Introducing *RangeShifter* a new tool for Landscape Ecology

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Diversity and Distributions, (Diversity Distrib.) (2010) 16, 321–330

BIODIVERSITY VIEWPOINT

Forum

Moving beyond static species distribution models in support of conservation biogeography

Ecography 33: 621–626, 2010
doi: 10.1111/j.1600-0587.2009.06023.x

Subject Editor: Jane Elith. Accepted 19 October 2009

Beyond bioclimatic envelopes: dynamic species' range and abundance modelling in the context of climatic change

Brian Huntley, Phoebe Barnard, Res Altwegg, Lynda Chambers, Bernard W. T. Coetzee, Lesley Gibson, Philip A. R. Hockey, David G. Hole, Guy F. Midgley, Les G. Underhill and Stephen G. Willis

call for a next generation of

"FULLY INTEGRATED" DYNAMIC MODELS

combine climatic suitability, habitat suitability/dynamics, population dynamics and dispersal *(Huntley et al. 2010)*

mechanistic representation of **MOVEMENT BEHAVIOUR**

(e.g. movement ecology framework, Nathan et al. 2008)

- Individual-based, spatially explicit, stochastic model

Methods in Ecology and Evolution

British Ecological Society

Methods in Ecology and Evolution 2014, 5, 388–396 doi: 10.1111/2041-210X.12162

APPLICATION

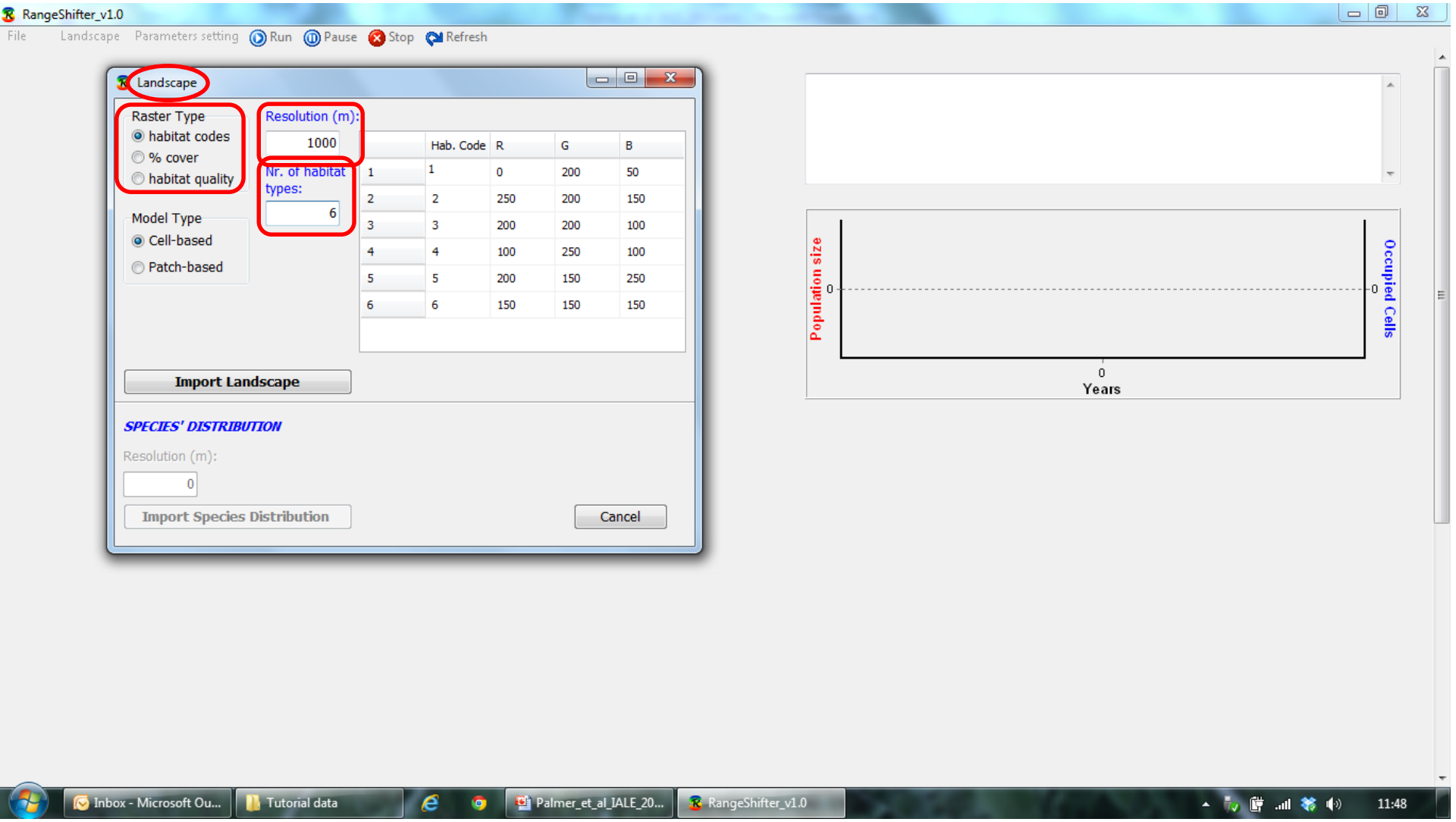
RangeShifter: a platform for modelling spatial eco-evolutionary dynamics and species' responses to environmental changes

Greta Bocedi[1]*, Stephen C.F. Palmer[1], Guy Pe'er[2], Risto K. Heikkinen[3], Yiannis G. Matsinos[4], Kevin Watts[5] and Justin M.J. Travis[1]

(2) assisting realization of integrated & dynamic conservation strategies

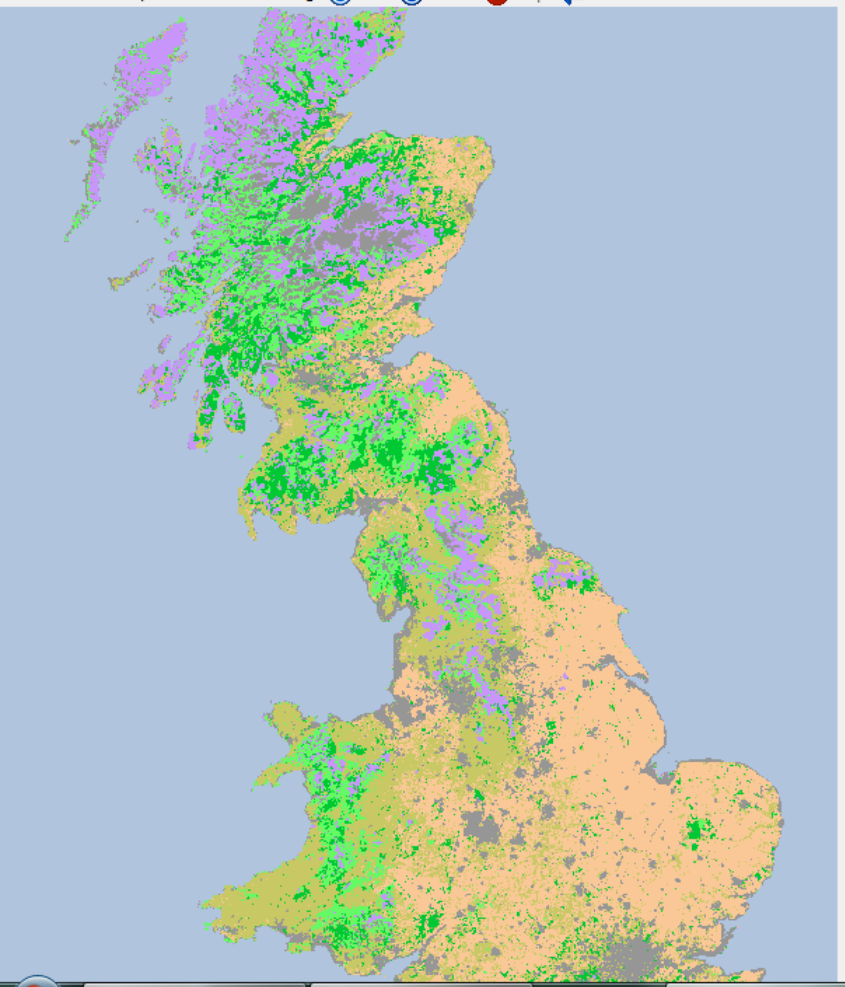
- Modelling platform for developing new theory on species' eco-evolutionary responses to environmental changes

