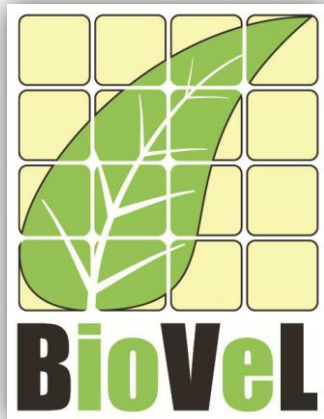


Eigen analysis Workflow for local execution



BioVeL – Biodiversity Virtual e-Laboratory

Workflow Documentation

Eigen analysis workflow for local execution

July 2014

Capacities Programme of Framework 7: EC e-Infrastructure Programme –
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283359
Mr Alex Hardisty
<http://www.biovel.eu>
36 months



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1 Description

The Eigen analysis workflow provides an environment for the analysis of a stage-matrix and performs several analyses on it.

The Eigen analysis results are a set of demographic statistics:

- Lambda or dominant eigenvalue (λ).
- The stable stage distribution (w).
- The sensitivity matrix
- The elasticity matrix.
- Reproductive value (v).
- The damping ratio (ρ).

2 General

2.1 Name of the workflow in myExperiment.

Name: Eigen Analysis Workflow for local execution.

Download: The pack can be downloaded at myExperiment under the following address:
<http://www.myexperiment.org/packs/635.html> or the workflow:
<http://www.myexperiment.org/workflows/3284.html>

2.2 Date, version and licensing

Last updated: 25th July 2014

Version: 3

Licensing: CC-BY-SA

2.3 How to cite this workflow

To report work that has made use of this workflow, please add the following credit acknowledgement to your research publication:

The input data and results reported in this publication (tutorial) come from data (Dr. Gerard Oostermeijer unpublished results and publication: Oostermeijer, J.G.B. M.L. Brugman, E.R. de Boer; H.C.M. Den Nijs. 1996. Temporal and Spatial Variation in the Demography of *Gentiana pneumonanthe*, a Rare Perennial Herb. *The Journal of Ecology*, 84: 153-166.) using BioVeL workflows and services (www.biovel.eu). Eigen Analysis workflow was run on *<date of the workflow run>*. BioVeL is funded by the EU's Seventh Framework Program, grant no. 283359.

3. Scientific specifications

3.1 Keywords

BioVeL, Matrix Population Models, stage matrix, Lambda (λ), Sensitivity analysis, Elasticity analysis, Damping ratio, stable stage distribution (w), reproductive value (v).

3.2 Scientific workflow description

The aim of the Eigen Analysis Workflow is to provide a connected environment for the analysis of a stage matrix. The workflow accepts a stage matrix in a .txt format. The output is provided as a set of R results and graphic plots.

The Eigen analysis results are a set of demographic statistics:

- 1) Lambda or dominant eigenvalue:** The population will be stable, grow or decrease at a rate given by lambda: e.g.: $\lambda = 1$ (population is stable), $\lambda > 1$ (population is growing) and finally $\lambda < 1$ (population is decreasing).
- 2) The stable stage distribution:** It is the proportion of the number of individuals per stage and it is given by (w).

Elasticity and Sensitivity: Sensitivity and elasticity analyses are prospective analyses.

- 3) The sensitivity matrix:** The sensitivity gives the effect on λ of changes in any entry of the matrix, including those that may, in a given context, be regarded as fixed at zero or some other value. The derivative tells what would happened to λ if a_{ij} was to change, not whether, or in what direction, or how much, a_{ij} actually change. The hypothetical results of such impossible perturbations may or may not be of interest, but they are not zero. It is up to you to decide whether they are useful (Caswell 2001).

When comparing the λ -sensitivity values for all matrix elements one can find out in what element a certain increase has the biggest impact on λ . However, a 0.01 increase in a survival matrix element is hard to compare to a 0.01 increase in a reproduction matrix element, because the latter is not bound between 0 and 1 and can sometimes take high values. Increasing matrix element a_{14} (number of S (seedlings) the next year produced by a G (Reproductive individuals)) with 0.01 from 7.666 to 7.676 does not have a noticeable effect on λ . For comparison between matrix elements it can therefore be more insightful to look at the impact of proportional changes in elements: by what percentage does λ change if a matrix element is changed by a certain percentage? This proportional sensitivity is termed elasticity (Description based on Oostermeijer data, based on Jongejans & de Kroon 2012).

