ILVO

Institute of Tropical Medicine

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HarmVect

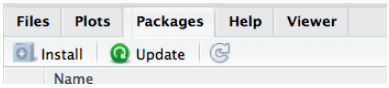
User manual

Contents

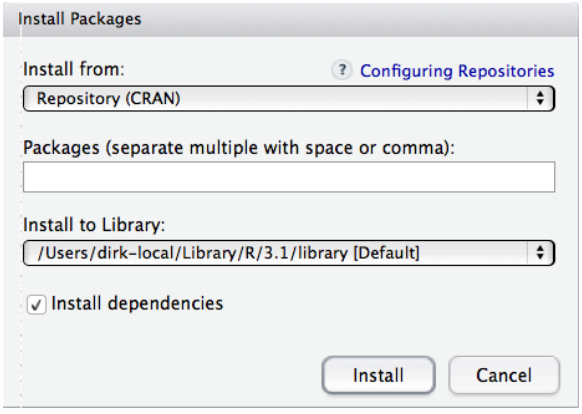
1 Installation

1.1 Software requirements

- **R**: Download and install the latest version of **R** from http://www.r-project.org[1]
- **RStudio**: Download and install the latest version of **RStudio** from http://www.rstudio.com
- **R Packages**: From within **RStudio** install the following packages: CLASSINT, FOREIGN, LATTICE, MAPTOOLS, RCOLORBREWER, RGEOS, SHINY, SP, STRINGR and RMARKDOWN
  - Select the `Packages` tab



  - Click the `Install` button



[1] On Macintosh, ensure **XQuartz** is up to date

– In the `Packages (separate multiple with comma or space)` entry field type the name of the required package(s), (**RStudio** will suggest an ever shorter list of possibilities), select and click the INSTALL button

1.2 Required files

Copy `HarmVect.zip` to the desired location and unzip. Change the name of the enclosing folder/directory to whatever. The following files should have been extracted and installed within the enclosing folder/directory (hereafter called the program folder/directory):

- `borderkey.txt`
- `clearCountriesMatrices.R`
- `climate.csv`
- `climate.R`
- `codes_trade.txt`
- `computePP.R`
- `coordinates.csv`
- `distanceFile.txt`
- `extraLegend.R`
- `general.R`
- `highwayLength.csv`
- `hostDistribution.csv`
- `import.R`
- `initialParameterValues.R`
- `knitrmaps.Rmd`
- `myCommunes2.csv`
- `myCommunes2.dbf`
- `myCommunes2.prj`
- `myCommunes2.qpj`
- `myCommunes2.shp`
- `myCommunes2.shx`
- `natural.R`
- `newEditPathCharFile.R`
- `newEditTradeFile.R`
- `newEditTransferFile.R`
- `outcomes.csv`
- `parkings.txt`
- `poaMap.R`
- `poe_airport.R`
- `poe_land.R`
- `poe_post.R`
- `poe_rail.R`
- `poe_sea.R`
- `poe_WW.R`
- `POE.R`
- `poeMap.R`
- `report.R`
- `reportParams.txt`

- riskMap.R
- roads.dbf
- roads.prj
- roads.qpj
- roads.shp
- roads.shx
- saveTraitFile.R
- server.R
- ui.R
- uiComputePP.R
- uiCountries.R
- uiCreateEditFile.R
- uiGeneral.R
- uiImport.R
- uiManualCalculator.R
- uiMatrix.R
- uiNatural.R
- uiPOE.R
- uiReport.R
- uiRiMa.R
- uiTraits.R

Attention!

Any name, allowed by the respective systems, can be used for the enclosing directory/-folder. However, it is essential **not to change the names** of the individual files. An error will occur when any of the file names are changed. An error also occurs when the above files are **not in the same directory/folder**.

The enclosing directory/folder is henceforth referred to as the **default directory**.

2 General

2.1 Create a subfolder/subdirectory for the species-specific files

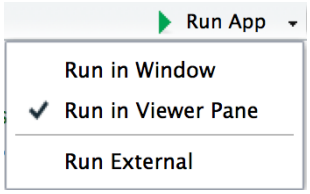
Manually create a subfolder/subdirectory within the default directory to hold the files that are specifically created for the invasive arthropod in question. It is suggested that the genus name in question be used (*e.g.* `Tuta`, `Aedes`, ...). It is furthermore suggested to use the genus name, followed by a number code, if more than one species within the same genus are to be dealt with (*e.g.* `Monochamus1`, `Monochamus2`, ...).

2.2 Starting the program

1. Open either `ui.R` or `server.R` or both in **RStudio**
2. Select either `ui.R` or `server.R`: the top right of the script pane (the top left pane) should show a green arrow with the text `Run App`

> **Attention!**
> If `Run App` does not show, it may be due to either:
>
> - the package `shiny` not being installed
> - the name of either `ui.R` or `server.R` having been changed
> - the fact that both files are not in the same directory/folder
> - the left panels of **RStudio** being too narrow

3. Click the small triangle to the right of `Run App` and select **Run in Viewer Pane** from the drop-down menu



4. Click the **Viewer** tab in the right bottom window pane and maximise its size by moving the horizontal divider to the top and the vertical divider as far left as possible, making sure the green arrow in the script pane remains visible (once the program runs, the divider can be moved further left to increase the size of the Viewer pane even more)

5. Click the green arrow in the script pane to start the program

2.3 Stopping the program

The program is stopped by clicking STOP either in the **Console** pane or in the **Viewer** pane. In case the program produces an error, the STOP button must also be clicked before the program can be restarted.

2.4 Overview of files produced and used by HarmVect

Figure 2.1 graphically shows the various files produced and used by HarmVect.

Because the information needed when computing and producing the maps is collected from various files, it is essential that names used in the different files (countries, commodities, place names, etc.) are totally identical to allow cross-reference between the files. HarmVect therefore produces the files it needs automatically, thus ensuring correctly spelled, unique names for the above entities. However, the data entry spreadsheet feature of **RStudio** is very limited and very basic (especially on Macintosh). The approach taken is to let HarmVect produce the file automatically in the `.txt` or `.csv` format, using the information selected by the user (*e.g.* countries of origin, matrices). It then allows the user to save this blank file and fill out the required data in Excel™. It is the user's responsibility not to change any of the names used in the files to ensure full compatibility. This procedure is explained in detail in section 4.7.

Good to know!

Any file created within HarmVect is a text file (`.txt`) or comma-separated value file (`.csv`) that can be opened and edited in Excel™and re-used in HarmVect as long as it is saved as a tab-delimited text file respectively comma-separated value file from Excel™.

Do however note that R uses only decimal points and not commas.

An error is sometimes produced in HarmVect after a `.txt` file has been edited and saved in Excel™: this is usually due to Excel™not having added a final carriage return (newline) token at the end of the last line. Adding a final carriage return in a text editor solves the problem.

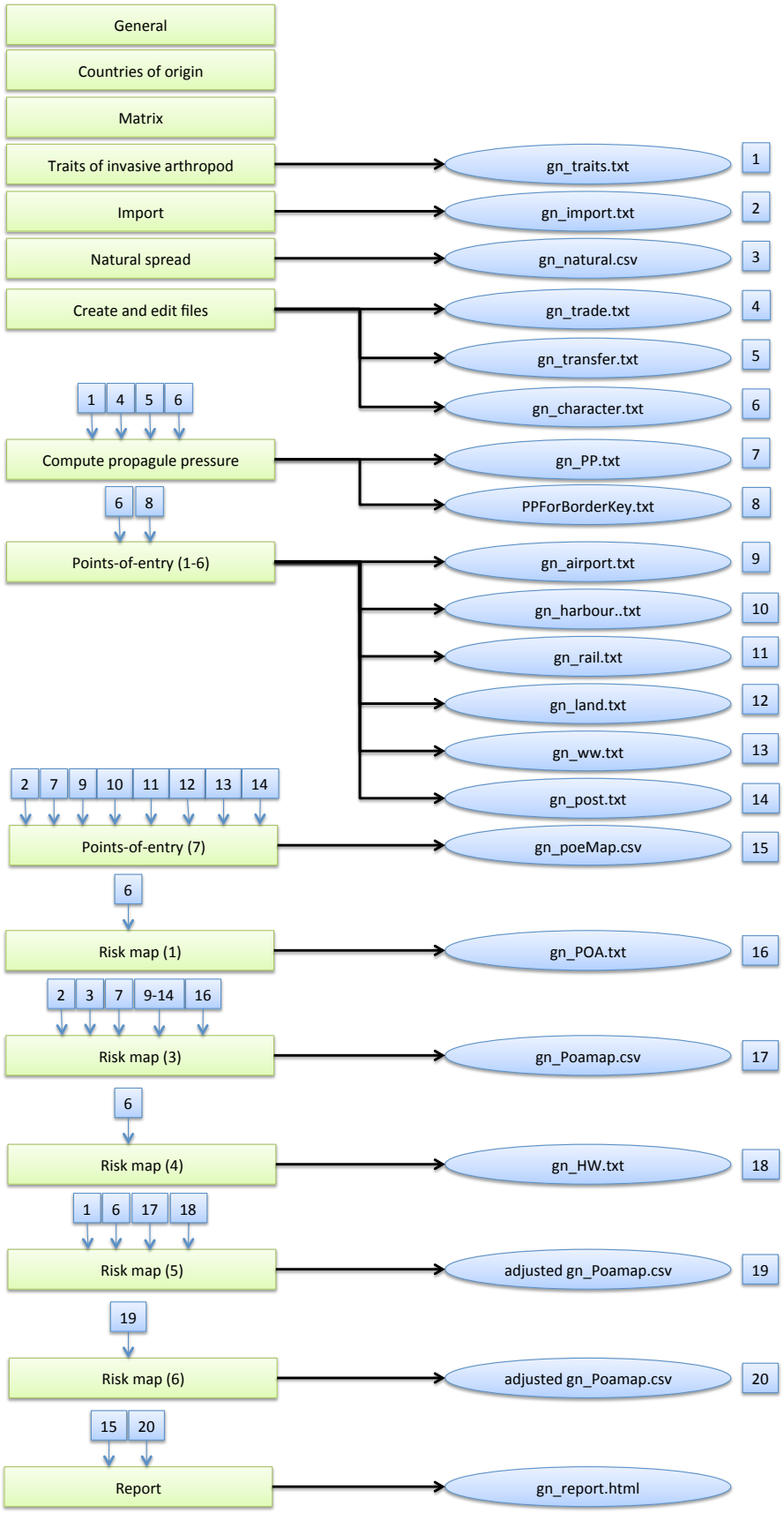


Figure 2.1: Files created and used by HarmVect
gn = genus name

3 Guided tour

3.1 Invasive arthropod description

This chapter guides the user to the necessary data input and manipulation to generate the overall risk map for the (entirely fictious) invasive arthropod *Exemplum nullum*. Wherever more information and an explanation is needed on what data needs to be entered and what is happening in the program, please check chapter 4.

The arthropod is currently found on `Saint Kitts and Nevis` and in the `Cook Islands`, where it parasitises `psittaciformes`, `eggplants` and `quinces`.

Its temperature tolerance range lies between 10°C and 35°C. It has a reproductive rate of 250 larvæ per female and a dispersal capacity of 250 km.

There is an annual import of 1000 propagules via Zaventem airport for research conducted at Scherpenheuvel-Zichem. There is also import through Frankfurt Airport (10000 propagules) and although this is for use abroad there is a risk of escapees and natural spread from there.

Table 3.1 shows the trade and transfer data obtained from the national statistics office. Table 3.2 shows the probability of detection of infestation on the different matrices/items in function of the entry route. Table 3.3 lists the abiotic conditions during the transport of the various matrices/items.

Table 3.1: Trade and transfer statistics

Matrix	Origin	Infestation rate	Quantity (number) entering Belgium	Proportion via air	Proportion via sea
	TRADE				
Psittaciformes	Saint Kitts and Nevis	0.001	100000	1	0
Psittaciformes	Cook Islands	0.025	1000000	1	0
Eggplants	Saint Kitts and Nevis	0.002	5000000	0.8	0.2
Eggplants	Cook Islands	0.005	2000000	0.8	0.2
Quinces	Saint Kitts and Nevis	0.001	10000000	1	0
Quices	Cook Islands	0.001	20000000	1	0
Non-host cargo	Saint Kitts and Nevis	0.00001	70000000	0.5	0.5
Non-host cargo	Cook Islands	0.00001	70000000	0.5	0.5
	TRANSFER				
Tourism	Saint Kitts and Nevis	0.0001	100000	0.95	0.05
Tourism	Cook Islands	0.0001	250000	0.95	0.05

Table 3.2: Detection rates

Matrix	Origin	Detection air	Detection sea
Psittaciformes	Saint Kitts and Nevis	0.1	0
Psittaciformes	Cook Islands	0.1	0
Eggplants	Saint Kitts and Nevis	0.001	0.001
Eggplants	Cook Islands	0.001	0.001
Quinces	Saint Kitts and Nevis	0.001	0
Quices	Cook Islands	0.001	0
Non-host cargo	Saint Kitts and Nevis	0.0001	0.0001
Non-host cargo	Cook Islands	0.0001	0.0001
Tourism	Saint Kitts and Nevis	0.5	0.5
Tourism	Cook Islands	0.5	0.5

Table 3.3: Pathways characteristics

Matrix	air t°_{min}	air t°_{max}	air RH_{min}	air RH_{max}	sea t°_{min}	sea t°_{max}	sea RH_{min}	sea RH_{max}
Psittaciformes	12	30	0	100	12	30	0	100
Eggplants	12	30	0	100	12	30	0	100
Quinces	12	30	0	100	12	30	0	100
Non-host cargo	12	30	0	100	12	30	0	100
Tourism	12	30	0	100	12	30	0	100

The points-of-entry (proportion in brackets) of the various matrices are :

- Airports
  - Psittaciformes: Steenokkerzeel (0.8), Chievres (0.1), Florennes (0.1)
  - Eggplants: Antwerpen (0.25), Charleroi (0.75)
  - Quinces: Zaventem (0.25), Kortrijk (0.25), Grace-Hollogne (0.25), Oostende (0.25)
  - Non-host cargo: Beauvechain (0.2), Bertrix (0.2), Tienen (0.2), Peer (0.2), Koksijde (0.2)

  - Tourism: Hechtel-Eksel (1)

- Harbours
  - Psittaciformes: Antwerpen (1)
  - Eggplants: Oostende (1)
  - Quinces: Brugge (1)
  - Non-host cargo: Brugge (1)
  - Tourism: Gent (1)

The imported psittaciformes (parrots) are distributed to three zoos in Antwerpen, Mechelen en Brugelette. The vegetables and fruits are further distributed throughout Belgium to the population at large.

3.2 Before starting the program

1. Within the default folder create a sub-folder called `Exemplum`

Verify that this sub-folder/sub-directory exists.

3.3 Side–panel "General"

1. Enter `Exemplum` in the **Name of sub-directory to save files** field and click **Set sub-directory**
2. Enter `Exemplum nullum` in the **Name invasive species** and click **Set species name**

The completed panel should look like Figure 3.1[1].

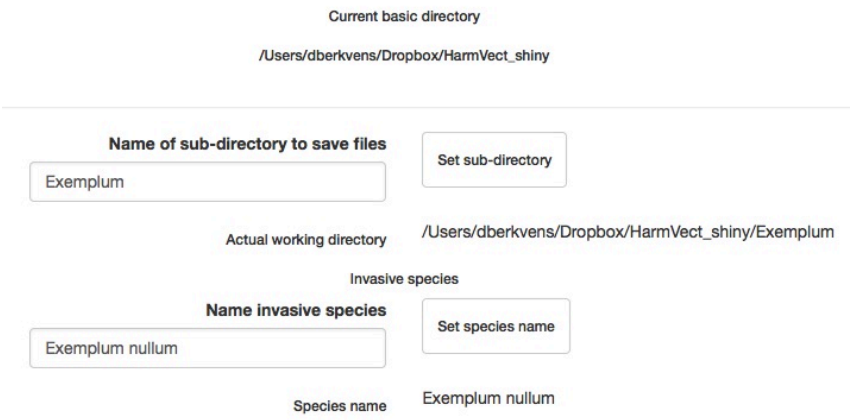


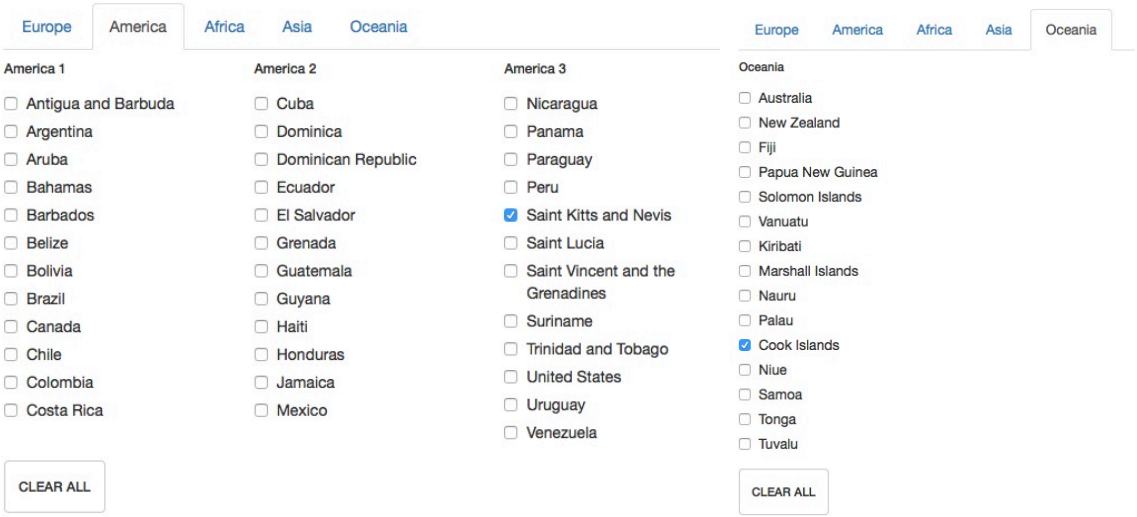
Figure 3.1: Species sub-directory and name

[1]Current basic directory and first part of sub-directory depend on user's specific situation

3.4 Side–panel “Countries of origin”

1. Click on the **America** sub-panel tab and select ☐ **Saint Kitts and Nevis**
2. Click on the **Oceania** sub-panel tab and select ☐ **Cook Islands**

The sub-panels should appear as in Figure 3.2.