Example 1: species range expansion

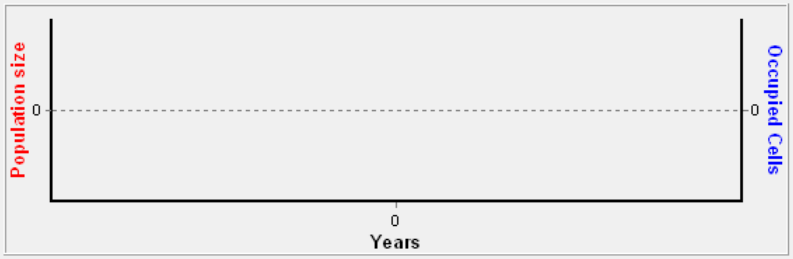


RangeShifter_v1.0

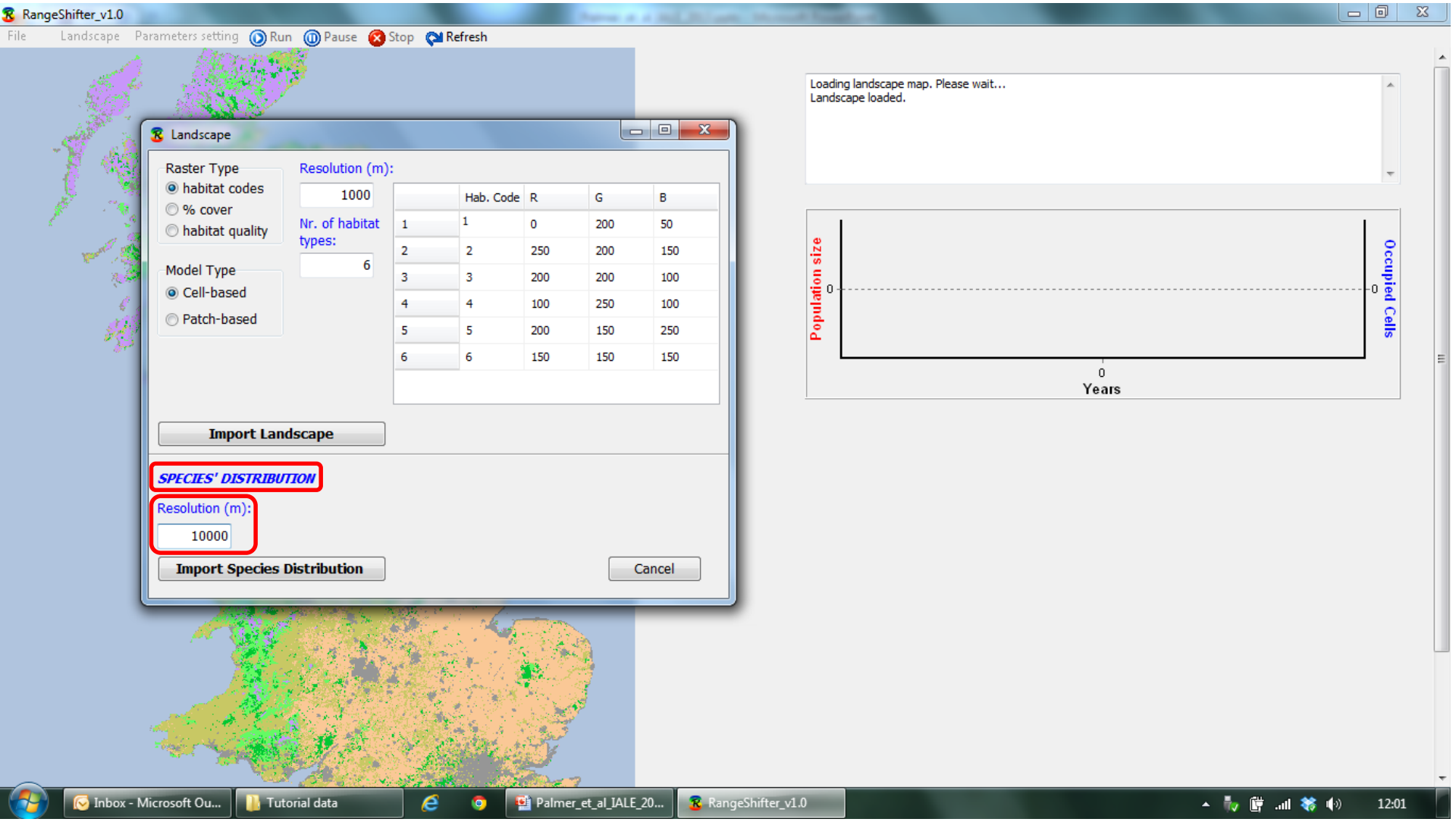
File Landscape Parameters setting Run Pause Stop Refresh