- 4) The Elasticity matrix:** The elasticities sum to 1 across the whole matrix (Caswell 1986; de Kroon et

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al. 1986; Mesterton-Gibbons 1993) and can be interpreted as proportional contributions of the corresponding vital rates to the matrix (see van Groenendael et al. 1994).

5) Reproductive value (v): scaled so $v[1]=1$. To what extent will a plant or animal of a determinate category or stage, contribute to the ancestry of future generation.

6) The damping ratio: it can be considered as a measure of the intrinsic resilience of the population, describing how quickly transient dynamics decay following disturbance or perturbation regardless of population structure, the larger the ρ , the quicker the population converges.

Those statistics are function of the vital rates, and through them of biological and environmental variables.

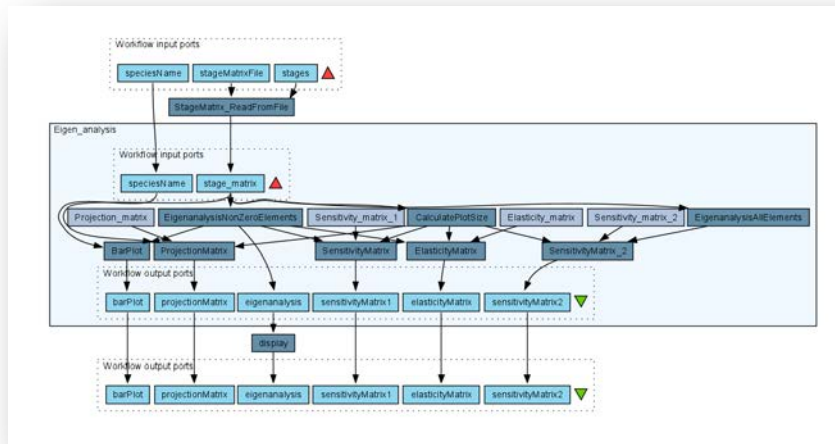


Figure 1. Eigen Analysis workflow in Taverna workbench.

For more detailed description of the functions, please visit the Tutorial section.

4 Technical specifications

4.1 Execution environment and installation requirements

The Workflow requires a Taverna Engine. The simplest way to install a Taverna Engine is to install Taverna Workbench. The workflow also requires an Rserve installation with popdemo package installed. It is possible to setup the workflow to use a remote Rserve. However, instructions for installing a local Rserve are provided below.

4.2 Taverna installation, including updates and plugins

4.2.1 Taverna installations

- Taverna Workbench: Version 2.4 or 2.5. For installation files and instructions, please go to <http://www.taverna.org.uk/download/workbench>

4.2.2 Taverna Dependencies

- Install R software in your computer. See: <http://www.r-project.org/>
- Start R, and install package Rserve:
 - `install.packages("Rserve")`
- Install package popbio
 - `install.packages("popbio")`
- Local R Server: (Rserve) running at port 6311. See <https://wiki.biodel.eu/x/3ICD> for additional information.

4.2.3 How it works

- First, open R, once R is opened, type `library(Rserve)` and press enter; then type `Rserve()` and press enter again. You will see then the following message: Starting Rserve...

```
"C:\PROGRA~1\R\R-30~1.1\library\Rserve\libs\x64\Rserve.exe"
```

After this operation you can open Taverna and run the workflow.

5 Tutorial

5.1 Introduction

In this tutorial, you will use an input file MTers87_88.txt, called in myexperiment.org: Stage Matrix of *Gentiana pneumonanthe* 1987-88. This file will be used to perform the eigen analysis analyses on it. Finally you will be able to export your results to different formats.

5.2 Input data.

5.2.1 Data preparation/format

The workflow accepts input data (matrices) in a .txt format, all decimal numbers in the matrix must be indicated by dots e.g.: 0.578. The example matrix for the tutorial is available in: <http://www.myexperiment.org/packs/635.html> or here below.