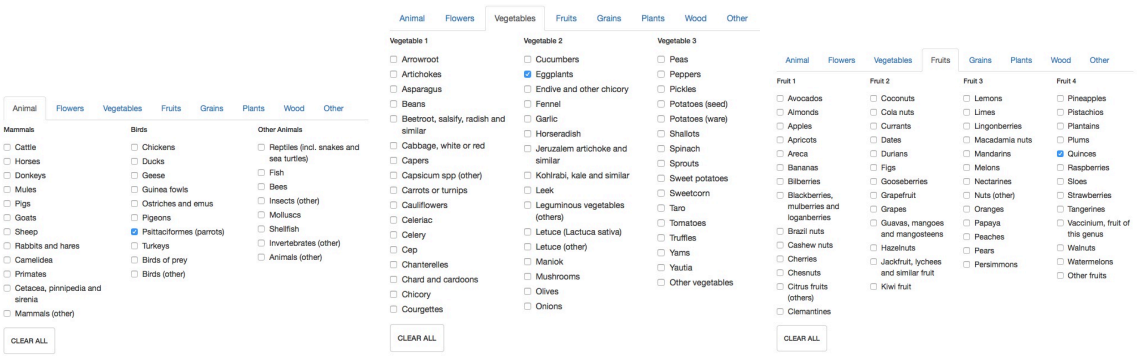
(a) America sub-panel **(b)** Oceania sub-panel

Figure 3.2: Selection of countries of origin

3.5 Side–panel “Matrix”

1. Click on the **Animal** sub-panel tab and select ☐ **Psittaciformes (parrots)**
2. Click on the **Vegetables** sub-panel tab and select ☐ **Eggplants**
3. Click on the **Fruits** sub-panel tab and select ☐ **Quinces**

The sub-panels should appear as in Figure 3.3



(a) Animals sub-panel **(b)** Vegetables sub-panel **(c)** Fruits sub-panel

Figure 3.3: Selection of matrices

3.6 Side–panel "Traits of invasive arthropod"

1. Slide the **Temperature mortality thresholds** lower and upper sliders[2] until they indicate respectively 10℃ and 35℃
2. Enter 250 in the **Reproductive rate** entry field
3. Slide the **Dispersal capacity** upper slider until it indicates 250
4. Keep the default values for all other traits
5. Click on the **Save trait file** button

The completed panel should look like Figure 3.4 (note the `Saved` below the **Save trait file** button. Verify that the file `exemplum_traits.txt` exists in the `Exemplum` sub-folder.

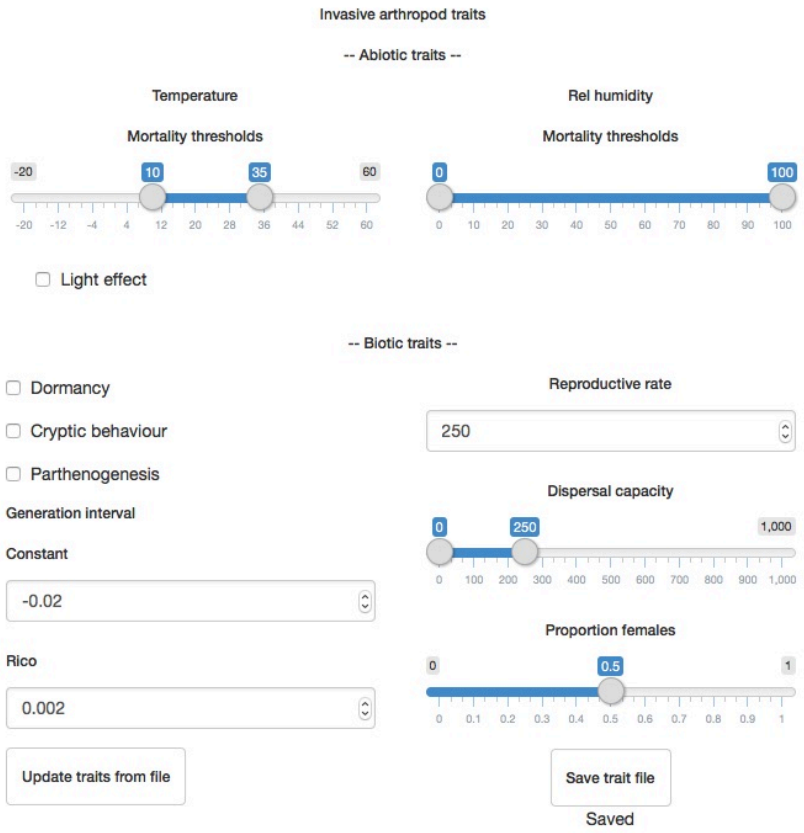


Figure 3.4: Arthropod characteristics panel

3.7 Side–panel "Import"

1. Find and select `Zaventem` in the drop-down menu under **POE 1**. *E.g.* enter `za` in the menu (where it now says ...) and click on `Zaventem`

[2]When a slider has been moved and is still selected, it can be fine-tuned with the left and right arrows on the keyboard

2. Find and select `Scherpenheuvel-Zichem` in the drop-down menu under **POA 1**. *E.g.* enter `zi` and select `Scherpenheuvel-Zichem`

3. Enter 1000 in the **PP1** entry field

4. Click **Save import data to file**

The top of the panel should appear as in Figure 3.5. Verify that the file `exemplum_import.txt` exists in the `Exemplum` sub-folder

Figure 3.5: Top of the arthropod import panel

3.8 Side–panel “Natural spread”

1. Enter 8.56288[3] in the **Longitude 1** entry field

2. Enter 50.039493 in the **Latitude 1** entry field

3. Enter 10000 in the **Propagule 1** entry field

4. Click the **Save natural spread file** button

5. Click the **Plot natural spread**, if desired[4]

The top of the panel should look like Figure 3.6. If the map has been produced it should resemble Figure 3.7. Verify that the file `exemplum_natural.csv` has been added to the `Exemplum` sub-folder.

Figure 3.6: Top of the arthropod natural spread panel

[3]Longitude and latitude of Frankfurt-Flughafen, Frankfurt am Main
[4]See section 4.9 for details on management (*e.g.* saving) of maps

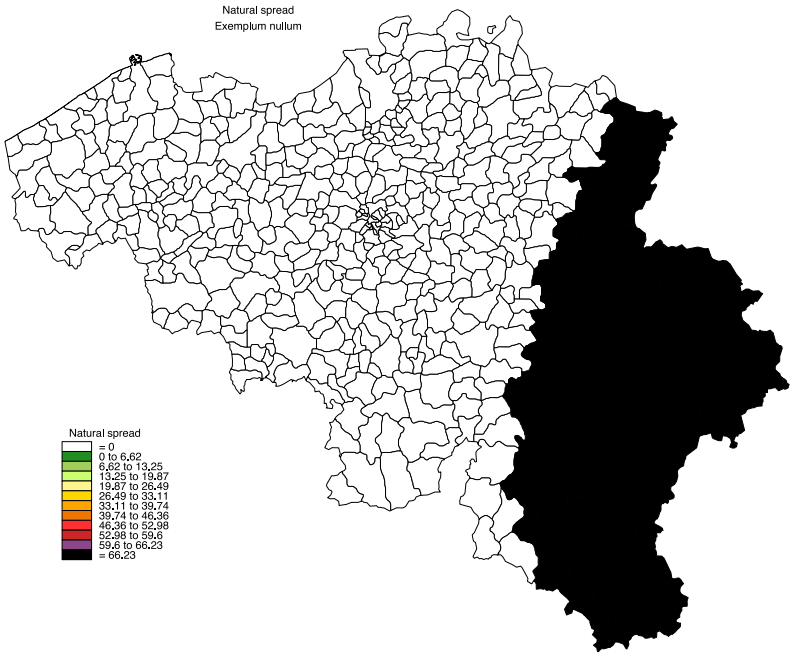


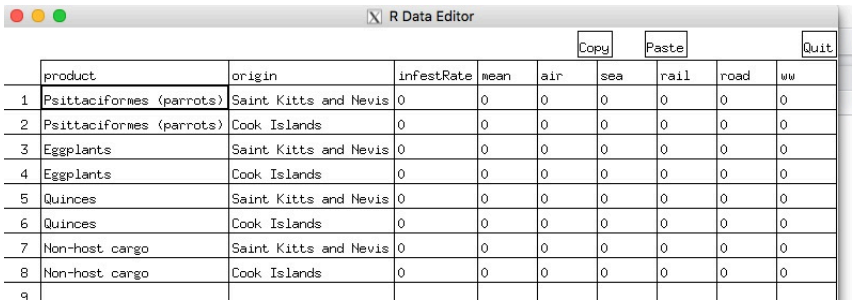
Figure 3.7: Natural spread within the territory

3.9 Side–panel “Create and edit files”

The same sequence of file creation and data editing is followed for the three sub-panels.

1. In the **Trade** sub-panel, click the **Create** button
2. Verify the spreadsheet/data editor, which is generated and opened. It should resemble Figure 3.8
3. Click **Quit** to close the data editor and return to **RStudio**
4. Click **Save** to save the empty (all zeroes) file in the proper sub-directory[5]
5. Edit the `exemplum_trade.txt` file in Excel™and save again as tab-delimited text file and verify that it resembles Figure 3.9
6. Repeat steps 1-5 for `exemplum_transfer.txt` and `exemplum_character.txt` (sub-panel **Transfer** and sub-panel **Pathway characteristics**) and verify that they, after editing in Excel™, resemble respectively Figure 3.10 and Figure 3.11

[5]It is possible that the first click in **RStudio** is ‘lost’ because it has to be re-activated. If so, click again on **Save**



R Data Editor

Copy Paste Quit

	product	origin	infestRate	mean	air	sea	rail	road	ww
1	Psittaciformes (parrots)	Saint Kitts and Nevis	0	0	0	0	0	0	0
2	Psittaciformes (parrots)	Cook Islands	0	0	0	0	0	0	0
3	Eggplants	Saint Kitts and Nevis	0	0	0	0	0	0	0
4	Eggplants	Cook Islands	0	0	0	0	0	0	0
5	Quinces	Saint Kitts and Nevis	0	0	0	0	0	0	0
6	Quinces	Cook Islands	0	0	0	0	0	0	0
7	Non-host cargo	Saint Kitts and Nevis	0	0	0	0	0	0	0
8	Non-host cargo	Cook Islands	0	0	0	0	0	0	0
9									

Figure 3.8: Trade file generated automatically and opened in the data editor

product	origin	infestRate	mean	air	sea	rail	road	ww	post	detAir	detSea	detRail	detRoad	detWW	detPost
Psittaciformes (parrots)	Saint Kitts and Nevis	0.001	100000	1	0	0	0	0	0	0.1	0	0	0	0	0
Psittaciformes (parrots)	Cook Islands	0.025	1000000	1	0	0	0	0	0	0.1	0	0	0	0	0
Eggplants	Saint Kitts and Nevis	0.002	5000000	0.8	0.2	0	0	0	0	0.001	0.001	0	0	0	0
Eggplants	Cook Islands	0.005	2000000	0.8	0.2	0	0	0	0	0.001	0.001	0	0	0	0
Quinces	Saint Kitts and Nevis	0.001	10000000	1	0	0	0	0	0	0.001	0	0	0	0	0
Quinces	Cook Islands	0.001	20000000	1	0	0	0	0	0	0.001	0	0	0	0	0
Non-host cargo	Saint Kitts and Nevis	0.00001	70000000	0.5	0.5	0	0	0	0	0.0001	0.0001	0	0	0	0
Non-host cargo	Cook Islands	0.00001	70000000	0.5	0.5	0	0	0	0	0.0001	0.0001	0	0	0	0

Figure 3.9: Trade file after editing in Excel™

product	origin	infestRate	mean	air	sea	rail	road	ww	post	detAir	detSea	detRail	detRoad	detWW	detPost
Tourism	Saint Kitts and Nevis	0.0001	100000	0.95	0.05	0	0	0	0	0.5	0.5	0	0	0	0
Tourism	Cook Islands	0.0001	250000	0.95	0.05	0	0	0	0	0.5	0.5	0	0	0	0
Commuting	Saint Kitts and Nevis	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Commuting	Cook Islands	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Military	Saint Kitts and Nevis	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Military	Cook Islands	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 3.10: Transfer file after editing in Excel™

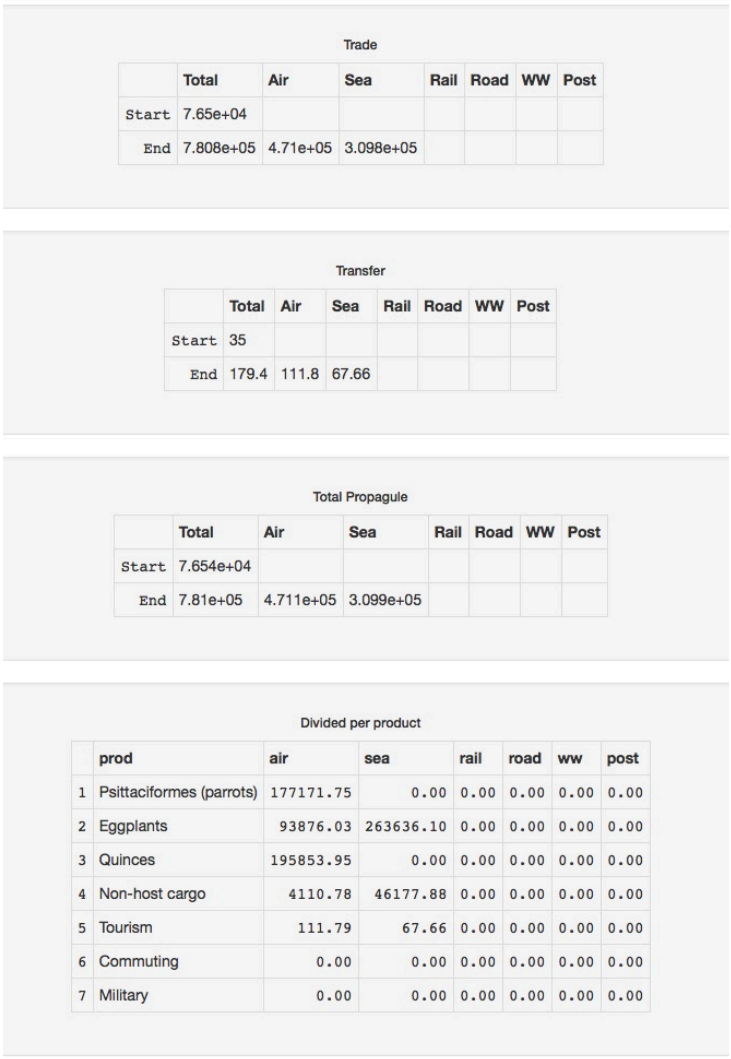
product	air_mint	air_maxt	air_minrh	air_maxrh	air_light	sea_mint	sea_maxt	sea_minrh	sea_maxrh
Psittaciforme	12	30	0	100	0	12	30	0	100
Eggplants	12	30	0	100	0	12	30	0	100
Quinces	12	30	0	100	0	12	30	0	100
Non-host car	12	30	0	100	0	12	30	0	100
Tourism	12	30	0	100	0	12	30	0	100
Commuting	12	30	0	100	0	12	30	0	100
Military	12	30	0	100	0	12	30	0	100

Figure 3.11: Pathway characteristics file after editing in Excel™(leftmost columns)

3.10 Side–panel "Compute propagule pressure"

1. Click the **Compute** button

Verify that the computed propagule pressure is as shown in Figure 3.12 and verify that the following two files have been added to the `Exemplum` sub-directory: `exemplum_PP.txt` and `PPForBorderKey.txt`.



Trade

	Total	Air	Sea	Rail	Road	WW	Post
Start	7.65e+04						
End	7.808e+05	4.71e+05	3.098e+05				

Transfer

	Total	Air	Sea	Rail	Road	WW	Post
Start	35						
End	179.4	111.8	67.66				

Total Propagule

	Total	Air	Sea	Rail	Road	WW	Post
Start	7.654e+04						
End	7.81e+05	4.711e+05	3.099e+05				

Divided per product

	prod	air	sea	rail	road	ww	post
1	Psittaciformes (parrots)	177171.75	0.00	0.00	0.00	0.00	0.00
2	Eggplants	93876.03	263636.10	0.00	0.00	0.00	0.00
3	Quinces	195853.95	0.00	0.00	0.00	0.00	0.00
4	Non-host cargo	4110.78	46177.88	0.00	0.00	0.00	0.00
5	Tourism	111.79	67.66	0.00	0.00	0.00	0.00
6	Commuting	0.00	0.00	0.00	0.00	0.00	0.00
7	Military	0.00	0.00	0.00	0.00	0.00	0.00

Figure 3.12: Estimated propagule pressure entering Belgium

3.11 Side–panel “Point-of-entry”

The first six sub-panels are used to compute the relative distribution of the respective propagule pressure entering the country via the different entry points for the various pathways (air, sea, rail, road, waterways and post). Each of the sub-panels permits the creation of the respective text-file, which can be edited in Excel™. Only the tabs **Airport** and **Harbour** are relevant in this example.