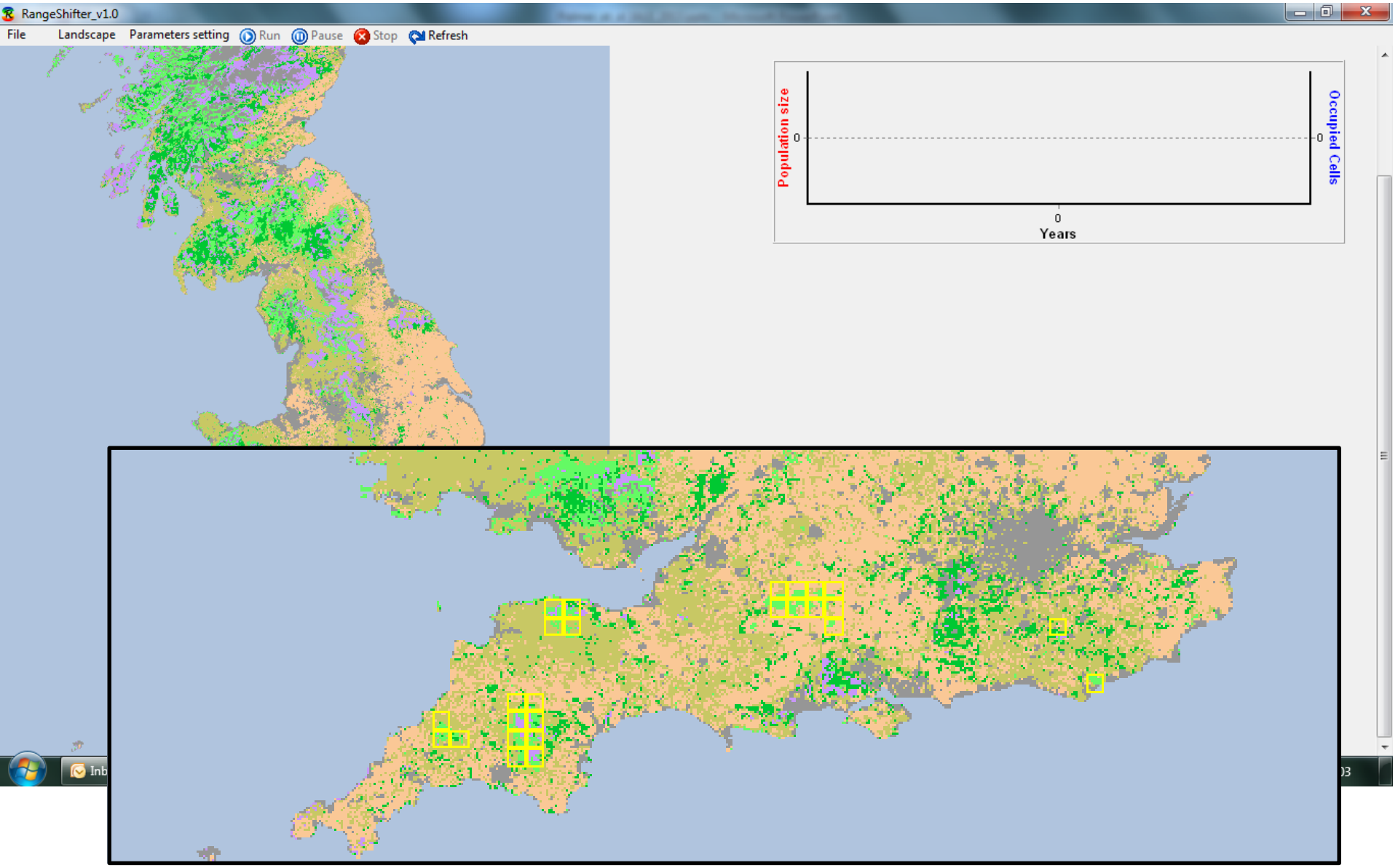


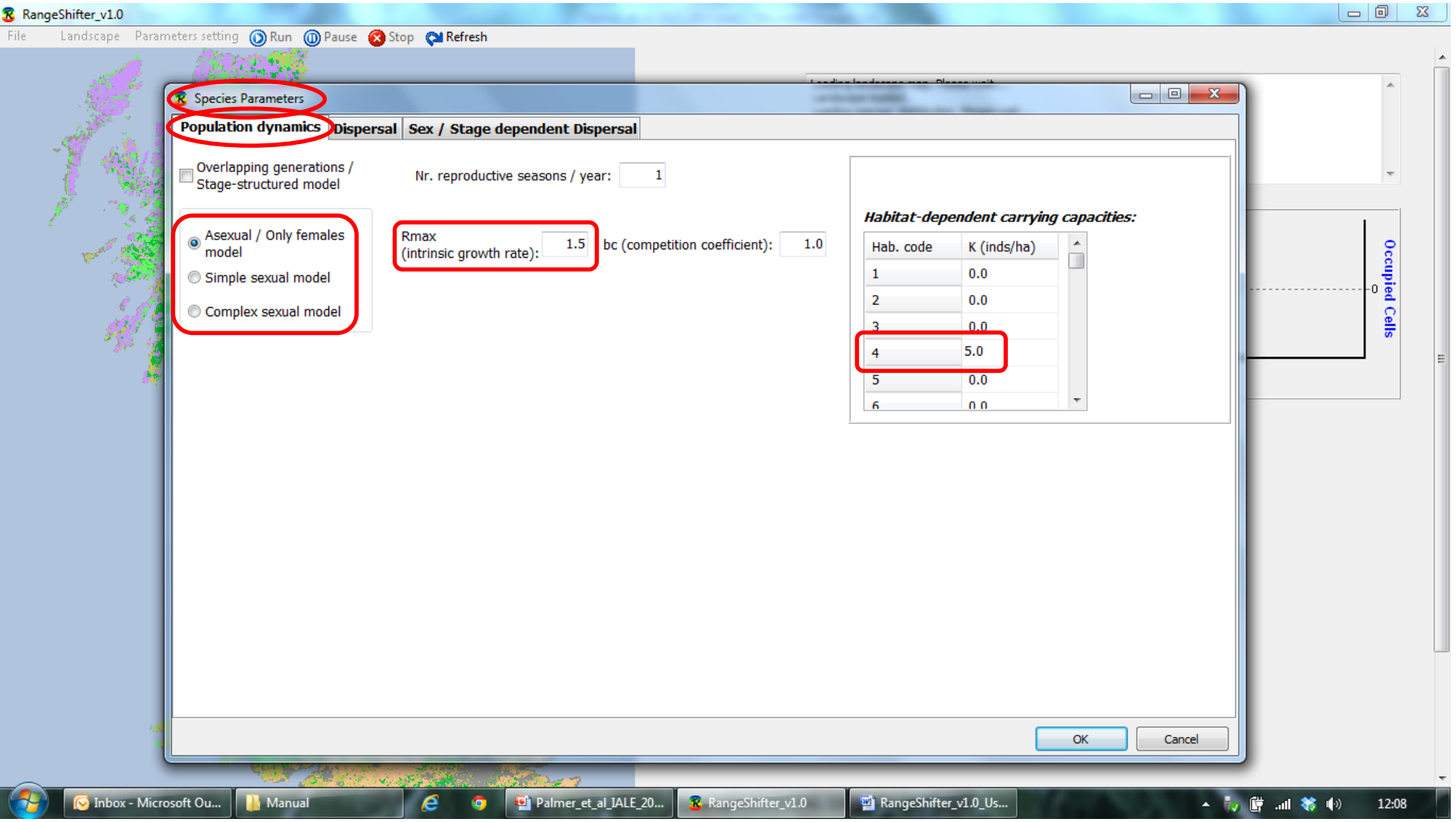
Loading landscape map. Please wait...
Landscape loaded.