5.2.2 Input data

The input files are in a .txt format: to download click here in each file:

Terschelling

- [MTers87_88.txt](#)

Example from:

J. Gerard B. Oostermeijer; M.L. Brugman; E.R. de Boer; H.C.M. Den Nijs. 1996. Temporal and Spatial Variation in the Demography of *Gentiana pneumonanthe*, a Rare Perennial Herb. *Journal of Ecology*, Vol. 84(2): 153-166.

Please note that the workflow as well as the tutorial is a beta version, and may contain errors. We hope you will still find it interesting to work with this workflow, and look forward to your feedback.

5.3 Select input data dialogue boxes.

The first step is to fill out the input ports:

5.3.1 INPUTPORTS

1) **SpeciesName:** Descriptive main title for labelling generated output (bar plot). To add the title, first press add value, fill a title and press enter (Fig. 3).

e.g. *Gentiana pneumonanthe*

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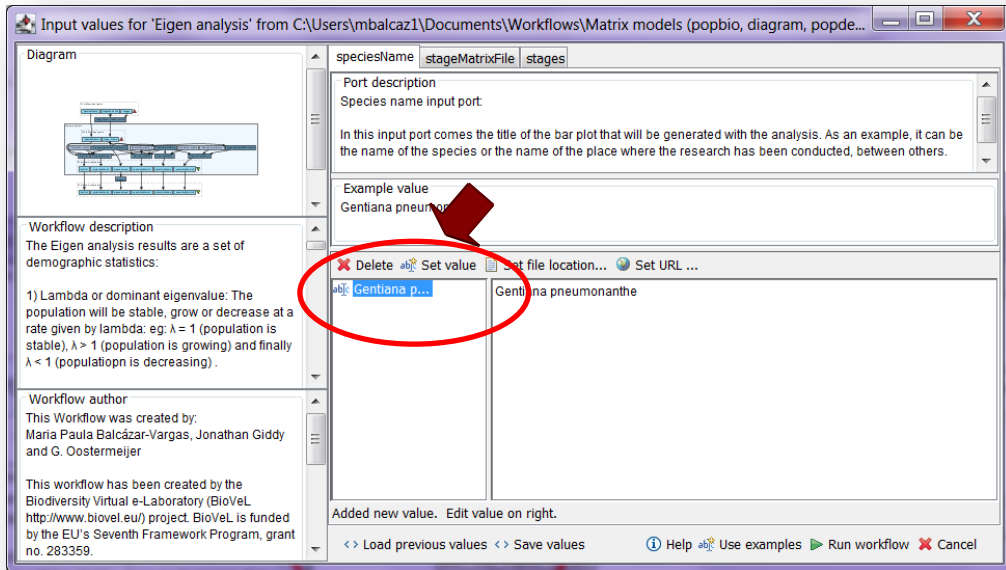


Figure 3. The title graph to be filled in.

2) ***stageMatrixFile***: The stage matrix without the stage names (as you see in the example). It should be provided as a txt-file. all decimal numbers in the matrix must be indicated by dots e.g.: 0.578 (Fig. 4).

File	Edit	Format	View	Help
0.0000	0.0000	0.0000	7.6660	0.0000
0.0579	0.0100	0.0000	8.5238	0.0000
0.4637	0.8300	0.9009	0.2857	0.8604
0.0000	0.0400	0.0090	0.6190	0.1162
0.0000	0.0300	0.0180	0.0000	0.0232

Figure 4. Stage matrix, .txt format and all decimal numbers in the matrix must be indicated by dots e.g.: 0.578.

Press Set file location (red arrow in Fig 5), a window dialog appears and the user selects the file (e.g. [MTers87_88.txt](#)) and then clicks the Open button (blue oval). Then the link to the file will appear on the Taverna window.