1. Repeat steps 1-5 of section 3.9 on tab **Airport** and **Harbour**
2. Edit both files in Excel™and verify that are like Figure 3.13 and Figure 3.14
3. Verify that `exemplum_airport.txt` and `exemplum_harbour.txt` have been added to the sub-folder `Exemplum`

Airport	Psittaciformes (parrots)	Eggplants	Quinces	Non-host car	Tourism	Commuting	Military
Antwerpen	0	0.25	0	0	0	0	0
Zaventem	0	0	0.25	0	0	0	0
Charleroi	0	0.75	0	0	0	0	0
Kortrijk	0	0	0.25	0	0	0	0
Grace-Hollogne	0	0	0.25	0	0	0	0
Oostende	0	0	0.25	0	0	0	0
Beauvechain	0	0	0	0.2	0	0	0
Bertrix	0	0	0	0.2	0	0	0
Steenokkerzeel	0.8	0	0	0	0	0	0
Chievres	0.1	0	0	0	0	0	0
Florennes	0.1	0	0	0	0	0	0
Tienen	0	0	0	0.2	0	0	0
Peer	0	0	0	0.2	0	0	0
Koksijde	0	0	0	0.2	0	0	0
Hechtel-Eksel	0	0	0	0	1	0	0
Wevelgem	0	0	0	0	0	0	0
Saint-Hubert	0	0	0	0	0	0	0
Knesselare	0	0	0	0	0	0	0
Ravels	0	0	0	0	0	0	0
Malle	0	0	0	0	0	0	0
Zutendaal	0	0	0	0	0	0	0

Figure 3.13: Airport distribution

Harbour	Psittaciforme	Eggplants	Quinces	Non-host car	Tourism	Commuting	Military
Antwerpen	1	0	0	0	0	0	0
Oostende	0	1	0	0	0	0	0
Brugge	0	0	1	1	0	0	0
Gent	0	0	0	0	1	0	0

Figure 3.14: Harbour distribution

4. In the **POE Map** sub-panel, select ☐ **Plot risk airports** and ☐ **Plot risk harbours** and click **Create risk map at points-of-entry**

5. Verify the map created in the **Plots** panel[6] (Figure 3.15)

[6]See section 4.9 for details on management (*e.g.* saving) of maps

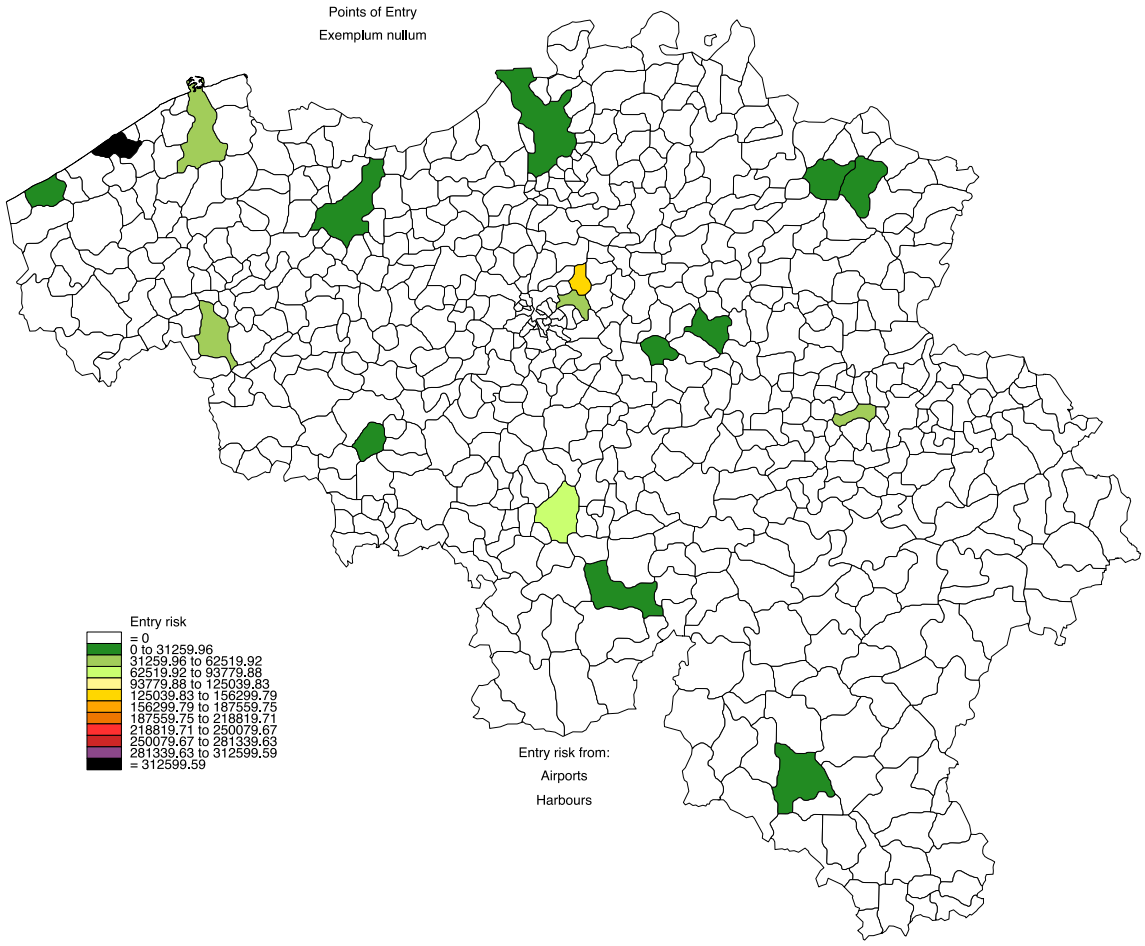


Figure 3.15: Risk map at points-of-entry

3.12 Side–panel “Risk map”

The first sub-panel is used to create the so-called propagule distribution file. This file indicates the proportion of propagules that escape at the point of entry and the further distribution throughout Belgium of the remainder (either to specific communes or distributed over the population at large).

1. In the drop-down menu, select `Antwerpen`, `Mechelen` and `Brugelette`
2. Click **Create** and verify the data-editor spreadsheet
3. Click **Quit** and upon return in **RStudio**, click **Save**
4. Edit `exemplum_POA.txt` in Excel™

Ensure that the resulting text file is as Figure 3.16.

Distribute	Psittaciformes (parrots)	Eggplants	Quinces	Non-host cargo	Tourism	Commuting	Military
air	0	0.1	0.05	0.5	0.1	0	0
sea	0	0.2	0.02	0.6	0.1	0	0
rail	0	0	0	0	0	0	0
road	0	0	0	0	0	0	0
ww	0	0	0	0	0	0	0
post	0	0	0	0	0	0	0
pop	0	1	1	1	1	0	0
Antwerpen	0.2	0	0	0	0	0	0
Mechelen	0.4	0	0	0	0	0	0
Brugelette	0.4	0	0	0	0	0	0

Figure 3.16: Propagule distribution file

Exemplum nullum has the capacity to fly locally after escaping for a distance of about 7.5 km. Its migration characteristic is described by a generalised logistic function with parameters: B = 0.8; Q = 250; v = 1 (put maximum distance to 20 km to visualise the graph). The resulting migration capacity is shown in Figure 3.17.

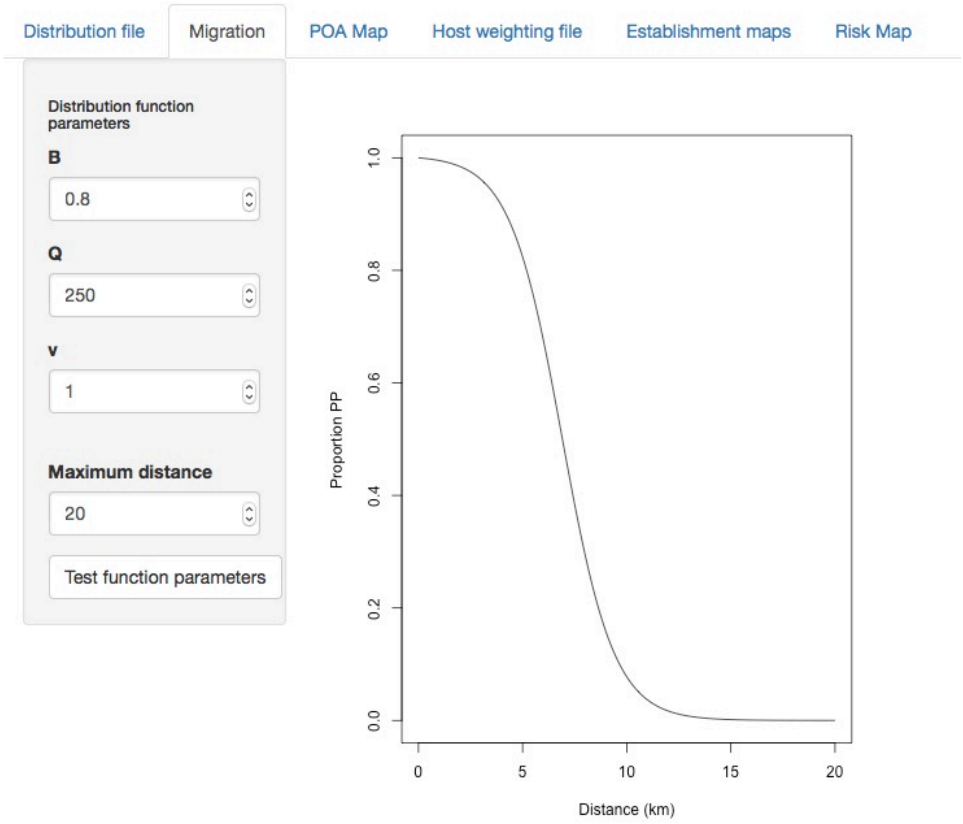


Figure 3.17: Migration distribution

The actual points-of-appearance map is produced in the **POA** sub-panel.

1. Select ☐ **Include migration**, ☐ **Include import** and ☐ **Include natural spread** (Lay-bys and highways are not relevant for this arthropod)

2. Click **Create risk map at points-of-appearance** (Figure 3.18

3. Verify the map created in the **Plots** panel[7] (Figure 3.19)

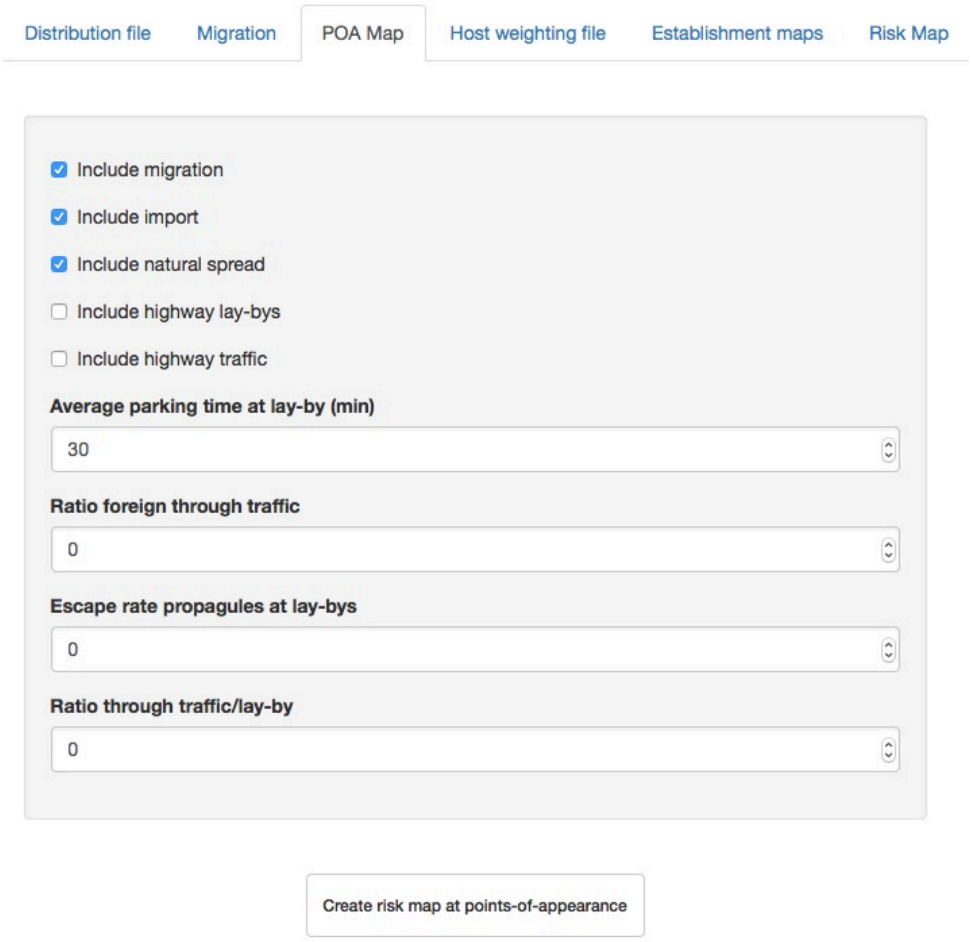


Figure 3.18: Create points-of-appearance map

[7]See section 4.9 for details on management (*e.g.* saving) of maps

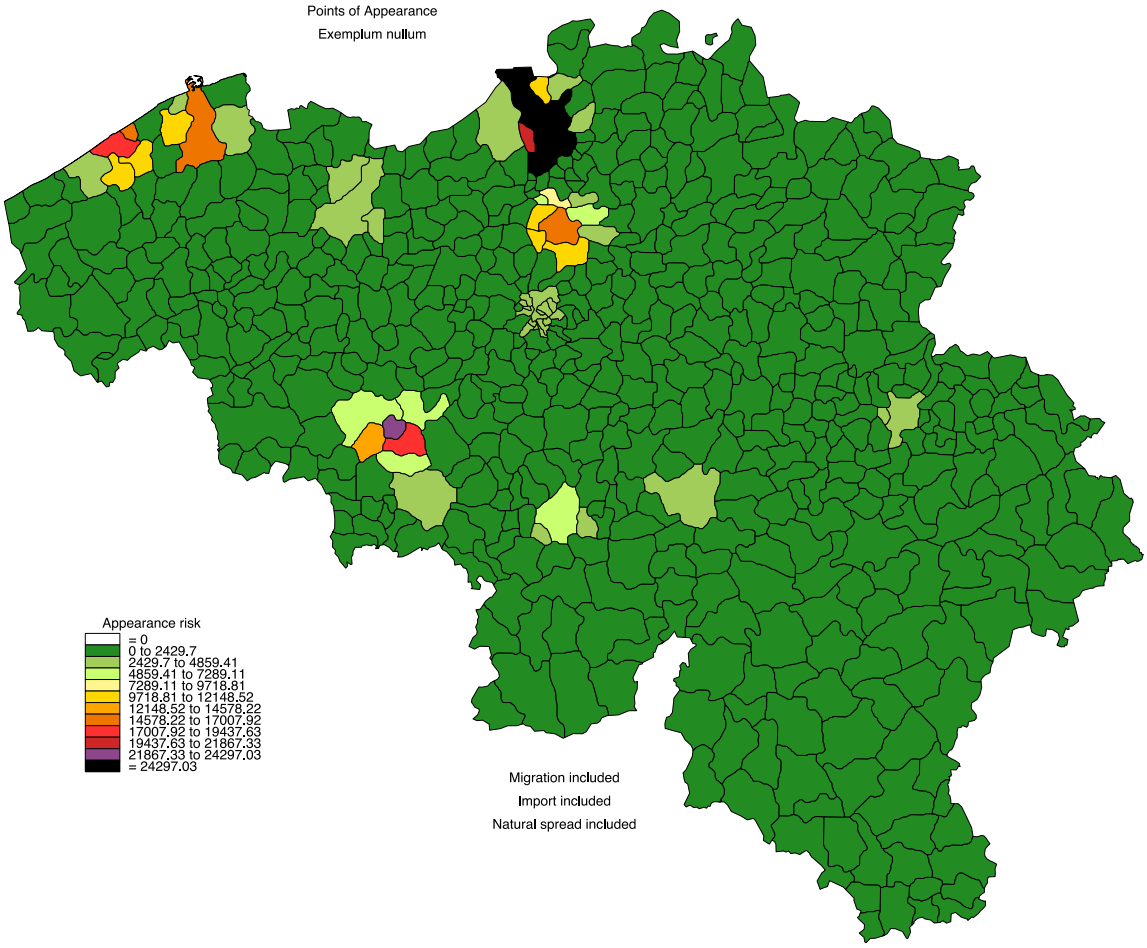


Figure 3.19: Points-of-appearance map

The relative importance of the various hosts is entered in the **Host weighting file** sub-panel.

1. Click **Create** and verify the data-editor spreadsheet
2. Click **Quit** and upon return in **RStudio**, click **Save**
3. Edit `exemplum_HW.txt` in Excel™(Figure 3.20)

Commodity	Weighting
Psittaciformes (parrots)	1
Eggplants	0.3
Quinces	0.3
Non-host cargo	0.01
Tourism	0.1
Commuting	1
Military	1

Figure 3.20: Host weighting file

The **Establishment maps** sub-panel *must* be used to create the `Climate suitability map`, the `Host distribution map` and the `Sheltered environment suitability map`.