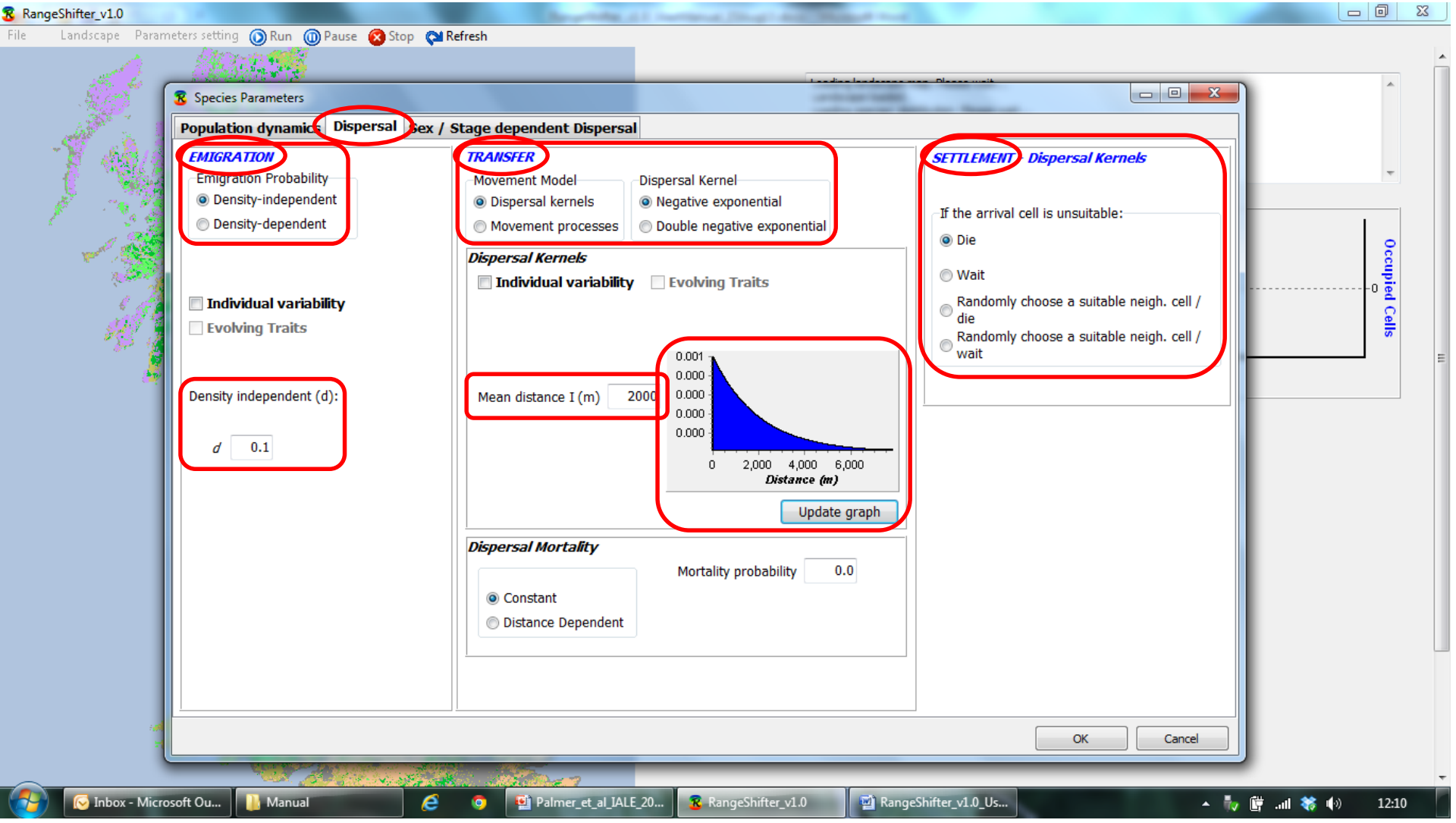


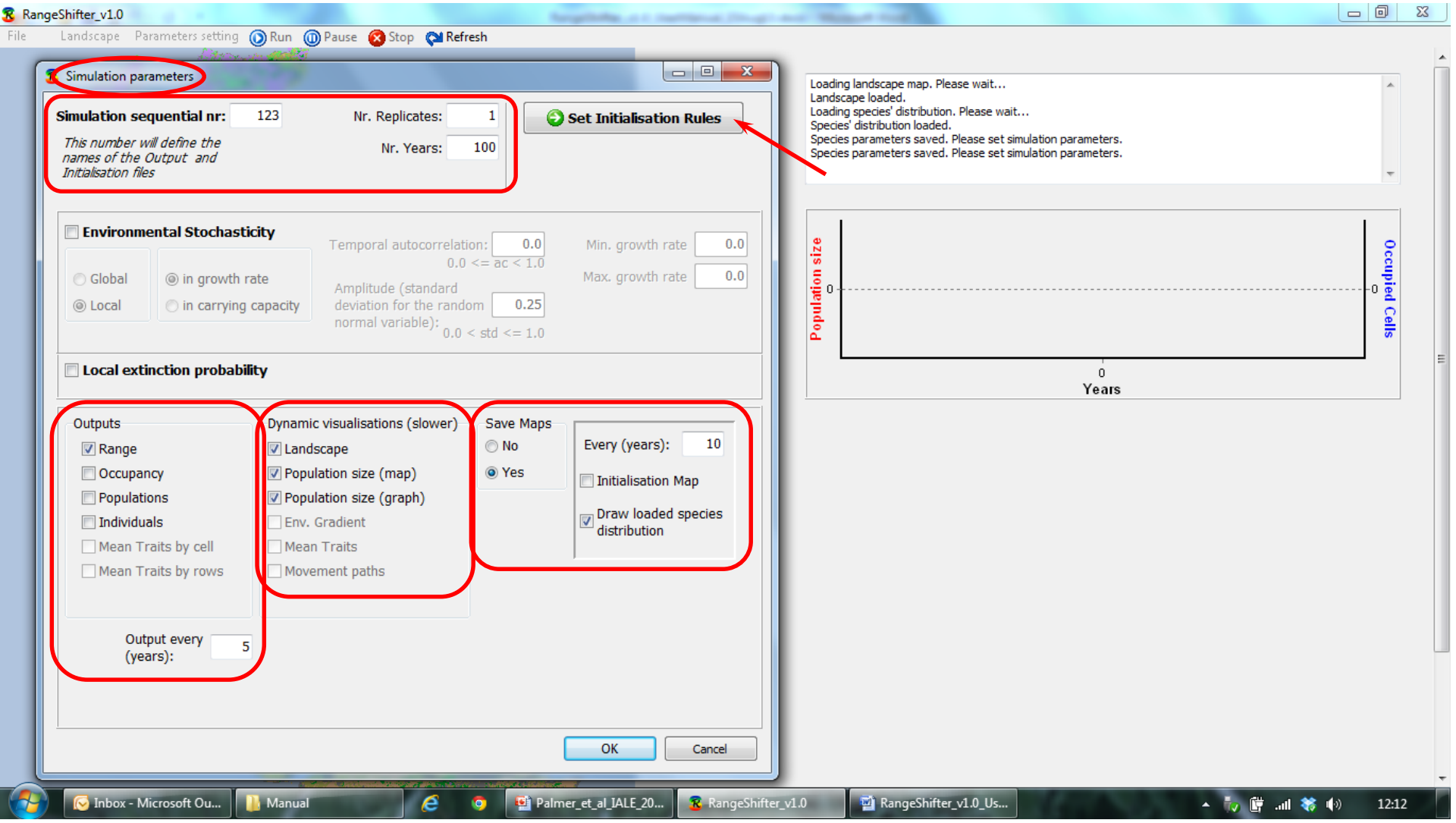
Inbox - Microsoft Ou... Tutorial data Palmer_et_al_IALE_20... RangeShifter_v1.0 11:50

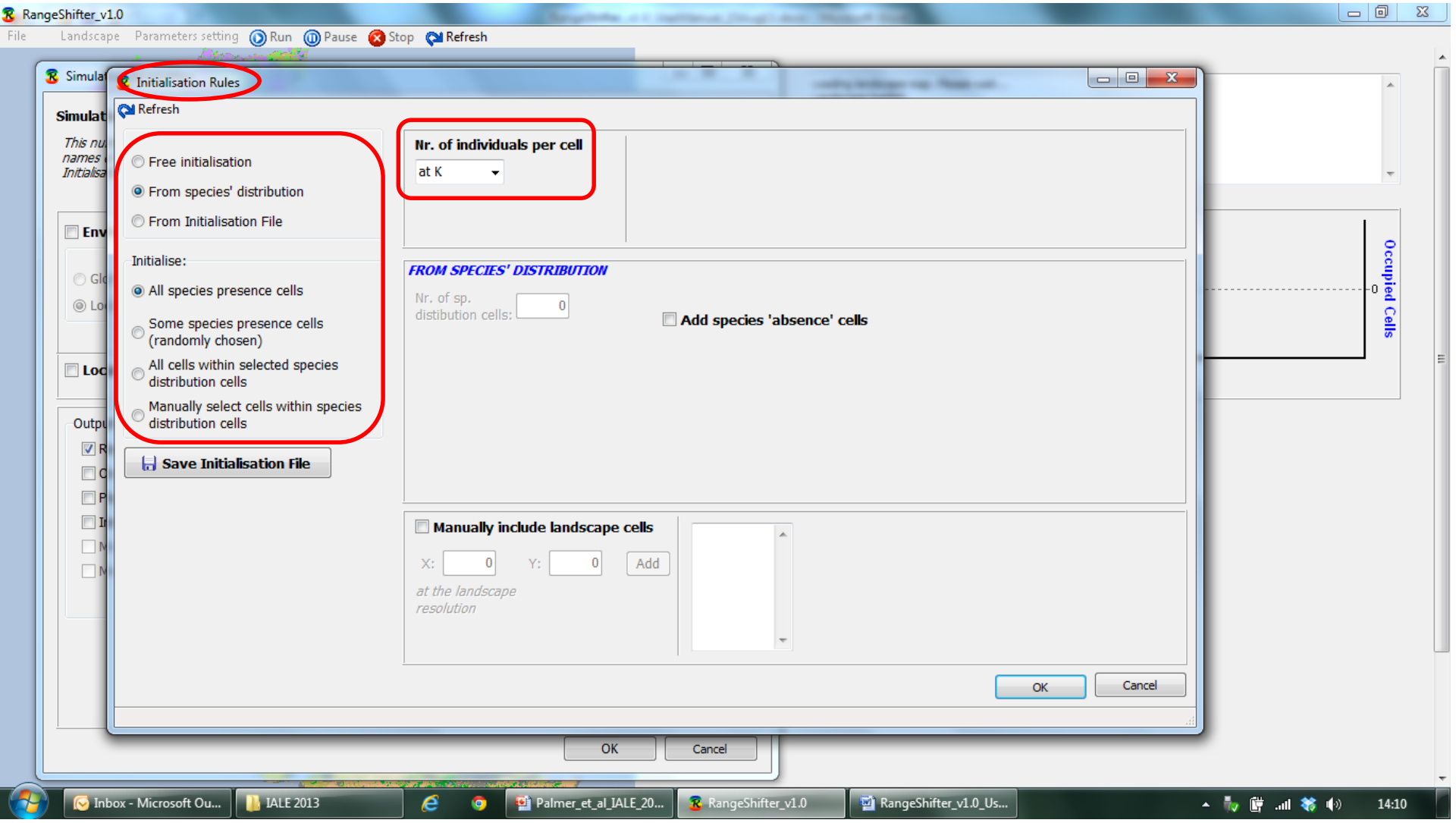

RangeShifter_v1.0
File
Landscape
Parameters setting
Run
Pause
Stop
Refresh
Loading landscape map. Please wait...
Landscape loaded.
Landscape
Raster Type
habitat codes
% cover
habitat quality
Model Type
Cell-based
Patch-based
Resolution (m):
1000
Nr. of habitat types:
6
Hab. Code
R
G
B
1 1 0 200 50
2 2 250 200 150
3 3 200 200 100
4 4 100 250 100
5 5 200 150 250
6 6 150 150 150
Import Landscape
SPECIES' DISTRIBUTION
Resolution (m):
10000
Import Species Distribution
Cancel
Population size
Occupied Cells
0
0
0
Years
Inbox - Microsoft Ou...
Tutorial data
Palmer_et_al_IALE_20...
RangeShifter_v1.0
12:01

