iscam-gui software package developed at the Pacific Biological Station by C. Grandin (https://github.com/cgrandin/iscam-gui). iscam-gui is written in the statistical language R, and provides a graphical user interface that allows users to run and show output of multiple iSCAM model scenarios in a comparative fashion.

A.2 MODEL DESCRIPTION

Note we can reference tables in the main document by using the ref keyword. Here we reference the table with random numbers in it: Table 2. Note that this reference *tab:example-table* was given to the R function make.xtable as an argument. See maindoc.Rnw.

We can also reference any equation found anywhere, such as 1 which is referenced by the tag *eq:sweptareaindex* or 2 which is referenced by *eq:cpuecalc*.

A.3 ANALYTIC METHODS: EQUILIBRIUM CONSIDERATIONS

Another section. The numbering happens automatically.

A.3.1 A STEADY-STATE AGE-STRUCTURED MODEL

Here is another equation written in a slightly different way than in the maindoc. Latex allows for lots of different ways to do things:

$$s_o = \frac{\kappa}{\phi_E},$$

and the density-dependent term is given by:

$$\beta = \frac{\kappa - 1}{R_o \phi_E}$$

Here is an example of an inline fraction: $s_o = \frac{\kappa}{\phi_E}$.

A.4 RESIDUALS, LIKELIHOODS, AND OBJECTIVE FUNCTION VALUE COMPONENTS

This is an example of nested lists using enumeration.. The objective function contains five major components:

1. The negative log-likelihood for the catch data
2. The negative log-likelihood for the relative abundance data
3. The negative log-likelihood for the age composition data
4. The prior distributions for model parameters
5. Three penalty functions that are invoked to regularize the solution during intermediate phases of the non-linear parameter estimation. The penalty functions:
   (a) constrain the estimates of annual recruitment to conform to a Beverton-Holt stock-recruit function
   (b) weakly constrain the log recruitment deviations to a normal distribution
   (c) weakly constrain estimates of log fishing mortality to a normal distribution ($\sim N(\ln(0.2), 4.0)$) to prevent estimates of catch from exceeding estimated biomass.

This example shows the use of some other special functions such as *widehat* both inline and in equation form: The residuals between the observed ($p_{t,a}$) and predicted proportions ($\widehat{p}_{t,a}$) is given by:

$$\eta_{t,a} = \ln(p_{t,a}) - \ln(\widehat{p}_{t,a}) - \frac{1}{A}\sum_{a=1}^{A}\left[\ln(p_{t,a}) - \ln(\widehat{p}_{t,a})\right] \quad \text{(A.1)}$$