1. Fill out the climate suitability map details as in Figure 3.21 and click **Generate climate map**, which generates the map shown in Figure 3.22

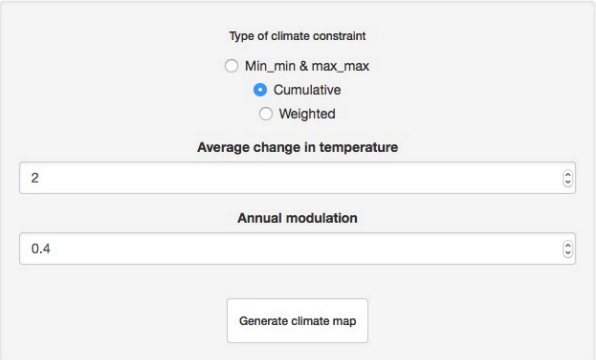


Figure 3.21: Create climate suitability map

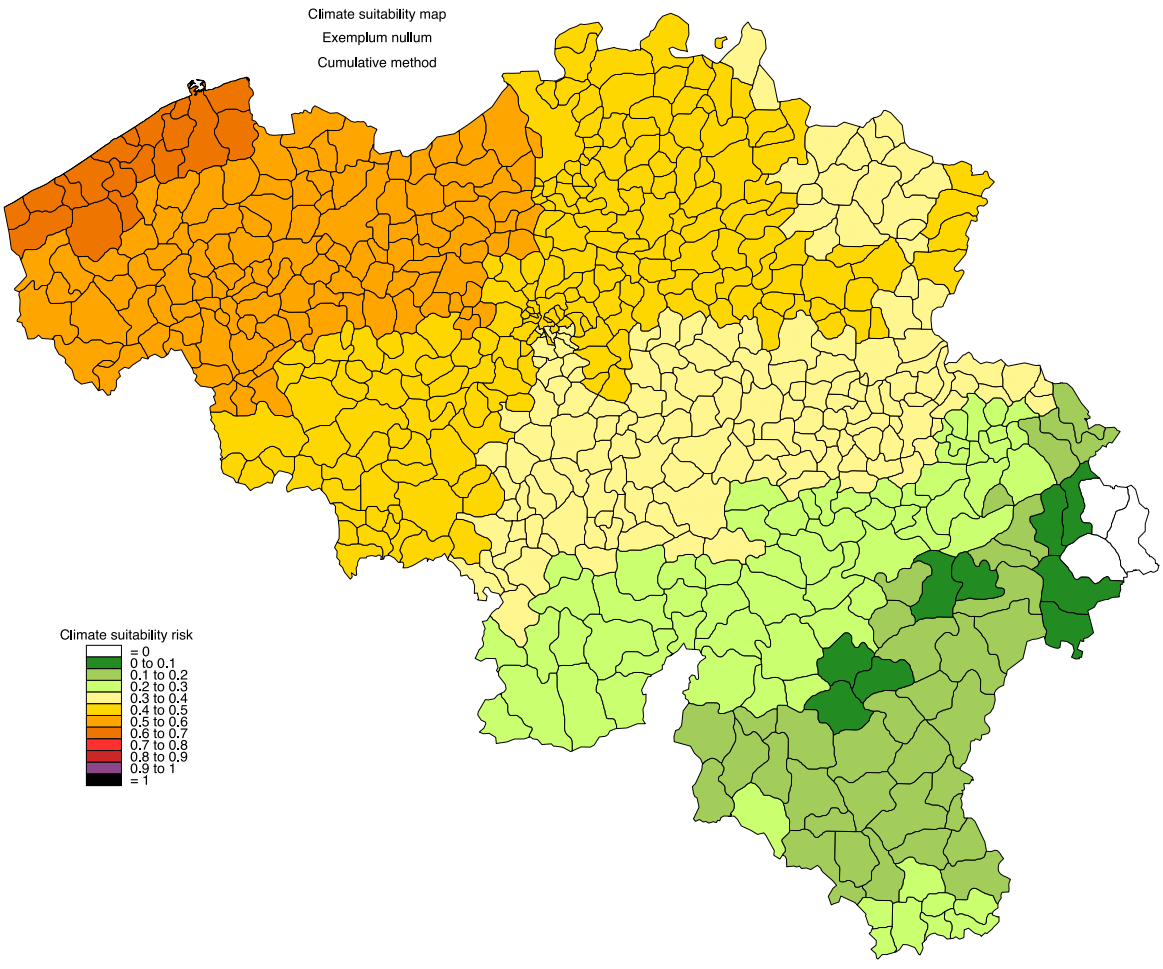


Figure 3.22: Climate suitability map

2. Humans are not suitable as hosts (leave the slider as is, Figure 3.23) and click **Generate host map**, which generates the map shown in Figure 3.24

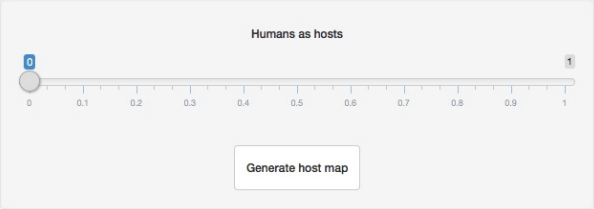


Figure 3.23: Create host distribution map

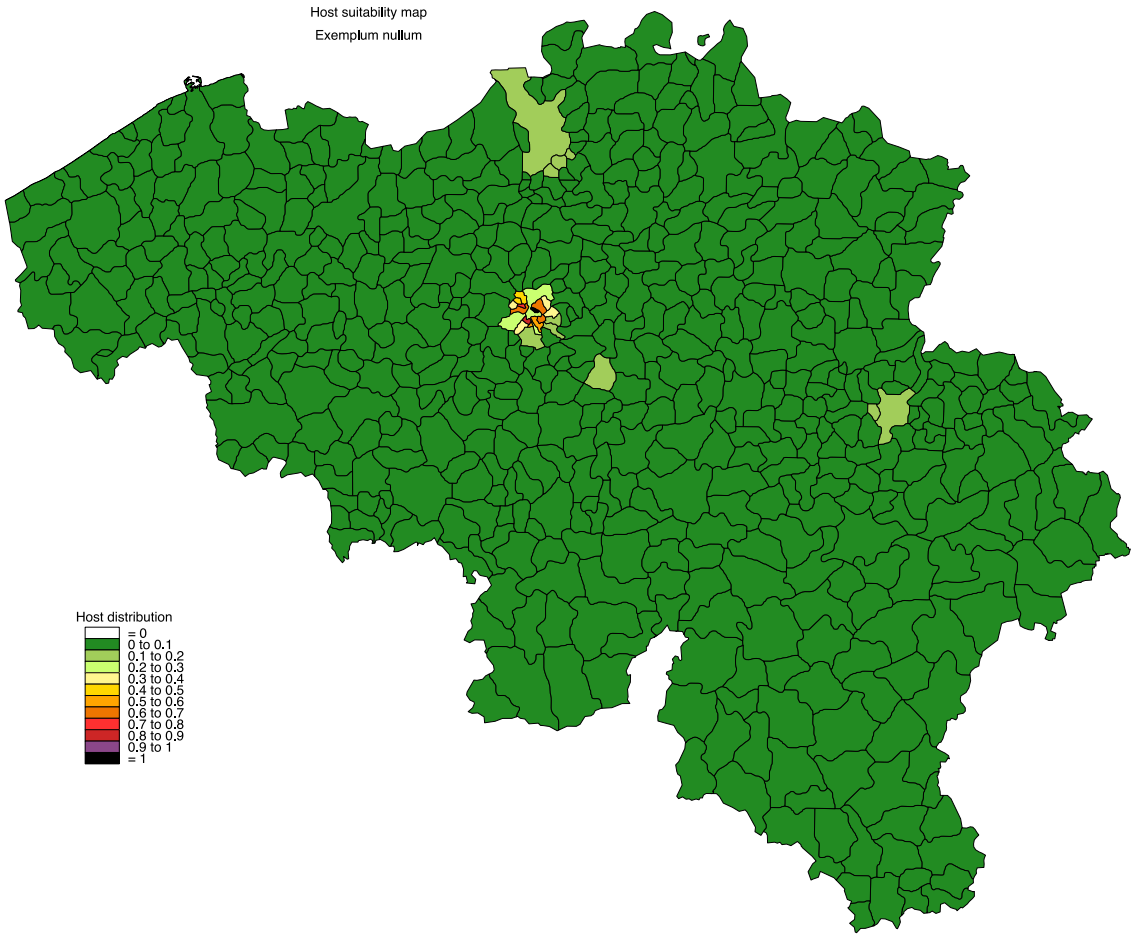


Figure 3.24: Host distribution map

3. In the **Indoor suitability map** well, select `Hasselt`, where people cultivate quinces indoors throughout the year, from the drop-down menu under **Choose commune**, increase the **Human indoor suitability** slider to one (Figure 3.25) and click **Generate sheltered environment map**, which generates the map shown in Figure 3.26

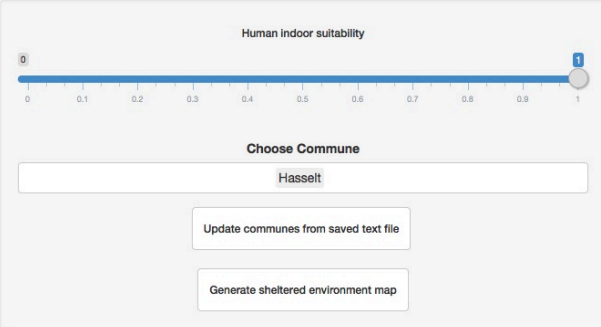


Figure 3.25: Create sheltered environment map

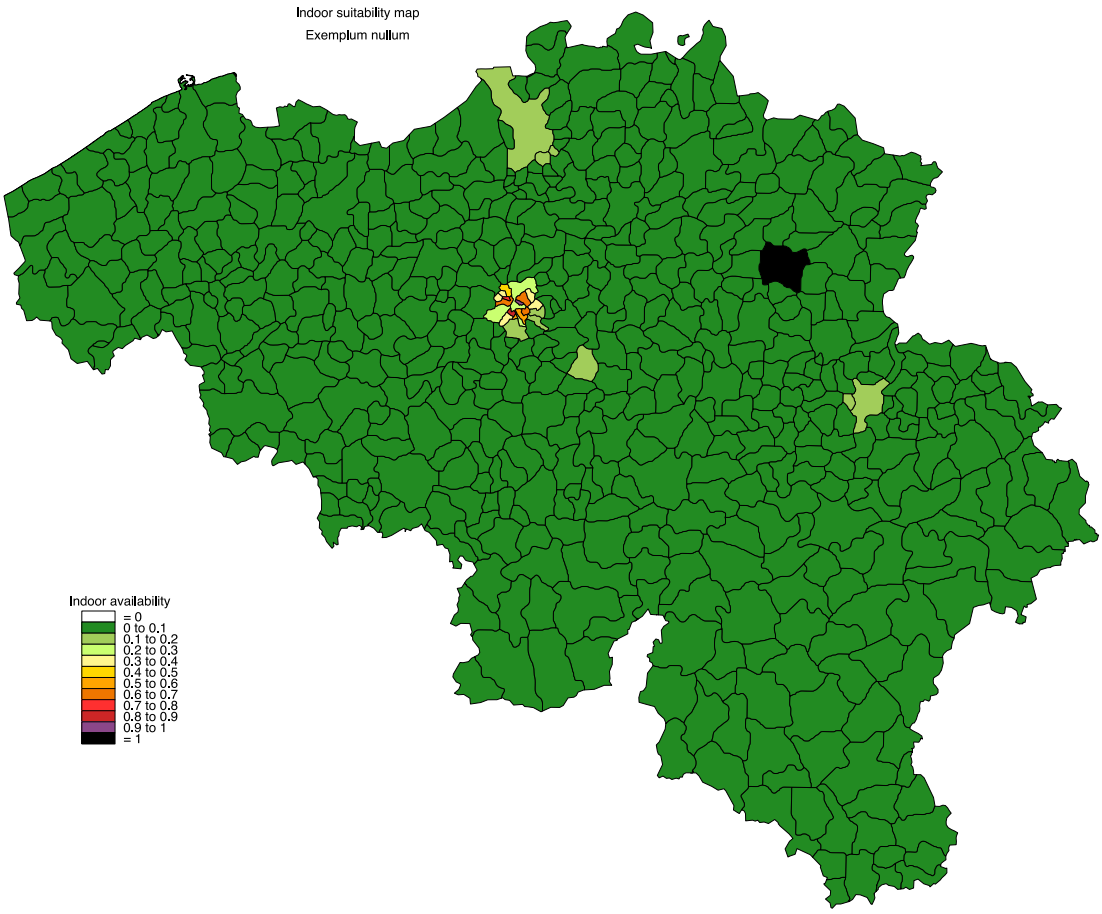


Figure 3.26: Sheltered environment map

In the **Risk Map** sub-panel, set the sliders as shown in Figure 3.27 and click **Create overall risk map** to generate the map shown in Figure 3.28.

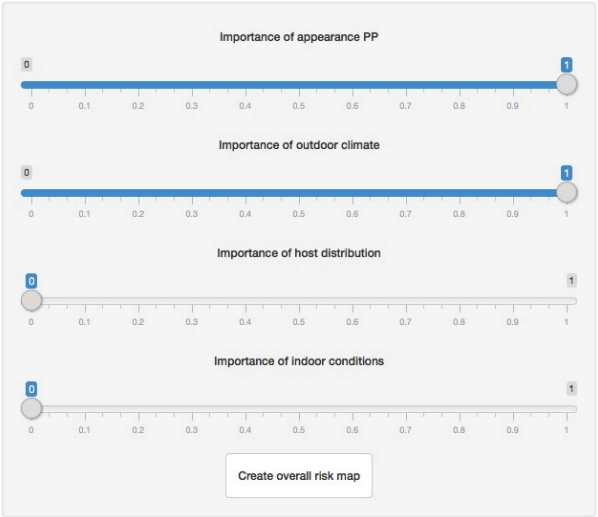


Figure 3.27: Create overall risk map

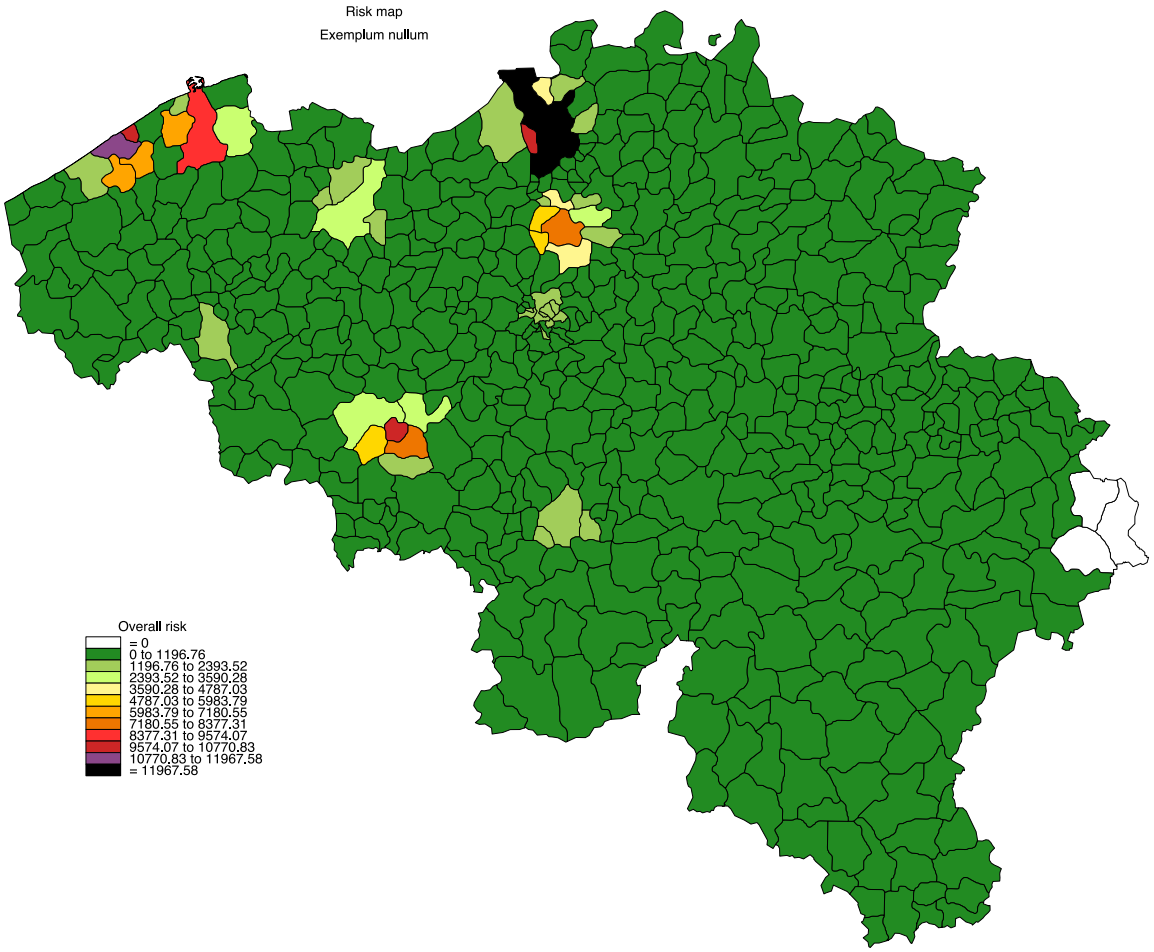


Figure 3.28: Overall risk map

3.13 Side–panel “Report”

Click **Create report** and verify that the file `exemplum_report.html` has been added to the `Exemplum` folder.

4 Reference manual

4.1 Side–panel "General"

Attention!
The text entry fields in "General" view pane must be filled out before proceeding with anything else. An error message will be shown virtually everywhere in the rest of the program if these two entry fields are not filled out.

When entering the view pane (Figure 4.1), the current default directory is shown at the top below **Current basic directory**.

Enter the name of the specific subfolder/subdirectory in the text input field below **Name of sub-directory to save files** and click the button `Set sub-directory`. The name of the selected folder/directory will be shown after **Actual working directory**. Enter the species name in the text input field **Name invasive species** and click the button `Set species name`. The species name will be shown after **Species name** (Figure 4.2).