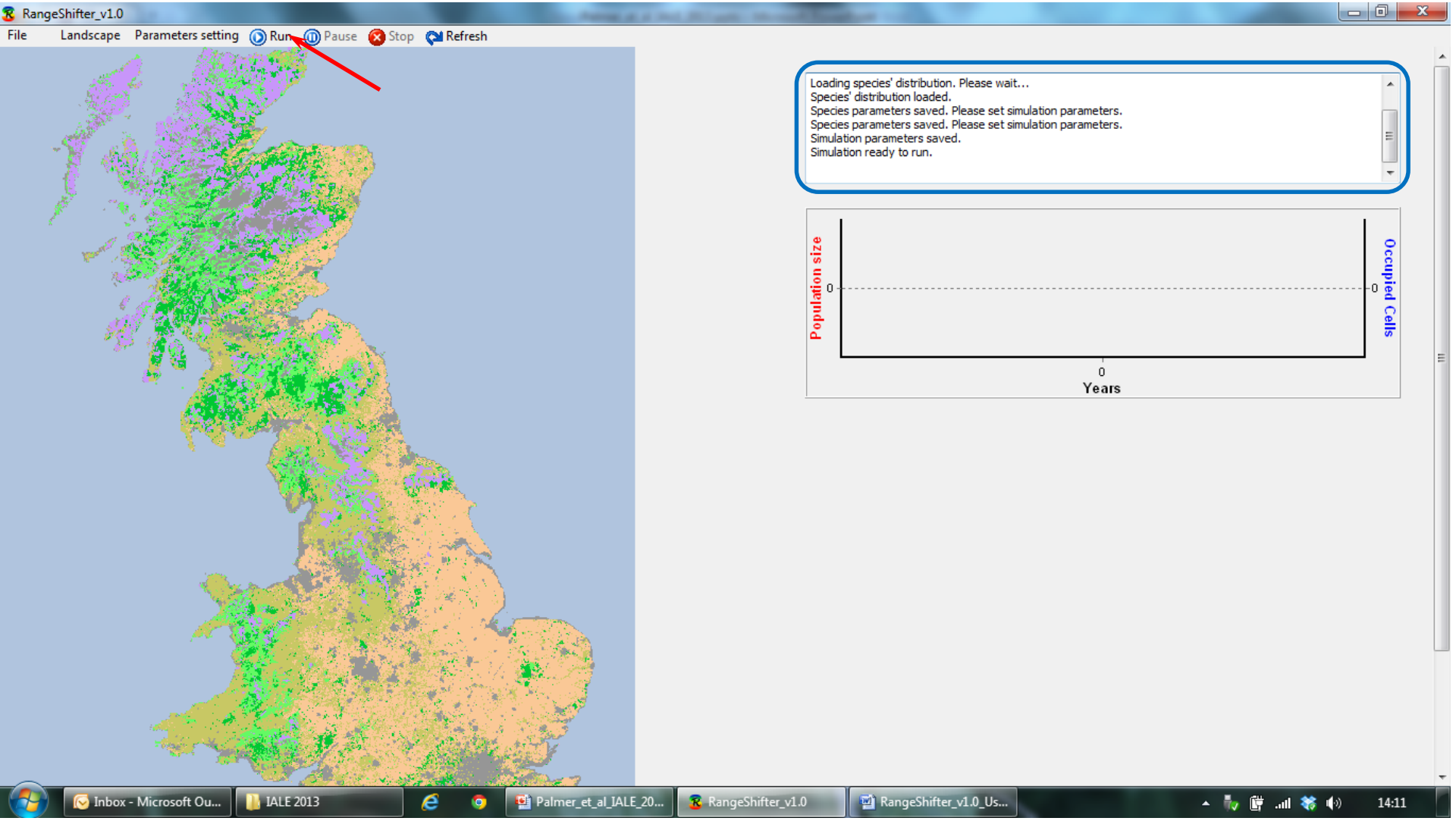

RangeShifter_v1.0
File
Landscape
Parameters setting
Run
Pause
Stop
Refresh
Population size
0
Occupied Cells
0
0
Years

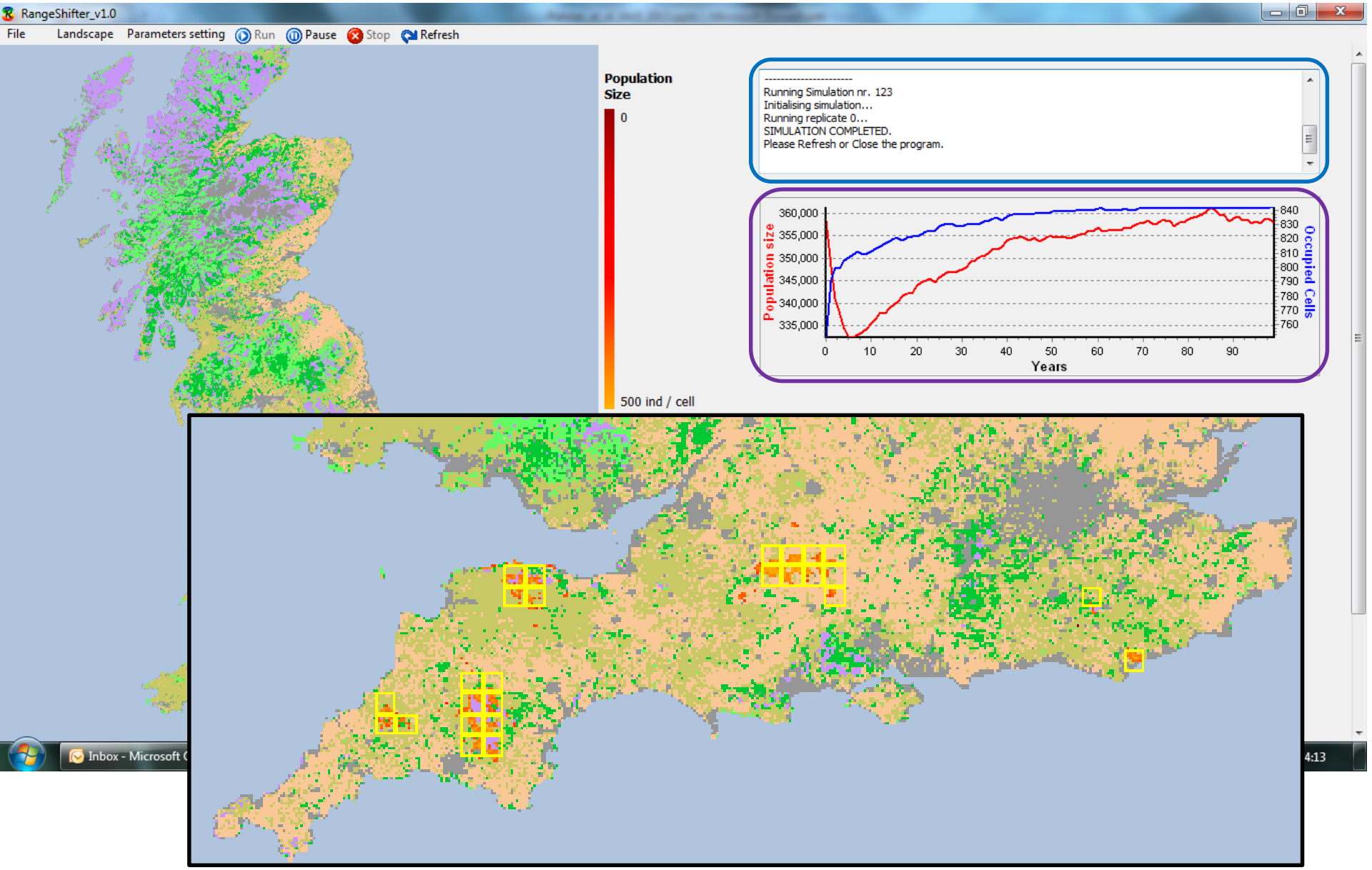

RangeShifter_v1.0
File
Landscape
Parameters setting
Run
Pause
Stop
Refresh
Species Parameters
Population dynamics
Dispersal
Sex / Stage dependent Dispersal
Overlapping generations / Stage-structured model
Nr. reproductive seasons / year:
1
Asexual / Only females model
Simple sexual model
Complex sexual model
Rmax (intrinsic growth rate):
1.5
bc (competition coefficient):
1.0
Habitat-dependent carrying capacities:
Hab. code
K (inds/ha)
1
0.0
2
0.0
3
0.0
4
5.0
5
0.0
6
0.0
OK
Cancel
Occupied Cells
0
Inbox - Microsoft Ou...
Manual
Palmer_et_al_IALE_20...
RangeShifter_v1.0
RangeShifter_v1.0_Us...
12:08