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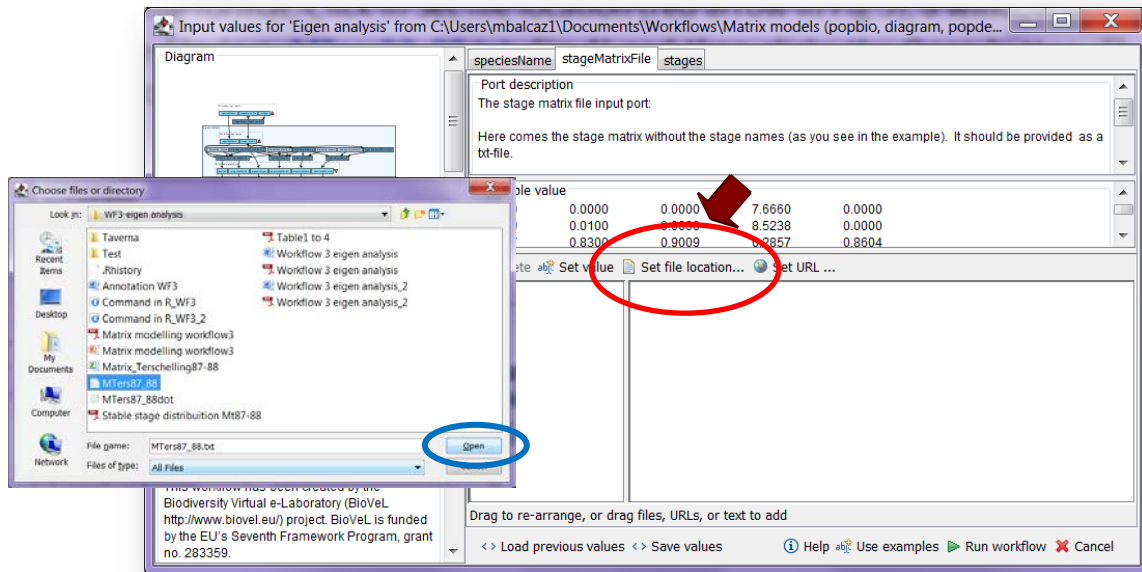


Figure 5. Input matrix to be filled in.

3) **stages**: the names of the stages or categories of the input matrix. In the following example, the matrix has 5 stages or categories.

e.g. the stages of this matrix are called:

- | | |
|-----------------------------|---|
| 1) Seedlings | S |
| 2) Juveniles | J |
| 3) Vegetative | V |
| 4) Reproductive individuals | G |
| 5) Dormant plants | D |

The respective name stages must be filled one by one. First press Add value (see arrow in Fig 6), fill a stage name (not longer than 8 characters) and press enter; then press add value and fill once again the next stage name, repeat the action until you have fill all the stages names.

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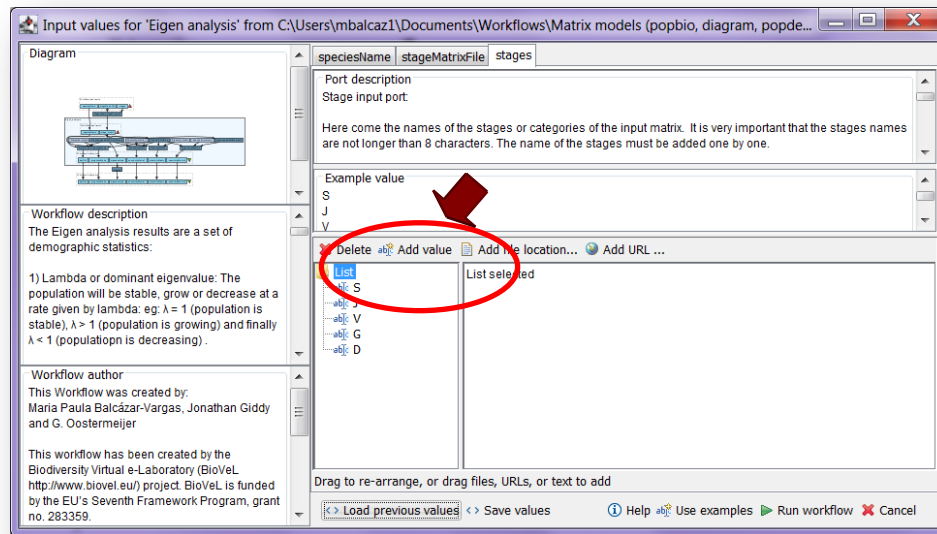


Figure 6. Inputs stages names to be filled in (example).

After the user has filled out the input ports, click **Run Workflow** button.

When the analyses are completed, they appear on different windows under results in Taverna, the user have to save each output separately.

5.4 Save data/results

5.4.1 OUTPUTS

First, click in the selected result window e.g. **barPlot** (Fig 7). Second, click in the left window on value 1 (red oval), Third, on the right window click on the save value (green oval). Fourth, name the file and determine the extension file. For a text file: e.g. .csv or .txt. For images: .jpg or png (Fig 8), Finale, save the file in the chosen map.