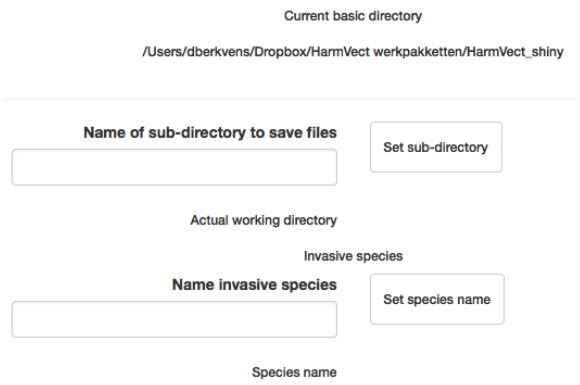


Figure 4.1: “General” view pane before data entry

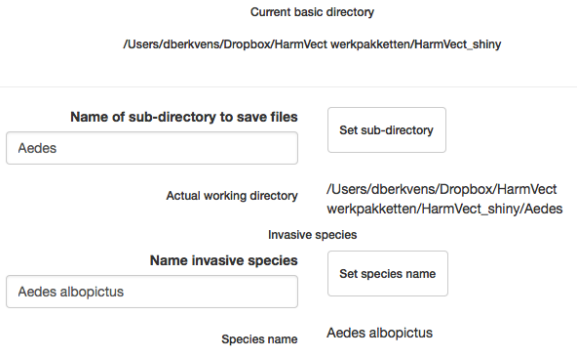


Figure 4.2: “General” view pane after data entry

4.2 Side–panel “Countries of origin”

Select the countries where the arthropod in question has been recorded or is suspected to occur, if required, from the various sub-panes representing the different continents (Figure 4.3). It is important to understand that nothing is being saved when selecting one or more countries. The list of selected countries is used when creating the trade, transfer and pathway characteristics files, as explained in section 4.7.

Use the `Clear all` button to set every checkbox to its default off state.

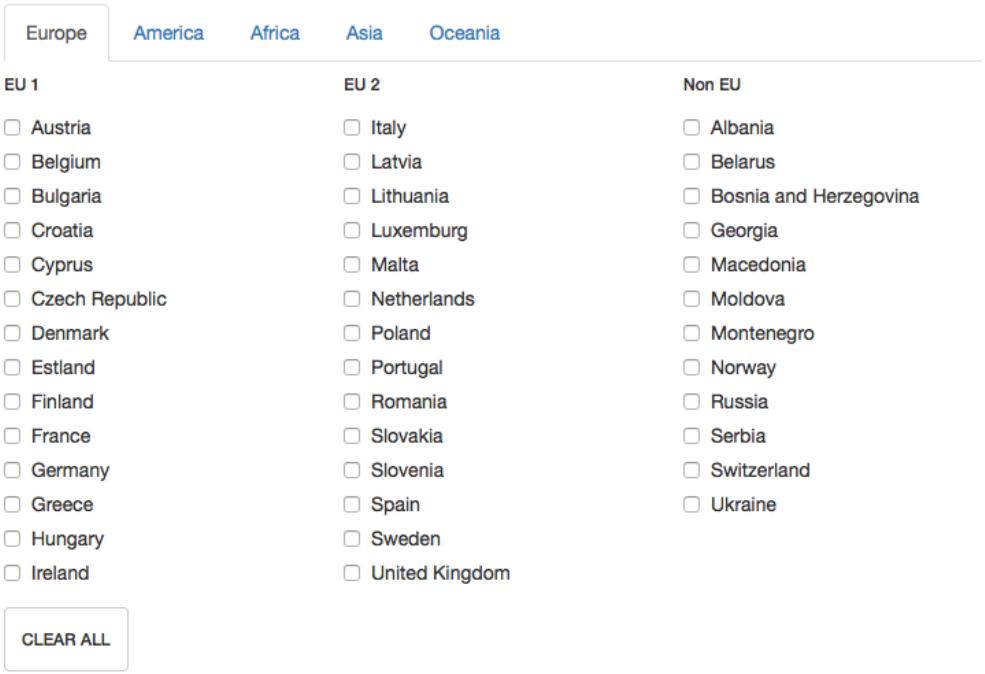


Figure 4.3: Select countries of origin

4.3 Side–panel “Matrix”

Select the matrix (matrices) which the arthropod in question can use as ‘host’[1] or associated commodity, if necessary from the various panes Figure 4.4. It is important to understand that nothing is being saved when selecting one or more matrices. The list of selected matrices is used when creating the trade, transfer and pathway characteristics files, as explained in section 4.7.

Use the `Clear all` button to set every checkbox to its default off state.

Use the **Other** sub-panel to indicate associated commodities, other than possible hosts. Examples are `Lucky bamboo` or `Used tyres` for *Aedes albopictus*.

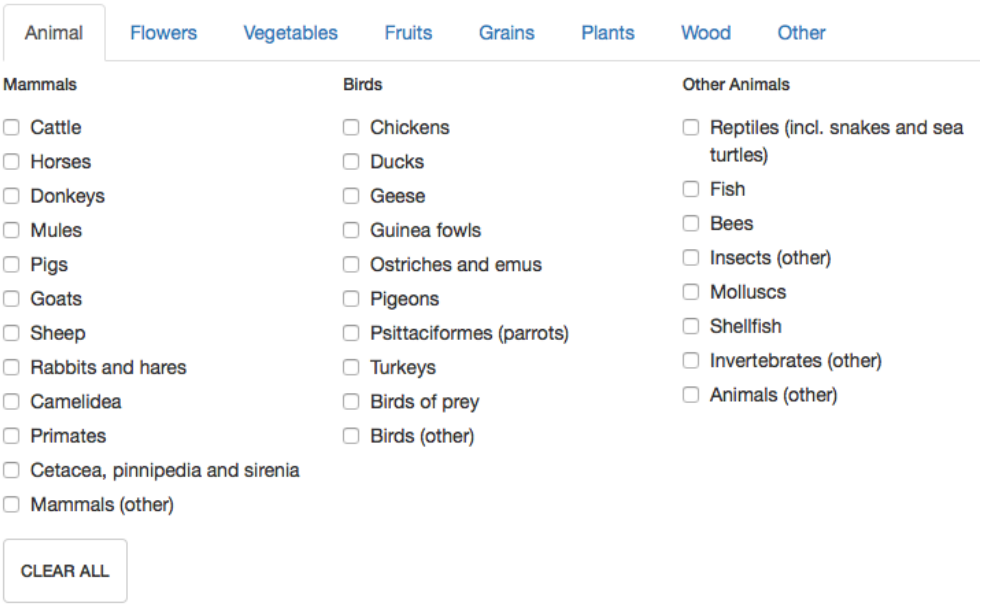


Figure 4.4: Select matrices used by invasive species

[1]Host is defined as any matrix in/on which the arthropod occurs naturally and in/on which it can survive and/or develop and/or reproduce.

4.4 Side–panel "Traits of invasive arthropod"

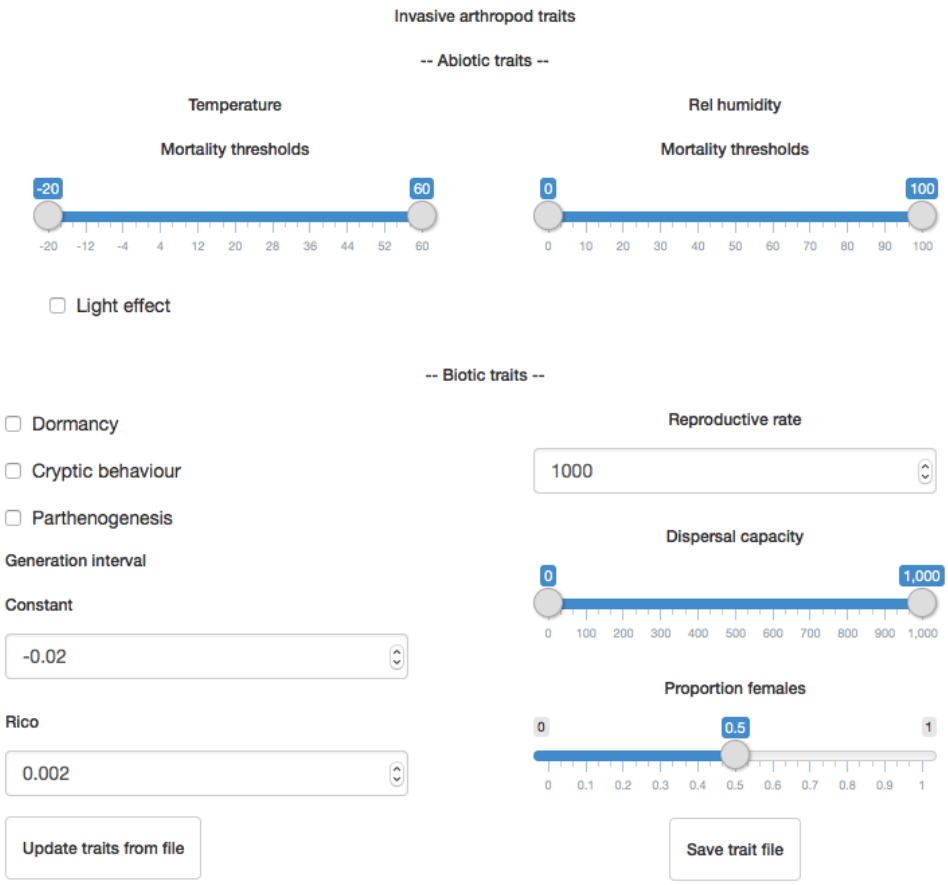


Figure 4.5: Survival and development traits of the invasive arthropod

1. **Either** create a new trait file:
   Enter the specific arthropod traits, using the sliders, checkboxes and/or input fields and click the button `Save trait file`. The file `gn_traits.txt`[2] will be saved automatically in the specific arthropod folder/directory. This file is used to compute the propagule pressure in section 4.8.

2. **Or** edit an existing trait file:
   Click the button `Update traits from file`. Adjust whatever parameters need updating and click the button `Save trait file`.

The checkboxes `Light effect`, `Dormancy`, `Cryptic behaviour` and `Parthenogenesis` are available and their status is saved in the `gn_traits.txt` file, but they are currently not used by the program.

[2] `gn` = genus name

4.5 Side–panel “Import”

Import of an exotic arthropod (because of its use in control or research programmes) requires indication of the point-of-entry (POE), point-of-appearance (POA)[3] and propagule pressure (PP) (Figure 4.6). The latter is done entering the number of organisms imported at the respective POE (ten entries available). The POE and POA (name of the respective communities) are entered by means of a pull-down interactive menu. Entering part of the community name (not necessarily the start of the name, capitalisation does not matter) narrows the choice of the community names offered. Once a community is selected, it no longer appears in the list (Figure 4.7).

Clicking **Save import data to file** creates the file `gn_import.txt`[4] in the species sub-directory.

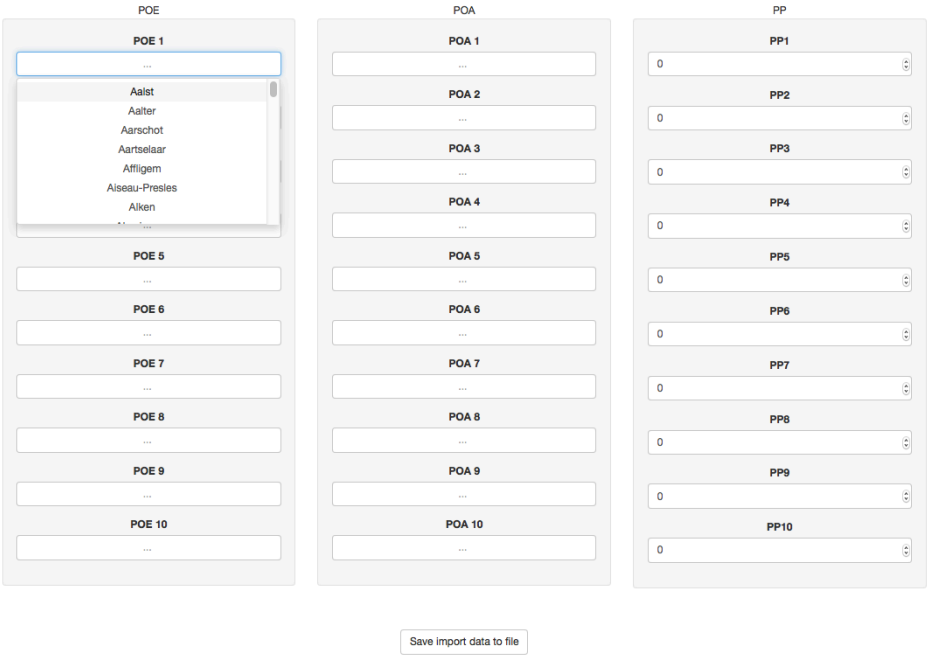
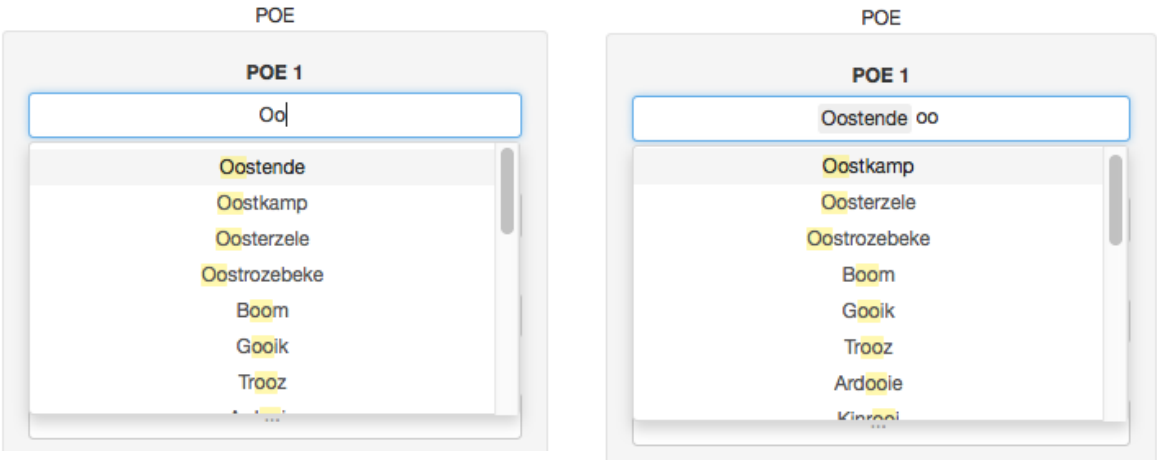


Figure 4.6: Import of the invasive arthropod

[3] Point-of-entry refers to the commune where the arthropod actually enters Belgium for the first time (*e.g.* the airport), whereas point-of-appearance refers to the destination (*e.g.* the research centre)

[4] `gn` = genus name



(a) Before selecting Oostende **(b)** After selecting Oostende

Figure 4.7: Selecting a community name

4.6 Side–panel "Natural spread"

This panel can be used to simulate points in neighbouring countries that pose a possible threat of introduction of an invasive arthropod by means of natural spread. The starting point of the natural spread is entered as a longitude and latitude (up to ten points can be entered, use decimal degree coordinates, *e.g.* the FOD entrance would be referred to as the pair {4.333437, 50.86355}). The propagule pressure at the point-of-origin is entered in the third field.

The distance from the point-of-origin to the centroid of the respective communities in Belgium is computed by means of the so-called **haversine** formula[5]:

$$d = 2 \cdot r \cdot sin^{-1}\left[\sqrt{sin^2\left(\frac{\varphi_2 - \varphi_1}{2}\right) + cos(\varphi_1) \cdot cos(\varphi_2) \cdot sin^2\left(\frac{\lambda_2 - \lambda_1}{2}\right)}\right]$$

with

$$\begin{aligned} d &= \text{great-circle distance between two points} \\ r &= \text{average radius} = 6371\text{km @ } 50^\circ\text{N} \\ \{\varphi_i, \lambda_i\} &= \text{latitude and longitude of point } i \text{ (in radians)} \end{aligned}$$

The propagule pressure released at the point-of-origin is divided equally over the communes whose distance from the point-of-origin is smaller than the maximum distance covered by the arthropod, as indicated in section 4.4.

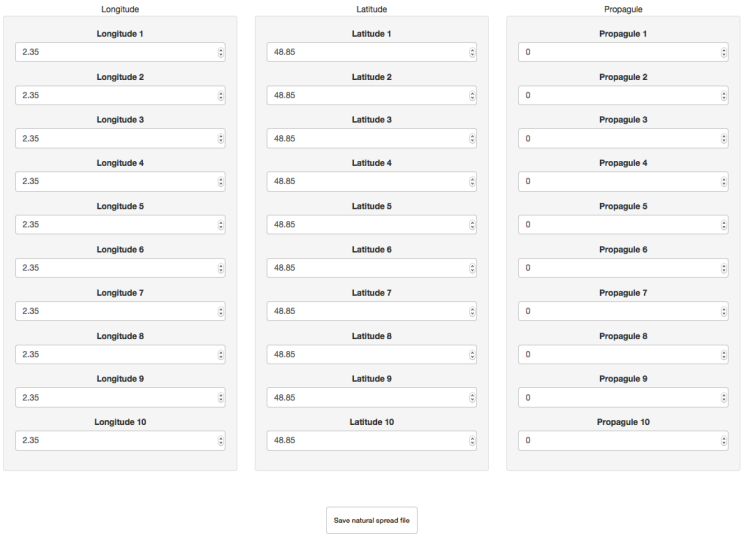


Figure 4.8: Natural spread of the invasive arthropod

Clicking **Save natural spread file** creates or updates the `gn_natural.csv`[6] file in the species sub-folder. If a visual presentation of the natural spread range is required,

[5] http://www.movable-type.co.uk/scripts/GIS-FAQ-5.1.html

[6] `gn` = genus name

clicking the button **Plot natural spread** generates this map.