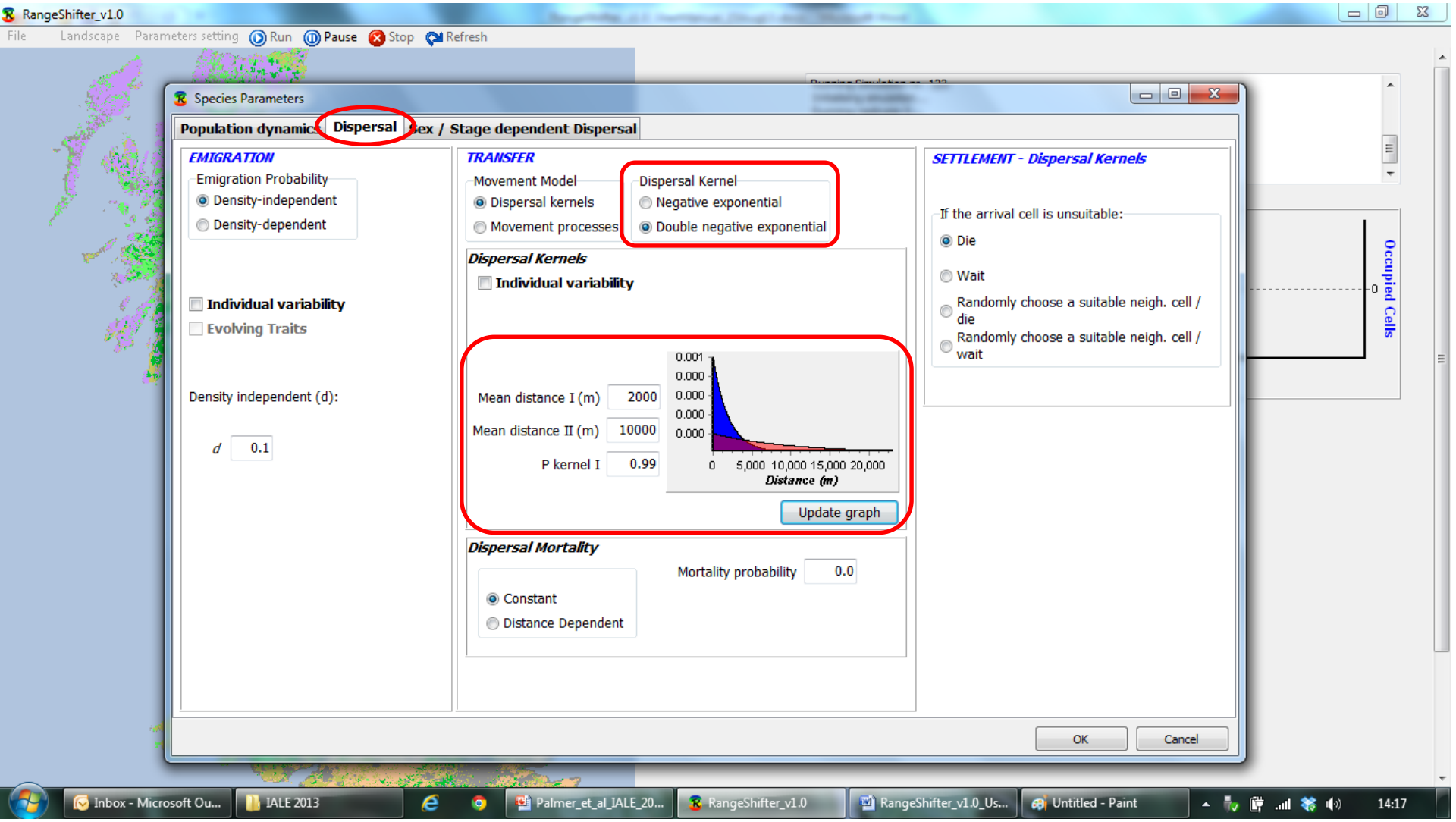

RangeShifter_v1.0
File
Landscape
Parameters setting
Run
Pause
Stop
Refresh
Species Parameters
Population dynamics
Dispersal
Sex / Stage dependent Dispersal
EMIGRATION
Emigration Probability
Density-independent
Density-dependent
Individual variability
Evolving Traits
Density independent (d):
d
0.1
TRANSFER
Movement Model
Dispersal kernels
Movement processes
Dispersal Kernel
Negative exponential
Double negative exponential
Dispersal Kernels
Individual variability
Evolving Traits
Mean distance I (m)
2000
0.001
0.000
0.000
0.000
0.000
0
2,000
4,000
6,000
Distance (m)
Update graph
Dispersal Mortality
Constant
Distance Dependent
Mortality probability
0.0
SETTLEMENT
Dispersal Kernels
If the arrival cell is unsuitable:
Die
Wait
Randomly choose a suitable neigh. cell / die
Randomly choose a suitable neigh. cell / wait
Occupied Cells
OK
Cancel
Inbox - Microsoft Ou...
Manual
Palmer_et_al_IALE_20...
RangeShifter_v1.0
RangeShifter_v1.0_Us...
12:10