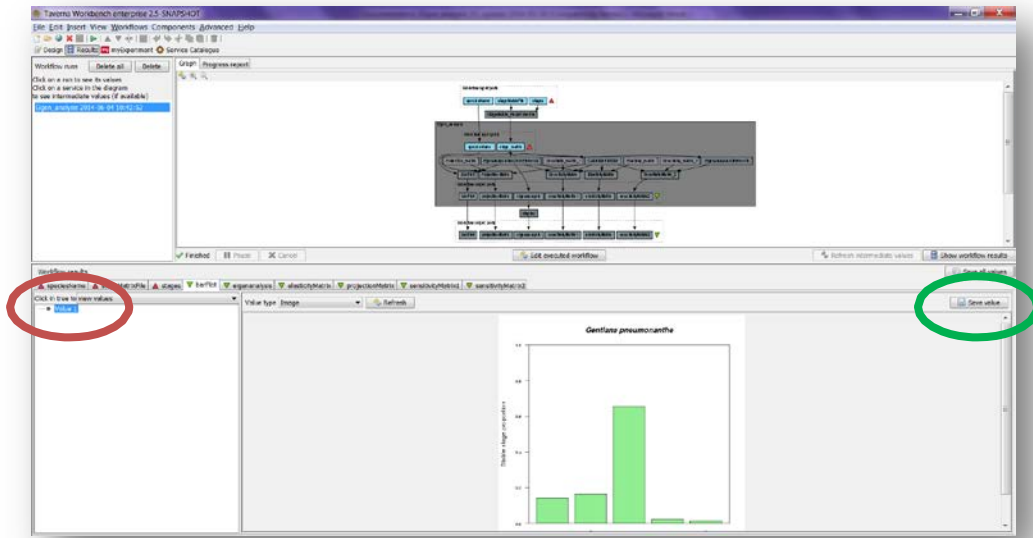


Figure 7. barPlot output window.

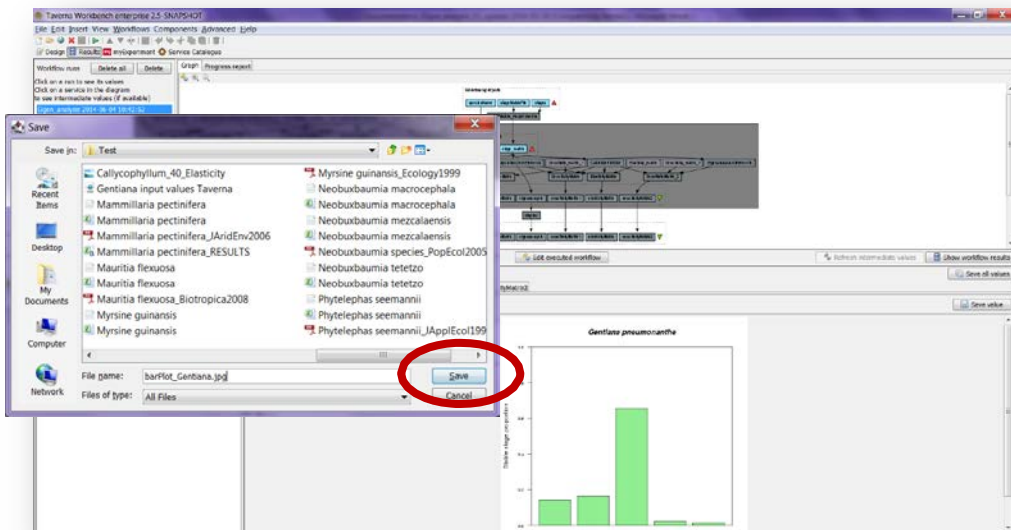


Figure 8. Name the file and determine the extension file. For a text file: e.g. .csv or .txt. For images: e.g.: .jpg or png.

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- 1) **Bartplot**: A bar plot which shows the stable stage distribution (w) of the analysed matrix. In other words, it plots the proportion of individuals per stage (Fig 9).