> **Attention!**
> The computation of the natural spread file depends on the arthropod characteristics, saved in `gn_traits.txt`[7]. If this file is changed, make sure the natural spread file is generated and saved again.

Figure 4.10 shows the result of a (strictly hypothetical) example whereby 10,000 propagules are released at Maastricht airport and 5,000 propagules are released at Calais harbour (Figure 4.9 shows the corresponding input). The (hypothetical) invasive arthropod has a dispersal capacity of 56 km.[8]

Figure 4.9: Natural spread of the invasive arthropod: input hypothetical example

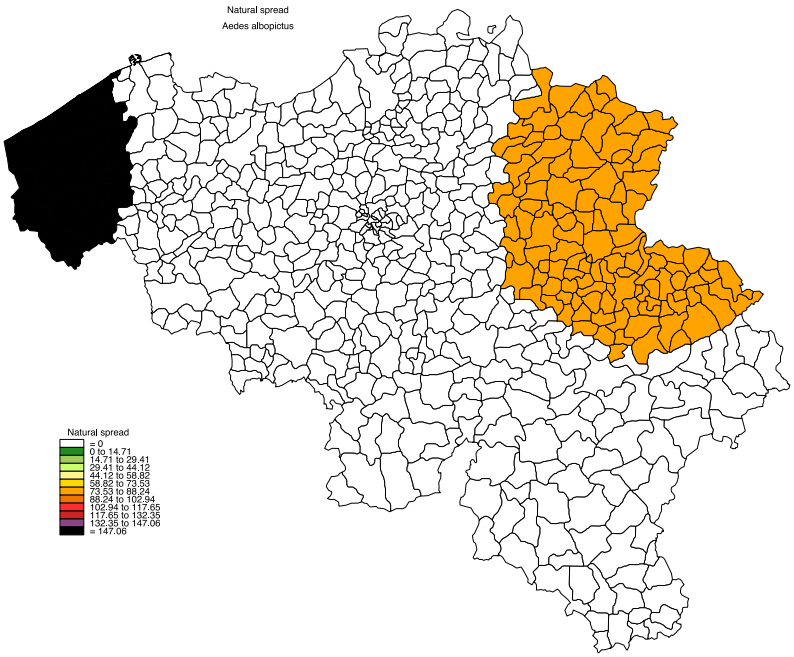


Figure 4.10: Hypothetical example: natural spread of the invasive arthropod

[7] `gn` = genus name
[8] See section 4.9 for details on management (*e.g.* saving) of maps

4.7 Side–panel “Create and edit files”

This tab-panel houses three identically organised sub-panels, one each for trade-related aspects, transfer-related aspects and pathway-characteristic aspects (Figure 4.11). Each sub-panel allows the user to either create a new trade/transfer/pathway file or edit an existing file and save the resulting file. The name of the file is generated automatically by the program from the information entered in section 4.1. The names are respectively `gn_trade.txt`, `gn_transfer.txt`, `gn_character.txt`[9]).

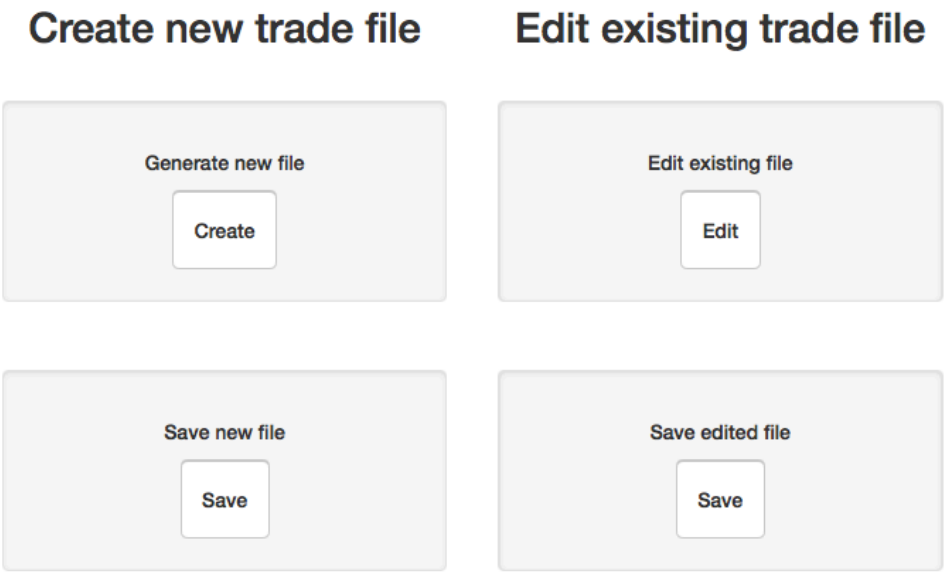


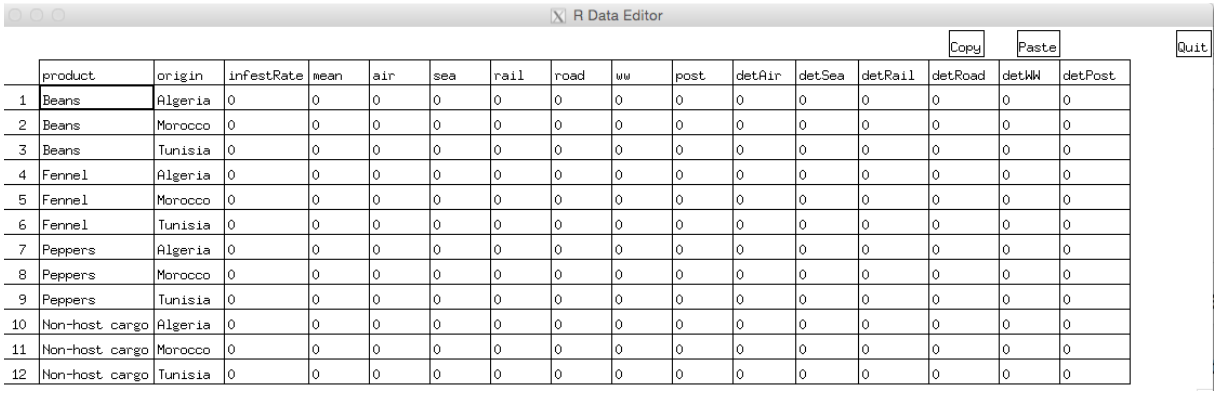
Figure 4.11: File management

1. **Create new file**

   (a) Click the button ’Create’ in the `Generate new file` well.
   The result of this action is the creation of a spreadsheet externally, respectively in XQuartz (Macintosh) and Data Editor (Windows), as RStudio does not support the `de()` command (data editing) internally. Starting up this external environment may take some time, so no need to repeatedly click the button. The external environment is minimally basic and editing a spreadsheet is not exactly user-friendly. The idea is simply to automatically create a spreadsheet with the correct column names and row entries (country/matrix combinations). Filling out and editing the spreadsheet is best done in Excel™. When editing is done in the external environment, click the `Quit` button to return to RStudio. The spreadsheet is returned to RStudio and can be saved from there (do note that on Macintosh, upon return from the external environment, the first click in RStudio is used to re-activate it and is not processed into any further action). Examples of the data editor respectively on Macintosh and under Windows are shown in Figures 4.12 and 4.13.

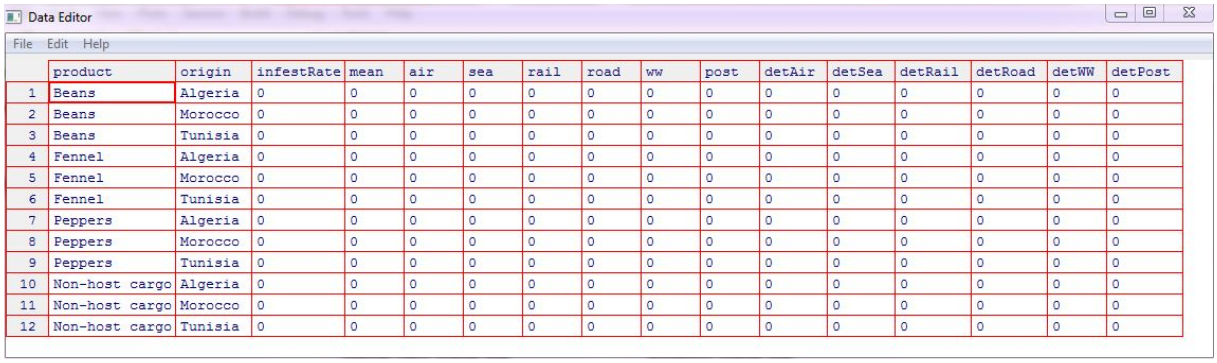
   (b) Save the new file by clicking the button **Save** in the `Save new file` well. The filename is generated automatically and the file is saved in the correct subfolder/directory.

[9] `gn` = genus name



	product	origin	infestRate	mean	air	sea	rail	road	ww	post	detAir	detSea	detRail	detRoad	detWW	detPost
1	Beans	Algeria	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	Beans	Morocco	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	Beans	Tunisia	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	Fennel	Algeria	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	Fennel	Morocco	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	Fennel	Tunisia	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	Peppers	Algeria	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	Peppers	Morocco	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	Peppers	Tunisia	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	Non-host cargo	Algeria	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	Non-host cargo	Morocco	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	Non-host cargo	Tunisia	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 4.12: Data editor Macintosh



	product	origin	infestRate	mean	air	sea	rail	road	ww	post	detAir	detSea	detRail	detRoad	detWW	detPost
1	Beans	Algeria	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	Beans	Morocco	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	Beans	Tunisia	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	Fennel	Algeria	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	Fennel	Morocco	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	Fennel	Tunisia	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	Peppers	Algeria	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	Peppers	Morocco	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	Peppers	Tunisia	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	Non-host cargo	Algeria	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	Non-host cargo	Morocco	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	Non-host cargo	Tunisia	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 4.13: Data editor Windows

2. **Edit existing file**

   (a) Open the file to be edited by clicking **Edit** in the `Edit existing file` well. This is only meant to be used for small changes, for which opening Excel™ is considered too cumbersome. The right file is opened automatically from the information entered in section 4.1.

   (b) Edit the selected spreadsheet. See remarks under item 1a.

   (c) Save the new file by clicking the button **Save** in the `Save edited file` well.

3. **Data to be entered**

   (a) **Trade**

      i. Infestation rate (**infestRate**) refers to the infestation rate of the commodity at the point of origin

      ii. **Mean** refers to the annual quantity/number/volume of the commodity brought into Belgium. It is the user's responsibility to ensure that infestation rates and 'Mean' have compatible units

      iii. The pathway distribution key (**air**, **sea**, **rail**, **road**, **ww**, **post**) denote the proportion of the total commodity volume/number entering Belgium through the respective pathways. It is the user's responsibility to ensure that the sum of the six proportions is one

iv. **det...** with **dots** ∈ {**air**, **sea**, **rail**, **road**, **ww**, **post**} refer to the detection rates for the invasive arthropod associated with the respective commodity upon entering Belgium through the specific pathway

(b) **Transfer**
Refer to item 3a

(c) **Pathway characteristics**

i. **..._mint** and **..._maxt** with **dots** ∈ {**air**, **sea**, **rail**, **road**, **ww**, **post**} refer to minimum and maximum temperatures at which the respective commodity is transported in the respective pathway

ii. **..._minrh** and **..._maxrh** refer to minimum and maximum relative humidity (refer to item 3(c)i for details)

iii. **..._lights** indicates whether transport occurs within a lighted environment (refer to item 3(c)i for details)

4.8 Side–panel "Compute propagule pressure"

This tab–panel calculates the total propagule pressure for the selected invasive arthropod, automatically using the correct species files using the information entered in section 4.1. The output is presented in four tables. The output files, used in the remaining side-panels are generated automatically and carry the names `gn_PP.txt`[10] and `PPforBorderKey.txt`.

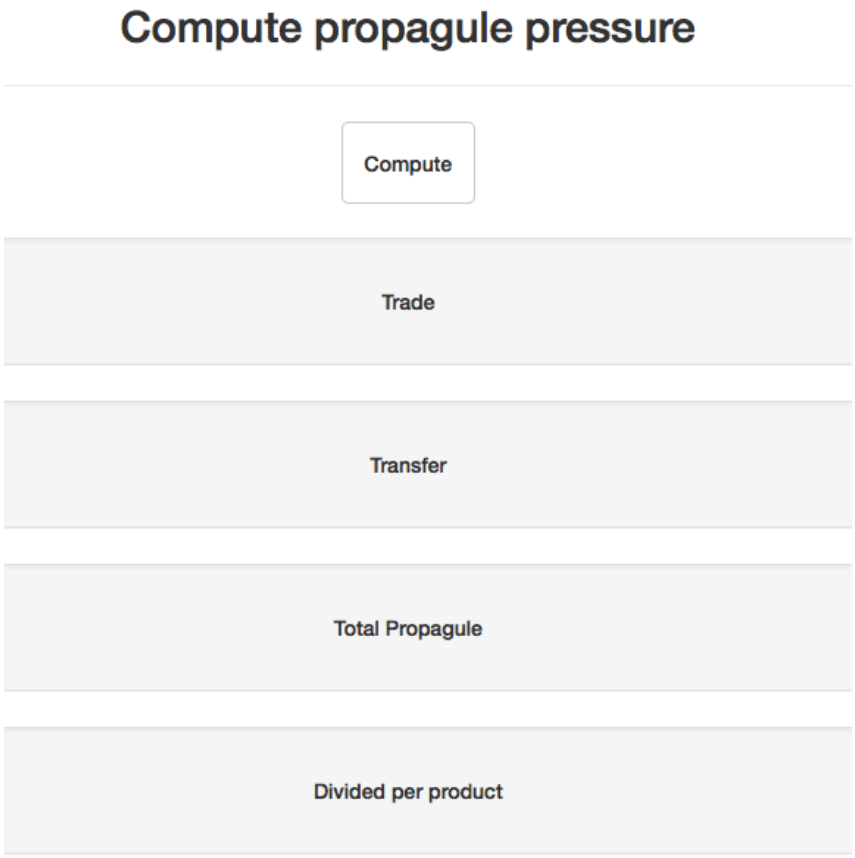


Figure 4.14: Compute the propagule pressure that enters Belgium

Click the **Compute** button and the four tables are generated.

1. Number of propagules at the country-of-origin (`Start`) and point-of-entry (`End`) through the various trade pathways

Trade

	Total	Air	Sea	Rail	Road	WW	Post
Start	97.06						
End	1502	4.764	1393	0.02322	103.6		0.007117

[10] `gn` = genus name

2. Number of propagules at the country-of-origin (`Start`) and point-of-entry (`End`) through the various transfer pathways

Transfer

	Total	Air	Sea	Rail	Road	WW	Post
Start	674.3						
End	1232	215.3	1.054	35.46	980		

3. Total number of propagules at the country-of-origin (`Start`) and point-of-entry (`End`) through the various pathways

Total Propagule

	Total	Air	Sea	Rail	Road	WW	Post
Start	771.3						
End	2734	220	1395	35.48	1084		0.007117

4. Number of propagules at point-of-entry in function of the ‘host’

Divided per product

	prod	air	sea	rail	road	ww	post
1	Cattle	0.00	0.00	0.00	0.01	0.00	0.00
2	Horses	0.00	0.00	0.00	0.01	0.00	0.00
3	Pigs	0.00	0.00	0.00	0.77	0.00	0.00
4	Goats	0.00	0.00	0.00	0.00	0.00	0.00
5	Sheep	0.00	0.00	0.00	0.00	0.00	0.00
6	Non-host cargo	0.00	1.04	0.02	0.12	0.00	0.01
7	Lucky Bamboo	0.00	362.83	0.00	0.00	0.00	0.00
8	Used Tires	4.76	1029.58	0.00	102.73	0.00	0.00
9	Tourism	215.26	1.05	35.46	980.03	0.00	0.00
10	Commuting	0.00	0.00	0.00	0.00	0.00	0.00
11	Military	0.00	0.00	0.00	0.00	0.00	0.00

4.9 Side–panel “Point-of-entry”

This tab-panel houses six identically organised sub-panels to generate point-of-entry data files for the different pathways. The procedure to create or edit the respective files is described in section 4.7. The individual files are used to generate the respective components of the point-of-entry map.

Data to be entered are a distribution key indicating for each commodity its proportion entering in the respective communes. It is the user’s responsibility that the sum per commodity equals one.

The `gn_land.txt`[11] is filled out automatically, but can be altered in Excel™.

The point-of-entry map itself is generated on the last sub-panel (Figure 4.15).

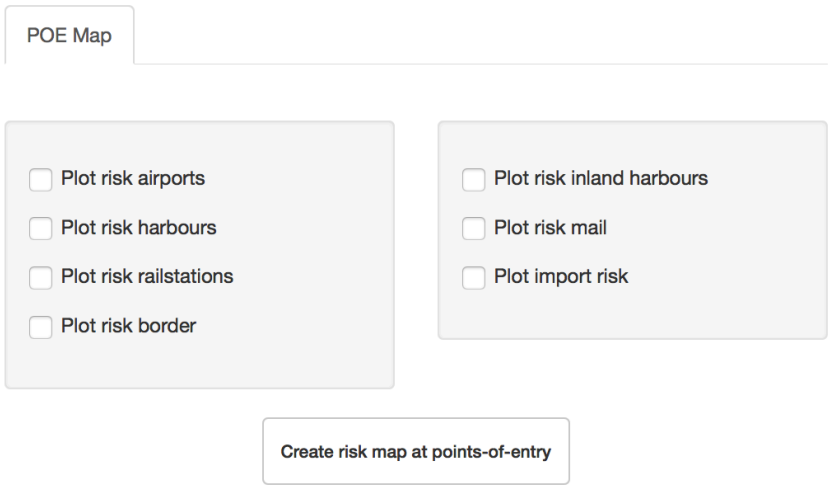
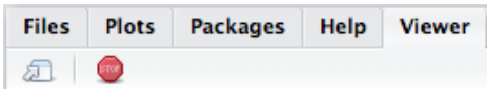


Figure 4.15: Point-of-entry risk map entry screen

1. Indicate the elements to be included in the risk map by selecting their respective check box
2. Click the button **Create risk map at points-of-entry** and go to the **Plots** tab. Clicking this button automatically generates the file `gn_poeMap.csv`[12]



Attention!