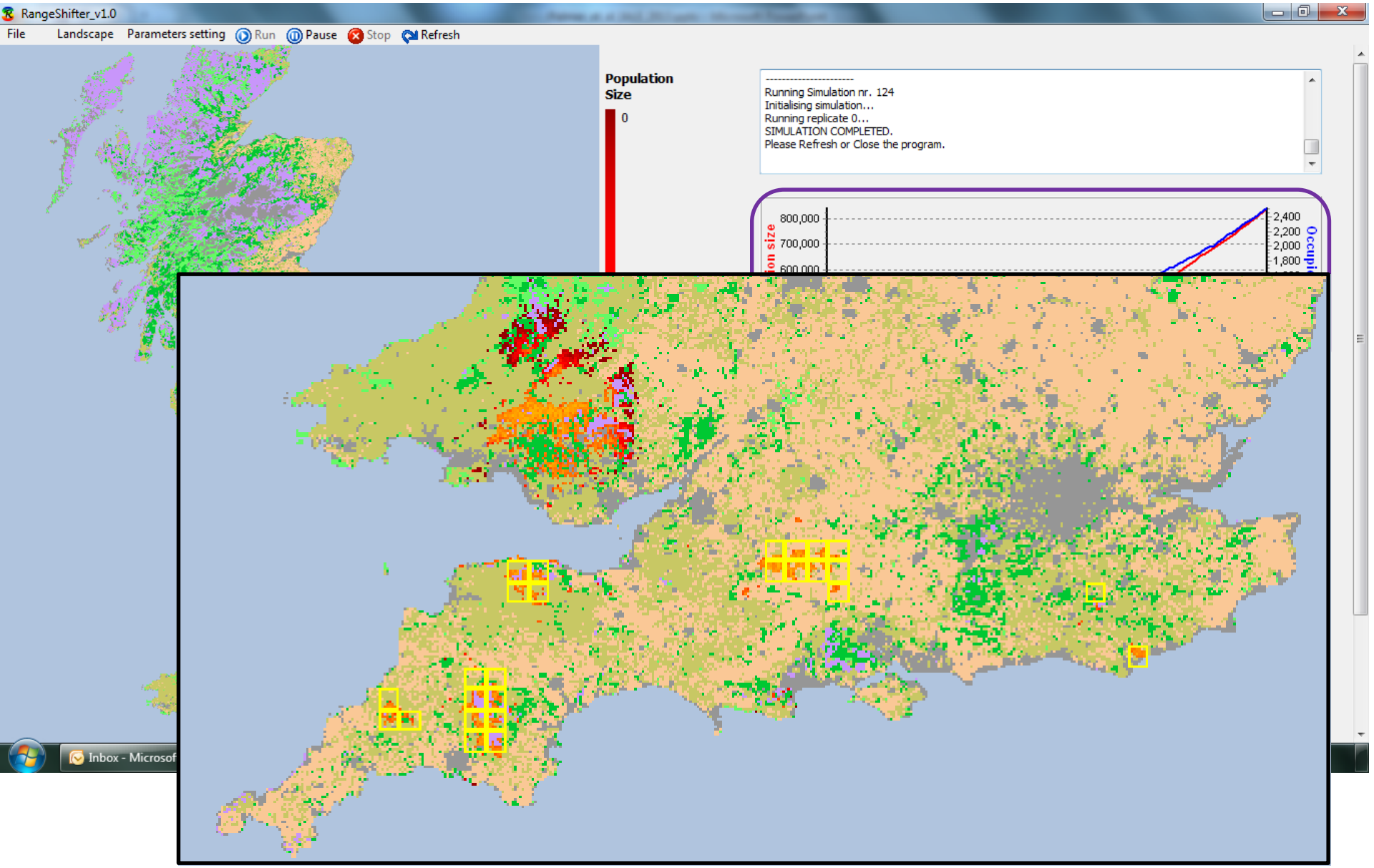

RangeShifter_v1.0
File
Landscape
Parameters setting
Run
Pause
Stop
Refresh
Simulation parameters
Simulation sequential nr: 123
Nr. Replicates: 1
This number will define the names of the Output and Initialisation files
Nr. Years: 100
Set Initialisation Rules
Environmental Stochasticity
Global
Local
in growth rate
in carrying capacity
Temporal autocorrelation: 0.0
0.0 <= ac < 1.0
Amplitude (standard deviation for the random normal variable): 0.25
0.0 < std <= 1.0
Min. growth rate 0.0
Max. growth rate 0.0
Local extinction probability
Outputs
Range
Occupancy
Populations
Individuals
Mean Traits by cell
Mean Traits by rows
Output every (years): 5
Dynamic visualisations (slower)
Landscape
Population size (map)
Population size (graph)
Env. Gradient
Mean Traits
Movement paths
Save Maps
No
Yes
Every (years): 10
Initialisation Map
Draw loaded species distribution
OK
Cancel
Loading landscape map. Please wait...
Landscape loaded.
Loading species' distribution. Please wait...
Species' distribution loaded.
Species parameters saved. Please set simulation parameters.
Species parameters saved. Please set simulation parameters.
Population size
Occupied Cells
0
0
0
Years
Inbox - Microsoft Ou...
Manual
Palmer_et_al_IALE_20...
RangeShifter_v1.0
RangeShifter_v1.0_Us...
12:12


RangeShifter_v1.0
File
Landscape
Parameters setting
Run
Pause
Stop
Refresh
Initialisation Rules
Refresh
Free initialisation
From species' distribution
From Initialisation File
Initialise:
All species presence cells
Some species presence cells (randomly chosen)
All cells within selected species distribution cells
Manually select cells within species distribution cells
Save Initialisation File
Nr. of individuals per cell
at K
FROM SPECIES' DISTRIBUTION
Nr. of sp. distibution cells:
0
Add species 'absence' cells
Manually include landscape cells
X:
0
Y:
0
Add
at the landscape resolution
OK
Cancel
Occupied Cells
0
OK
Cancel
Inbox - Microsoft Ou...
IALE 2013
Palmer_et_al_IALE_20...
RangeShifter_v1.0
RangeShifter_v1.0_Us...
14:10

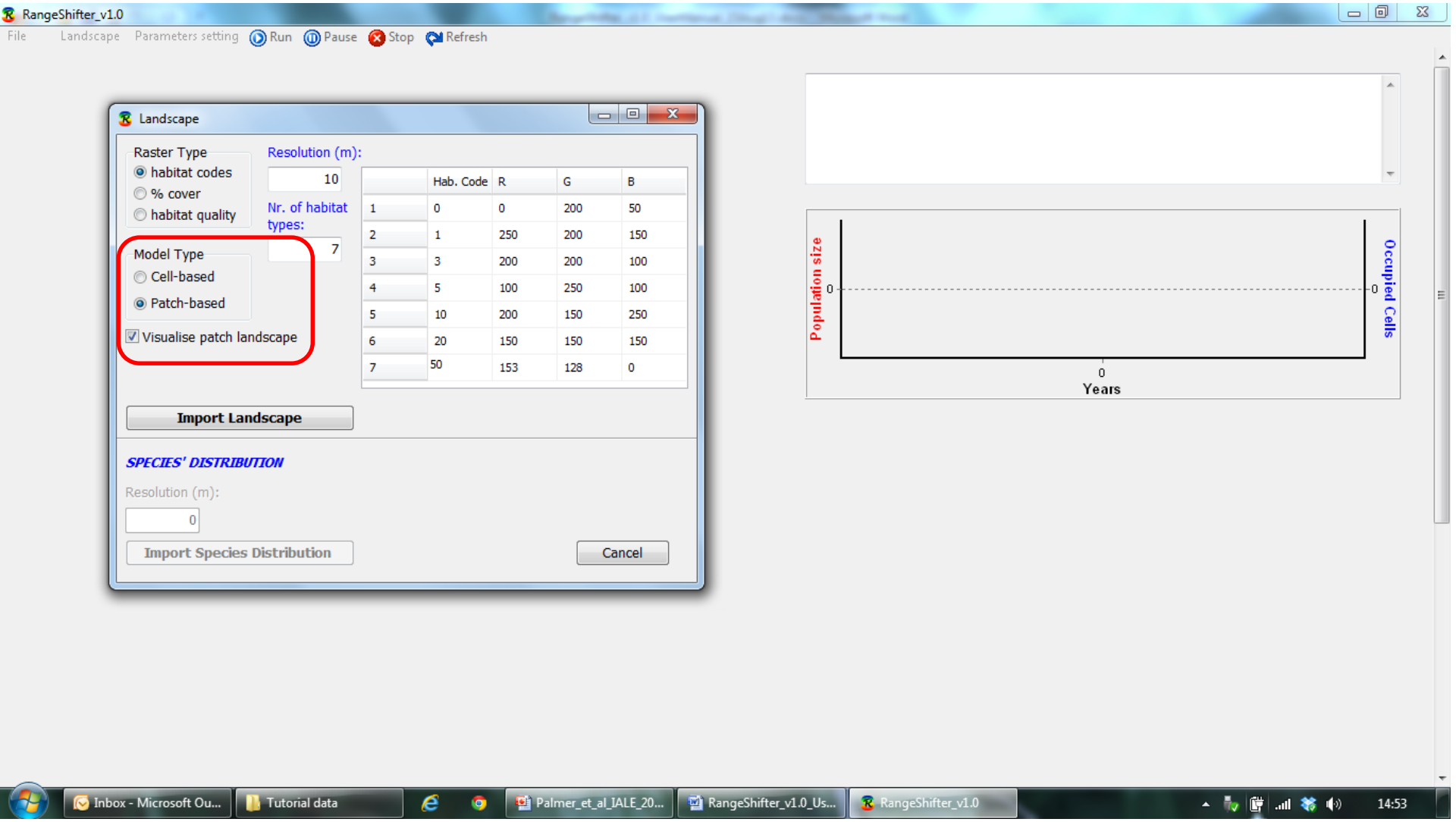

RangeShifter_v1.0
File
Landscape
Parameters setting
Run
Pause
Stop
Refresh
Loading species' distribution. Please wait...
Species' distribution loaded.
Species parameters saved. Please set simulation parameters.
Species parameters saved. Please set simulation parameters.
Simulation parameters saved.
Simulation ready to run.
Population size
Occupied Cells
0
0
0
Years
Inbox - Microsoft Ou...
IALE 2013
Palmer_et_al_IALE_20...
RangeShifter_v1.0
RangeShifter_v1.0_Us...
14:11