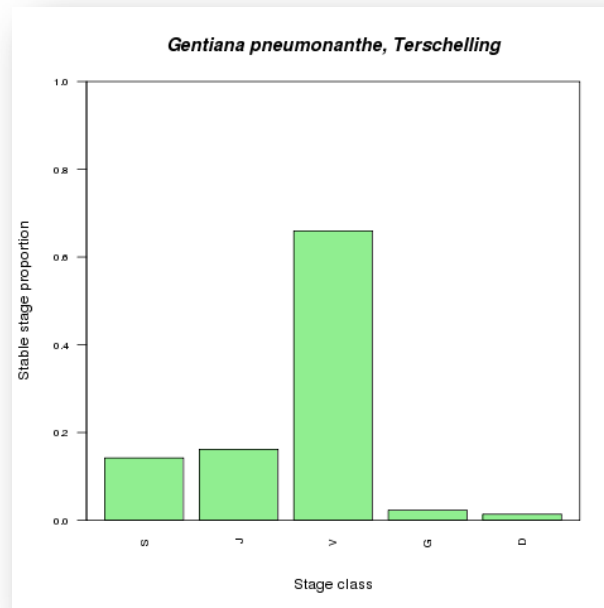


Figure 9. Bartplot output file.

- 2) **Eigen_analysis** (Fig. 10)

- a) **Lambda or dominant eigenvalue**: This value describes the population growth rate of a stage matrix. The population will be stable, grow or decrease at a rate given by lambda: e.g.: $\lambda = 1$ (population is stable), $\lambda > 1$ (population is growing) and finally $\lambda < 1$ (population is decreasing).
- b) **The stable stage distribution** (w): It is the proportion of the number of individuals per stage. It is given analytically by the right eigenvector (another property of the transition matrix) that corresponds to the dominant eigenvalue

Elasticity and Sensitivity: Sensitivity and elasticity analyses are prospective analyses.

- c) **The sensitivity matrix**: The sensitivity gives the effect on λ of changes in any entry of the matrix, including those that may, at a given context, be regarded as fixed at zero or some other value. The derivative tells what would happened to λ if a_{ij} was to change, not whether, or in what direction, or how much, a_{ij} actually change. The hypothetical results of such impossible perturbations may or may not be of interest, but they are not zero. It is up to you to decide whether they are useful (Caswell 2001).

When comparing the λ -sensitivity values for all matrix elements one can find out in what element a certain increase has the biggest impact on λ . However, a 0.01 increase in a survival matrix element is hard to compare to a 0.01 increase in a reproduction matrix element, because the latter is not bound between 0 and 1 and can sometimes take high values. Increasing matrix element a_{14} (number of S (seedlings) the next year produced by a G (Reproductive individuals)) with 0.01 from 7.666 to 7.676 does not have a noticeable effect on λ . For comparison between matrix elements it

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can therefore be more insightful to look at the impact of proportional changes in elements: by what percentage does λ change if a matrix element is changed by a certain percentage? This proportional sensitivity is termed elasticity (Description based on Oostermeijer data, based on Jongejans & de Kroon 2012).

- d) **The Elasticity matrix:** The elasticities of λ with respect to the stage are often interpreted as the “contributions” of each of the stages to λ . This interpretation relies on the demonstration, by de Kroon et al (1986) that the elasticities of the λ with respect to the stage, always sum to 1. For further information see: de Kroon, et al., 1986. and Caswell 2001.
- e) **Reproductive value (v):** scaled so $v[1]=1$. To what extent will a plant or animal of a determinate category or stage , contribute to the ancestry of future generation.
- f) **The damping ratio:** it can be considered as a measure of the intrinsic resilience of the population, describing how quickly transient dynamics decay following disturbance or perturbation regardless of population structure, the larger the p , the quicker the population converges.