Although it is possible to remove the graphs in the **Plots** pane (by clicking), this feature is not available when the program is running. It can thus happen that **RStudio** runs out of memory and hangs if ‘too’ many graph windows (maps) have been created. It is therefore recommended to leave the program every now and then, clean up the graphs (maps) and restart the program.

[11] `gn` = genus name
[12] `gn` = genus name

3. Individual maps can be saved/exported under different formats (Figure 4.16). A bit of experimenting may be required, especially with ‘aspect-ratios’ when saving a map. (In a Macintosh environment at least,) the best results are obtained by saving the map as a `.svg` format (selecting `SVG` after clicking **Save as Image...**).This file can be converted into a `.jpg`, `.png` or `.pdf` format by freeware such as (*e.g.*) **Gapplin** or **Inkscape**. An example is shown in Figure 4.17.[13]

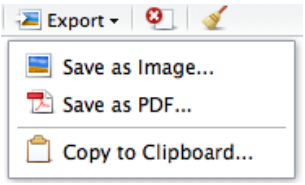


Figure 4.16: Different options to save/export map

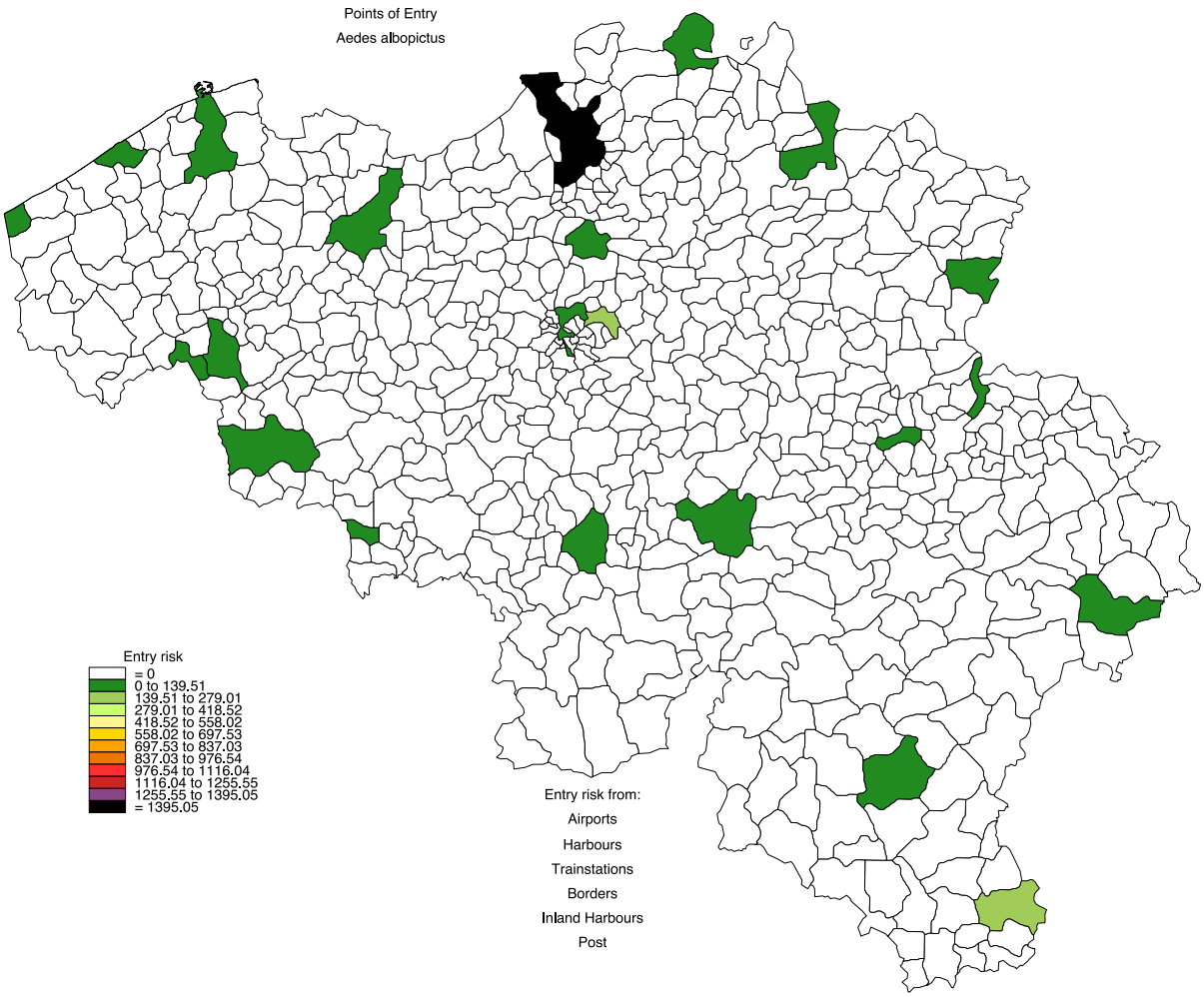


Figure 4.17: Point-of-entry risk map: *Aedes albopictus*

4. To go back to the input and output window click the **Viewer** tab.

[13]The maps shown are to be considered preliminary working documents, as they have not yet been validated.

4.10 Side–panel “Risk Map”

4.10.1 General

This tab-panel is subdivided in six sub-panels, that have to be addressed in the correct order from left-to-right to ensure changes to any of the files or parameters are reflected in the resulting maps.

4.10.2 Sub-panel “Distribution file”

The sub-panel “**Distribution file**” is used to create a text file holding the point-of-appearance distribution of the propagules. This sub-panel uses the same approach to create, save and edit its file as explained under section 4.7. Communes presenting a specific risk for the invasive arthropod in question are selected from the ‘intelligent’ scroll-down menu at the top of the pane (below **Choose Commune**). The file `gn_POA.txt`[14] is added to the genus sub-directory.

This file consists of two parts. The first part is fixed and consists of six lines (`air`, `sea`, `rail`, `road`, `ww` and `post`). These lines are used to enter the proportion of the propagule pressure that escapes at the point-of-entry.

The second part of the file consists of the seventh line (`pop`) and the selected communes (automatically added below `pop`). `Pop` is used to enter the proportion of the propagule pressure, which did not escape at the point-of-entry, that escapes as a result of something done by the general public, *i.e.* is distributed according to the population density. The selected communes may be used to further distribute the remaining proportion of the propagule pressure over these communes. It is the users responsibility that the sum of line 7 and the selected communes for each commodity is one.

An example is shown in Figure 4.18. In this (hypothetical) example, 50% of the propagules brought into Belgium by animal transport (cattle, horses, ..., sheep) escape at the point of entry, when brought in by air, sea, rail, inland harbour and post because of transshipment, whereas only 10% escape when brought in by means of road transport (no transhipment at border post). The propagules that did not escape upon entry all appear eventually by some action of the general public, with the exception of those brought in hiding in ‘lucky bamboo’ transports, which emerge during storage at the importing enterprise. Rethreading of used tyres poses a specific risk in communes hosting tyre recycling enterprises and the risk is proportional to the volume of tyres handled. Returning tourists have a smaller chance of having to open their luggage when entering Belgium by road.

[14] `gn` = genus name

	A	B	C	D	E	F	G	H	I	J	K	L
1	Distribute	Cattle	Horses	Pigs	Goats	Sheep	Non-host cargo	Lucky Bamboo	Used Tires	Tourism	Commuting	Military
2	air	0.5	0.5	0.5	0.5	0.5	0.5	0.005	0	0.3	0	0
3	sea	0.5	0.5	0.5	0.5	0.5	0.5	0.005	0	0.3	0	0
4	rail	0.5	0.5	0.5	0.5	0.5	0.5	0.005	0	0.3	0	0
5	road	0.1	0.1	0.1	0.1	0.1	0.1	0.005	0	0.001	0	0
6	ww	0.5	0.5	0.5	0.5	0.5	0.5	0.005	0	0.3	0	0
7	post	0.5	0.5	0.5	0.5	0.5	0.5	0.005	0	0.3	0	0
8	pop	1	1	1	1	1	1	0.1	0	1	0	0
9	Aalter	0	0	0	0	0	0	0	0.014	0	0	0
10	Beveren	0	0	0	0	0	0	0	0.1045	0	0	0
11	Brasschaat	0	0	0	0	0	0	0	0.0064	0	0	0
12	Dilbeek	0	0	0	0	0	0	0	0.0246	0	0	0
13	Evergem	0	0	0	0	0	0	0	0.1546	0	0	0
14	Frameries	0	0	0	0	0	0	0	0.6883	0	0	0
15	Hamme	0	0	0	0	0	0	0	0.0009	0	0	0
16	Kortrijk	0	0	0	0	0	0	0	0.0008	0	0	0
17	La Louviere	0	0	0	0	0	0	0	0.0015	0	0	0
18	Maasmechelen	0	0	0	0	0	0	0	0.0044	0	0	0
19	Lochristi	0	0	0	0	0	0	0.9	0	0	0	0

Figure 4.18: Example of point-of-appearance distribution file

4.10.3 Sub-panel “Migration”

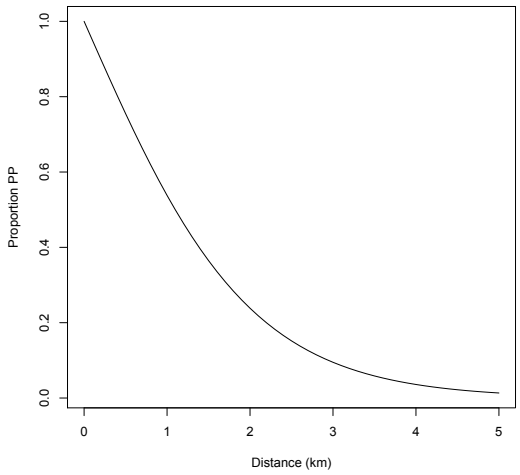
The “**Migration**” sub-panel allows the user to select the parameters of the function that describes the spatial dispersal of the arthropod in function of distance from the release point. The function is based on the generalised logistic function[15] (adapted to yield meaningful results by putting **A**=1 and **K**=0) and thus depends on three parameters (**B**, **Q** and **v**), that strictly speaking have no biological meaning as such. The **Maximum distance** entry field sets the maximum distance coverable by the arthropod. The function is:

$$p(x) = 1 - \frac{1}{\sqrt[v]{1 + Q \cdot e^{-B \cdot x}}}$$

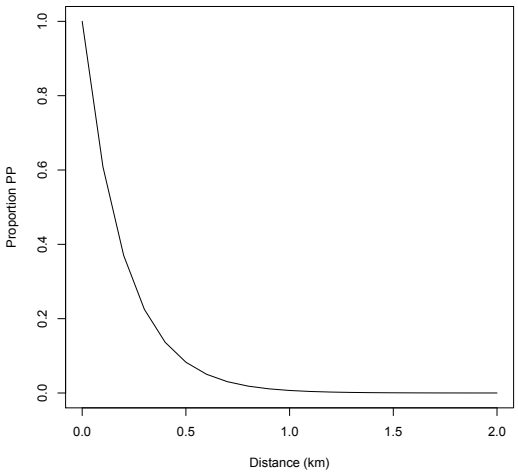
with x the Euclidean distance between the centroids of the release-point commune and the end-point commune.

The resulting function can be viewed by clicking the button `Test function parameters`. Figure 4.19 shows four examples of possible functions.

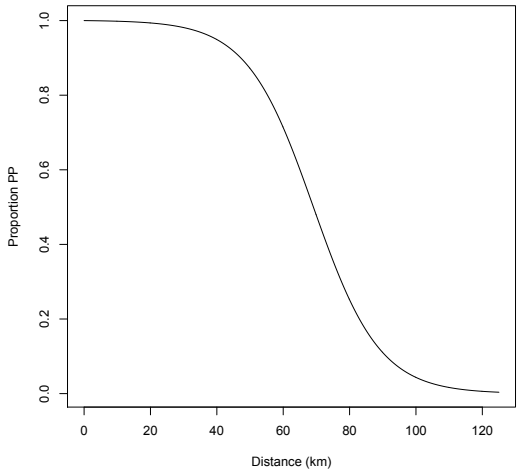
[15] https://en.wikipedia.org/wiki/Generalised_logistic_function



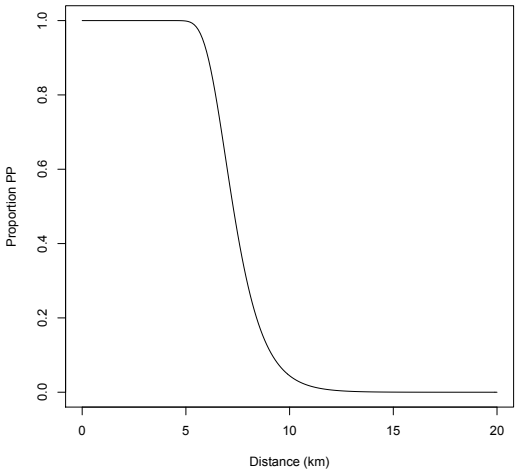
(a) **Q**=1; **B**=1; **v**=1; maxDist=5



(b) **Q**=0.01; **B**=5; **v**=1; maxDist=2



(c) **Q**=1000; **B**=0.1; **v**=1; maxDist=125



(d) **Q**=1; **B**=1; **v**=0.001; maxDist=20

Figure 4.19: Examples of migration functions

4.10.4 Sub-panel “POA Map”

The third sub-panel is where the points-of-appearance risk map is produced. The necessary files are read in automatically.

Selecting the checkbox **Include migration** distributes the propagule pressure around the point-of-appearance using the distribution function created in the previous sub-panel (subsection 4.10.3). Taking into account possible import (section 4.5) is done by checking the checkbox **Include import**. If there is natural spread (section 4.6), this is mapped by selecting the checkbox **Include natural spread**.

The final two checkboxes pertain to escapees from road transport, respectively when stationary in a lay-by (**Include highway lay-bys**) and when moving along a highway (**Include highway traffic**). The quantity of propagule-pressure potentially released in

the two conditions are calculated using the values of the four input fields.

The standard list of lay-bys is read in (found in the file `parkings.txt`): apart from the communes holding a lay-by, the total number of lay-bys is recorded (n_{lb}). The average time spent at a lay-by (`Average parking time at lay-by (min)`, t_{lb}) is used to scale the risk. The total propagule-pressure entering Belgium (pp_{tot}) is multiplied by the value entered in the field `Ratio foreign through traffic` (r_{ft}): *e.g.* a value of 2 means that the volume of throughput through Belgium (in terms of propagule-pressure) is twice as high as the volume actually entering and remaining in the country. The field `Escape rate propagules at lay-bys` records the number of propagules escaping per minute (e_{st}) from the stationary vehicle. The last field (`Ratio through traffic/lay-by`, r_{tl}) represents the ratio between the escape rate from moving vehicles (number/km) to the escape rate from stationary vehicles (number/min). For moving traffic itself, the total extra propagule pressure is divided over the communes with highways (n_{hw}) whereby the length of highways on each commune's territory (l_{hw_i}) is used as a weighting factor [16].

The extra risks (numbers of propagules) are added to risk-of-appearance for the communes involved. Thus, the following two formulas are currently used to calculate the additional risks arising from moving and stationary through-traffic for individual communes (i):

$$\text{lay-bys: } \text{risk}_{lay-by_i} = \frac{t_{lb} \times pp_{tot} \times r_{ft} \times e_{st}}{n_{lb}}$$

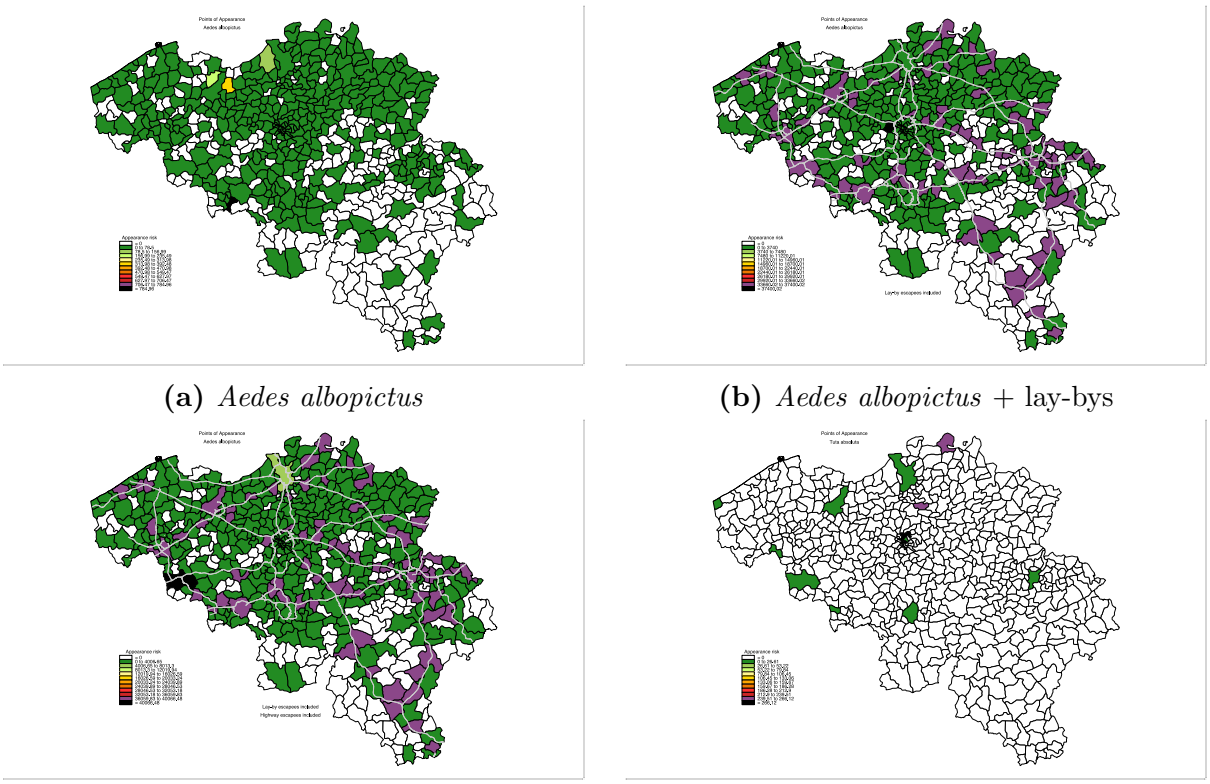
$$\text{highway: } \text{risk}_{highway} = \frac{pp_{tot} \times r_{ft} \times e_{st} \times r_{tl}}{n_{hw}} \times \frac{l_{hw_i}}{8}$$

Press the **Create risk map at points-of-appearance** to create the risk map. See remarks on plots in section 4.9. Examples are shown in Figure 4.20[17]. The file `gn_poaMap.csv`[18] is added to the species sub-folder.