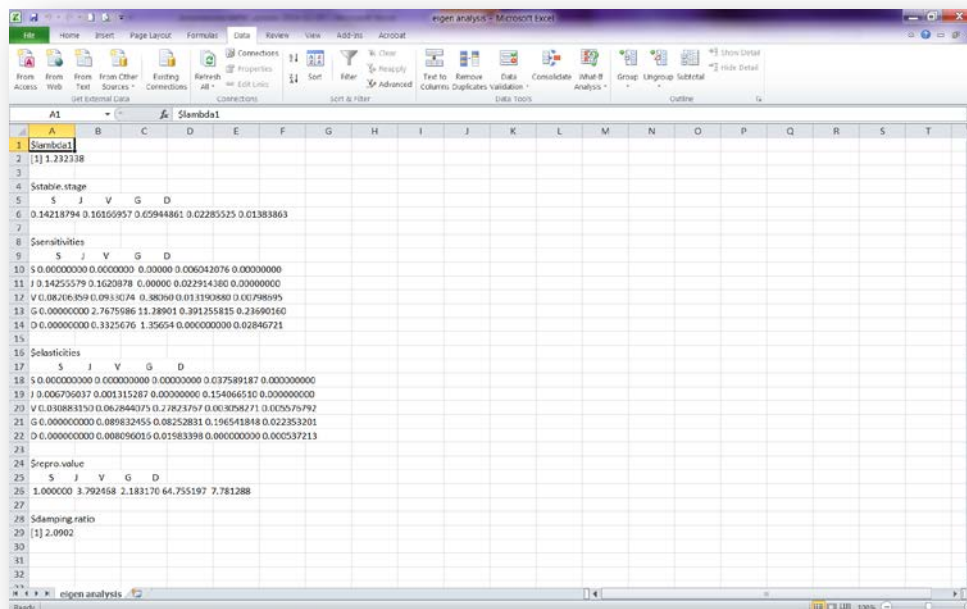


Figure 10. Eigen analysis output file open in excel.

- 3) **Projection matrix:** This creates a grid of coloured rectangles to display the *stage_matrix* (Fig 11).

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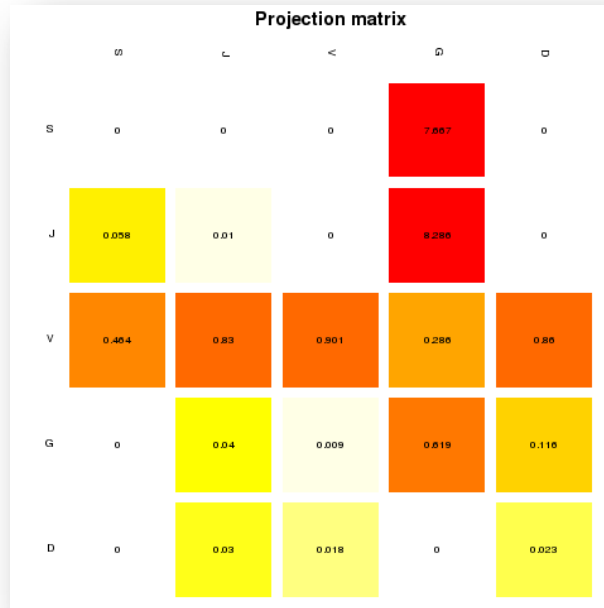


Figure 11. *Projection_matrix* opens as a coloured graph.

- 4) **Elasticity, Sensitivity 1 and Sensitivity 2 matrices:** Creates a grid of coloured rectangles to display the *elasticity_matrix* (Fig 12), *sensitivity_matrix 1* calculates the sensitivity values of non-zero elements and *sensitivity_matrix 2* calculates the sensitivities of all elements in the matrix (Fig 13 and 14).

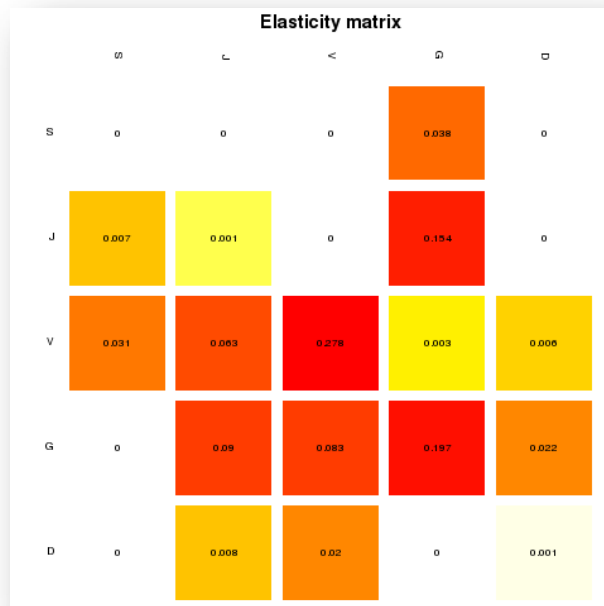


Figure 12. *elasticity_matrix* opens as a coloured graph.

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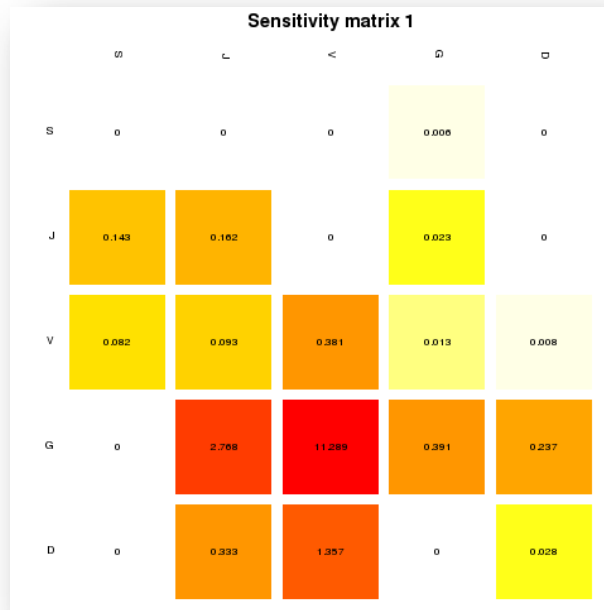


Figure 13. *sensitivity_matrix1* opens as a coloured graph.

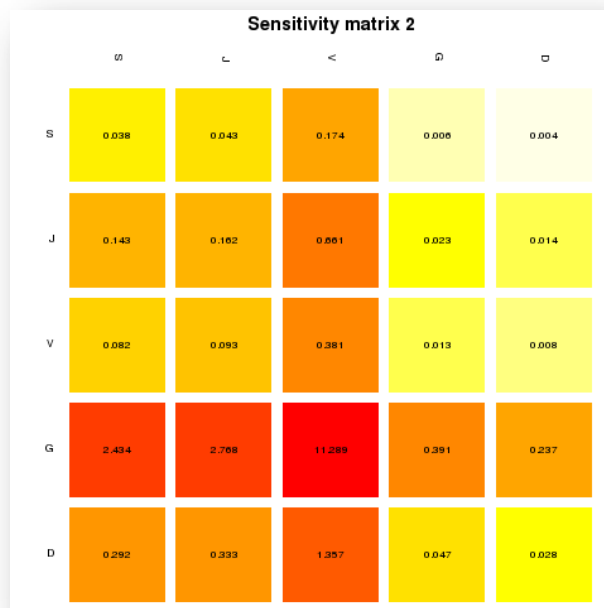


Figure 14. *sensitivity_matrix2* opens as a coloured graph.

6 Support

For questions with using the workflow, please write [support @biovel.eu](mailto:support@biovel.eu)

For definitions of technical and biological terms, please visit the BioVeL glossary page:
<https://wiki.biovel.eu/display/BioVeL/Glossary>

7 References

This workflow was created using and based on Packages 'popbio' in R. (Stubben & Milligan 2007; Stubben, Milligan & Nantel 2011).

Caswell, H. 2001. Matrix population models: Construction, analysis and interpretation, 2nd Edition. Sinauer Associates, Sunderland, Massachusetts.

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Jongejans E. & H. de Kroon. 2012. Matrix models. Chapter in *Encyclopaedia of Theoretical Ecology* (eds. Hastings A & Gross L) University of California, p415-423

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Oostermeijer J.G.B., M.L. Brugman; E.R. de Boer; H.C.M. Den Nijs. 1996. Temporal and Spatial Variation in the Demography of *Gentiana pneumonanthe*, a Rare Perennial Herb. *The Journal of Ecology*, Vol. 84(2): 153-166.

Stubben, C & B. Milligan. 2007. Estimating and Analysing Demographic Models Using the popbio Package in R. *Journal of Statistical Software* 22 (11): 1-23

Stubben, C., B. Milligan, P. Nantel. 2011. Package 'popbio'. Construction and analysis of matrix population models. Version 2.3.1

7.1 Acknowledgements

7.1.1 Authors

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7.1.2 Project funding

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7.2 Publications