[16] The number eight in the formula is there because at present the resolution used is roughly eight pixels to the kilometre.

[17] The maps shown are to be considered preliminary working documents, as they have not yet been validated.

[18] `gn` = genus name



(a) *Aedes albopictus*

(b) *Aedes albopictus* + lay-bys

(c) *Aedes albopictus* + lay-bys + highways

(d) *Tuta absoluta* at introduction in Spain

Figure 4.20: Examples of point-of-appearance maps.
submaps (b) and (c): $t_{lb} = 30$; $r_{ft} = 10$; $e_{st} = 10$; $r_{tl} = 0.5$

4.10.5 Sub-panel “Host weighting file”

The sub-panel “**Host weighting file**” is used to create a text file holding the weighting factors for the relative importance of the different hosts. This sub-panel uses the same approach to create, save and edit its file as explained under section 4.7. An example of a host-weighting file (for *Tuta absoluta*) is shown in Figure 4.21. The file `gn_HW.txt`[19] is added to the species sub-directory.

	A	B
1	Commodity	Weighting
2	Beans	0.001
3	Eggplants	0.5
4	Peppers	0.001
5	Potatoes (ware)	0.001
6	Tomatoes	1
7	Gooseberries	0.5
8	Melons	0.001
9	Live plants for open ground	0.001
10	Non-host cargo	0
11	Tourism	0
12	Commuting	0
13	Military	0

Figure 4.21: Example of host weighting file

[19] `gn` = genus name

4.10.6 Sub-panel “Establishment maps”

Three ‘maps’, possibly having an influence on the arthropod’s establishment at the point-of-appearance, are generated in the sub-panel **Establishment maps**. The actual maps are produced, but, more importantly, the modifying coefficients are recorded and saved in the `gn_poaMap.csv` file[20].

Attention!
If anything is changed in front of this sub-panel, it is important to regenerate the respective maps as `gn_poaMap.csv` will contain zeroes in the three columns corresponding to the establishment maps.

The first map to be generated is the **climate suitability map**. At present, three options are offered to compute this parameter (arthropod temperature tolerance limits are obtained from the corresponding `gn_traits.txt` file[21]):

1. **Min_min & max_max**: this is a yes/no (1/0) coding, with zero signifying unsuitable (*i.e.* OK for the risk manager) and one signifying totally suitable (*i.e.* not OK for the risk manager). A commune is considered suitable if its lowest annual minimum temperature is above the lower temperature limit of the arthropod and its highest annual maximum temperature is below the upper temperature limit of the arthropod. A commune is considered unsuitable in all other cases.

2. **Cumulative**: this is a continuous value coding (0–1), with zero signifying unsuitable (*i.e.* OK for the risk manager) and one signifying totally suitable (*i.e.* not OK for the risk manager). Per locality, the index is computed as the sum of month-degrees below the lower tolerance temperature limit and month-degrees above the upper temperature tolerance limit. The index is then standardised by dividing it by its maximum value across all communes and the result is subtracted from one:

$$S_j = \sum_{i=1}^{12} (t_i < t_m) \times (t_m - t_i) + (t_i > t_M) \times (t_i - t_M)$$

$$I_j = 1 - \frac{S_j}{max(S[\,])}$$

with:

$$\begin{aligned} j &= \text{commune } j,\ j \in \{1 \cdots 589\} \\ t_i &= \text{average minimum temperature per month}, i \in \{1 \cdots 12\} \\ t_m &= \text{lower limit of arthropod temperature tolerance range} \\ t_M &= \text{upper limit of arthropod temperature tolerance range} \end{aligned}$$

3. **Weighted**: this is a continuous value coding (0–1), with zero signifying unsuitable (*i.e.* OK for the risk manager) and one signifying totally suitable (*i.e.* not OK for the risk manager). Per commune an index is calculated by coding each month

[20] `gn` = genus name
[21] `gn` = genus name

as two (both monthly minimum and maximum temperatures lie within the arthropod's tolerance range), one (either the monthly minimum or the monthly maximum temperature lie outside the arthropod's tolerance range) or zero (both monthly minimum and maximum temperatures lie outside the arthropod's tolerance range). The sum is standardised by dividing by 24:

$$I_j = \frac{\sum_{i=1}^{12}(t_i \geqslant t_m) + \sum_{i=1}^{12}(t_i \leqslant t_M)}{24}$$

with:

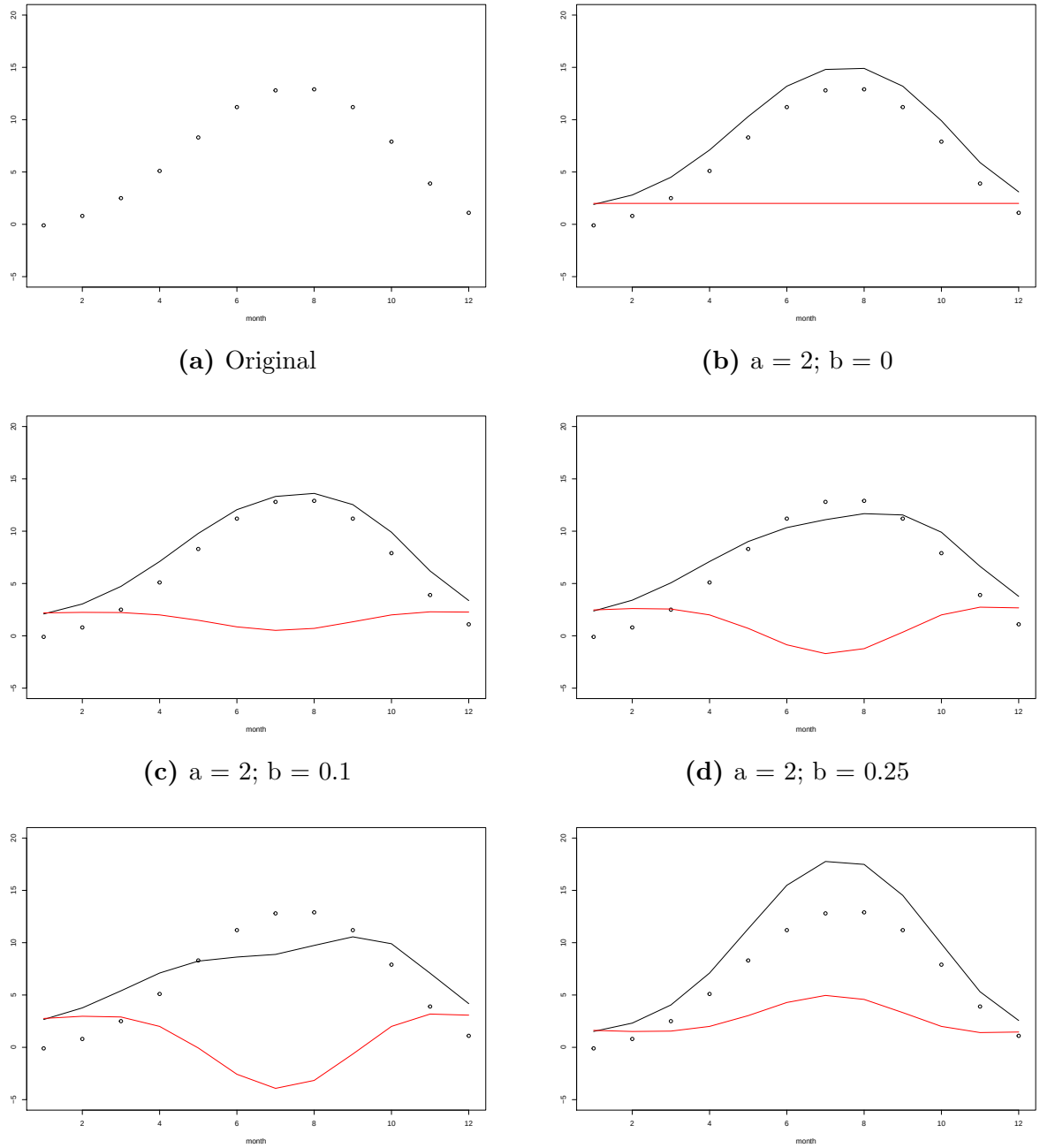
$$\begin{aligned} j &= \text{commune } j,\ j \in \{1 \cdots 589\} \\ t_i &= \text{average minimum temperature per month}, i \in \{1 \cdots 12\} \\ t_m &= \text{lower limit of arthropod temperature tolerance range} \\ t_M &= \text{upper limit of arthropod temperature tolerance range} \end{aligned}$$

The temperature per commune consists of longterm monthly average minimum temperatures (file `climate.csv` columns 3 to 14) and longterm monthly average maximum temperatures (file `climate.csv` columns 15 to 26). These temperatures can be adjusted for climate-change effects using the entry fields **Average change in temperature** and **Annual modulation**. The following formula is used (the month shift from 1...12 to 3...14 ensures that the extrema fall in January and July). Examples are shown in Figure 4.22:

$${}^{\circ}t_{mod_i} = ({}^{\circ}t_i + a) \times \left[1 + b \times sin\left(m_i \times \frac{\pi}{6}\right)\right]$$

with:

$$\begin{aligned} {}^{\circ}t_i &= \text{long-term average temperature of month } i \\ a &= \text{average change in temperature} \\ b &= \text{annual modulation} \\ m_i &= \text{month } i;\ \ i \in \{3 \ldots 14\}\ \ (\text{Jan ... Dec}) \end{aligned}$$



(a) Original

(b) a = 2; b = 0

(c) a = 2; b = 0.1

(d) a = 2; b = 0.25

(e) a = 2; b = 0.4

(f) a = 2; b = -0.2

Figure 4.22: Examples of temperature changes.
dots = original °t; black line = changed °t; red line = difference

The second establishment map that can be produced is the **Host availability map**. The map shows the availability of non-human hosts (using `gn_HW.txt`[22]) augmented by the presence of human hosts weighted by the value selected by the slider.

The last map deals with indoor (sheltered) environments. It first generates the general availability/suitability of human habitation (weighted by the value selected on the slider) and then adds specific communes selected in **Choose commune** dropdown menu,

[22] `gn` = genus name

dealing with the presence of specific environments (*e.g.* greenhouses, warehouses, ...). The list of selected communes is automatically saved to disk when the map is produced (`indoorCommune.txt`). This list can be read into the drop-down menu by clicking the button **Update communes from saved text file**.

4.10.7 Sub-panel “Risk Map”

This sub-panel gathers all the information, settings and indices and prints the overall arthropod introduction and (initial) establishment risk map. Sliders allow the user to weight different aspects (dimensions) of the risk:

- Importance of the actual appearance
- Importance of outdoor conditions (climate suitability)
- Importance of host availability
- Importance of indoor/sheltered environments

Press the **Generate overall risk map** to create this map. See remarks on plots in section 4.9. An example is shown in Figure 4.23[23].

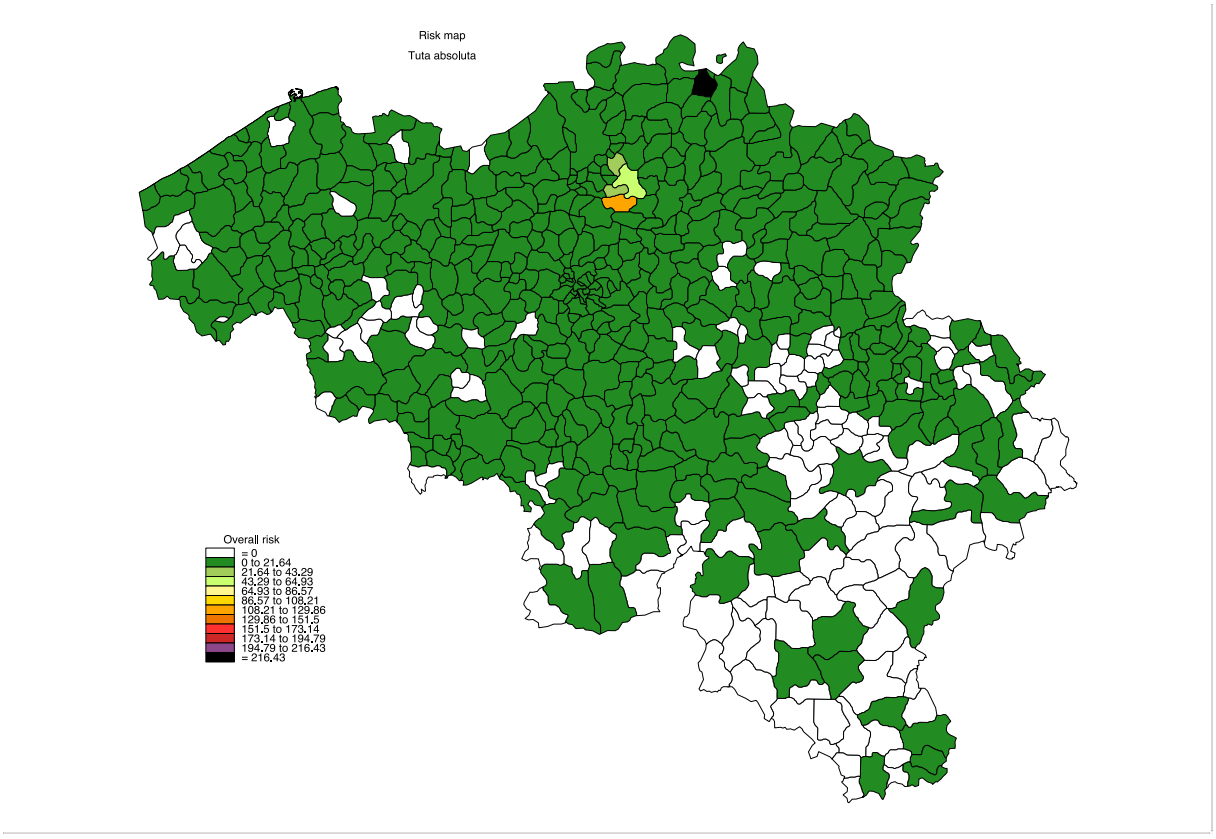


Figure 4.23: Example of an overall risk map

[23]The maps shown are to be considered preliminary working documents, as they have not yet been validated.

4.11 Side–panel “Report”

Clicking the button **Create Report** automatically generates a `gn_report.html`[24] file and saves it into the appropriate species subfolder/sub-directory. The only option is to indicate whether or not the highways are overlaid on the points-of-appearance map.

Generating the report makes use of the file `reportParams.txt`, which is created or updated automatically when the button **Create report** is clicked. The necessary information is collected from the “General” side-panel.

The elements are:

1. Points-of-entry
2. Points-of-appearance
3. Climate suitability
4. Host availability
5. Sheltered environment availability
6. Overall risk map

The file can be viewed with the aid of any standard browser.

[24] `gn` = genus name

4.12 List of R files used

- **Overall program**:
  `ui.R`, `server.R`, `initialParameterValues.R`
- **Side-panel "General"**:
  `uiGeneral.R`, `general.R`
- **Side-panel "Countries of origin"**:
  `uiCountries.R`, `clearCountriesMatrices.R`
- **Side-Panel "Matrix"**:
  `uiMatrix.R`, `clearCountriesMatrices.R`
- **Side-panel "Traits of invasive arthropod"**:
  `uiTraits.R`, `saveTraitFile.R`
- **Side-panel "Import"**:
  `uiImport.R`, `import.R`
- **Side-panel "Natural spread"**:
  `uiNatural.R`, `natural.R`
- **Side-panel "Create and edit files"**:
  `uiCreateEditFile.R`, `newEditTradeFile.R`, `newEditTransferFile.R`, `newEditPathCharFile.R`
- **Side-panel "Compute propagule pressure"**:
  `uiComputePP.R`, `computePP.R`
- **Side-panel "Point-of-entry"**:
  `uiPoe.R`, `POE.R`, `poe_airport.R`, `poe_land.R`, `poe_post.R`, `poe_rail.R`, `poe_sea.R`, `poe_WW.R`, `poeMap.R`
- **Side-panel "Risk map"**:
  `uiRiMa.R`, `poaMap.R`, `climate.R`, `riskMap.R`
- **Side-panel "Report"**:
  `uiReport.R`, `report.R`, `knitrmaps.Rmd`