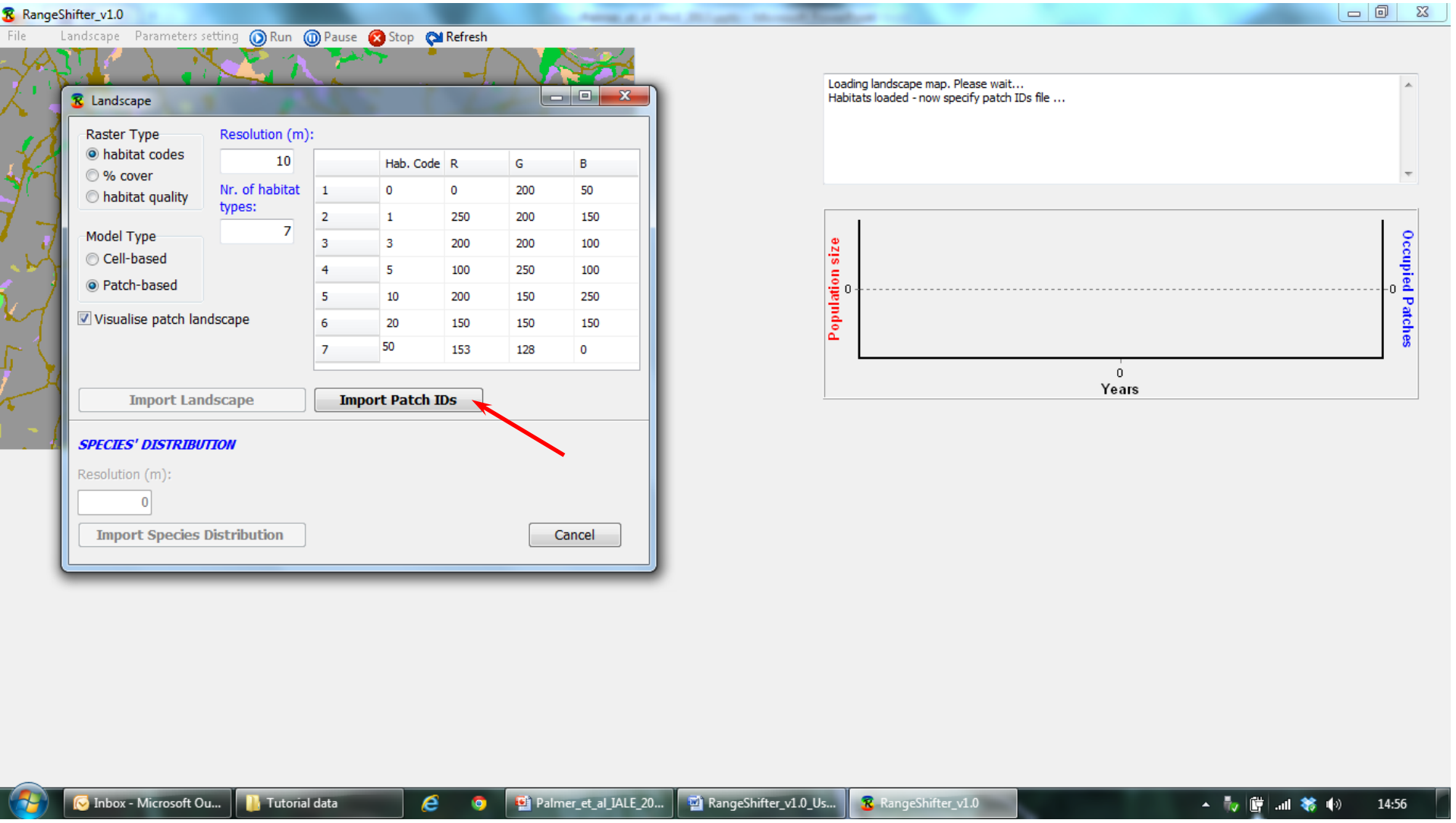

RangeShifter_v1.0
File
Landscape
Parameters setting
Run
Pause
Stop
Refresh
Population Size
0
500 ind / cell
Running Simulation nr. 123
Initialising simulation...
Running replicate 0...
SIMULATION COMPLETED.
Please Refresh or Close the program.
Population size
Occupied Cells
Years
360,000
355,000
350,000
345,000
340,000
335,000
840
830
820
810
800
790
780
770
760
0
10
20
30
40
50
60
70
80
90

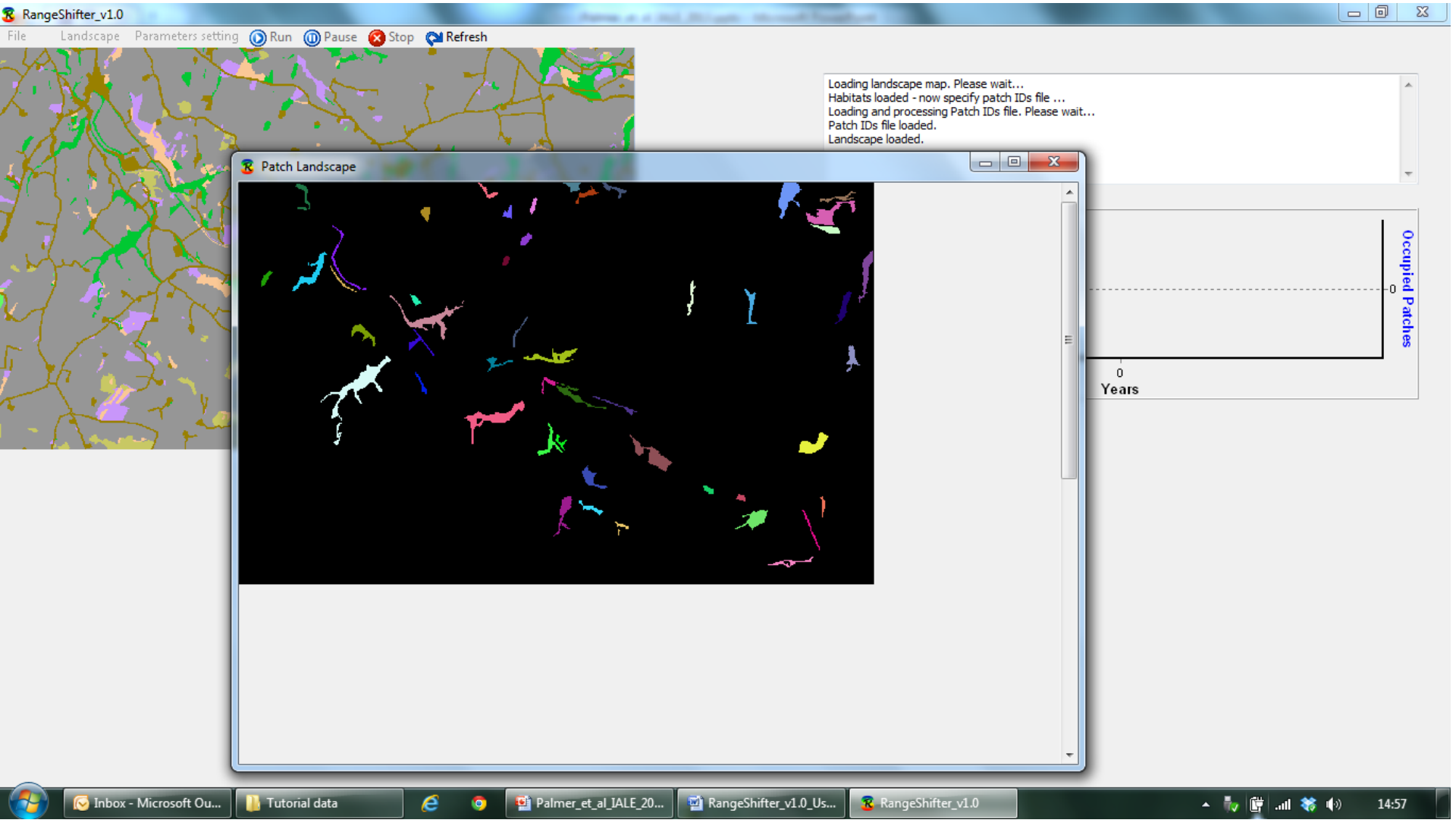

RangeShifter_v1.0
File
Landscape
Parameters setting
Run
Pause
Stop
Refresh
Species Parameters
Population dynamics
Dispersal
Sex / Stage dependent Dispersal
EMIGRATION
Emigration Probability
Density-independent
Density-dependent
Individual variability
Evolving Traits
Density independent (d):
d
0.1
TRANSFER
Movement Model
Dispersal kernels
Movement processes
Dispersal Kernel
Negative exponential
Double negative exponential
Dispersal Kernels
Individual variability
Mean distance I (m)
2000
Mean distance II (m)
10000
P kernel I
0.99
0.001
0.000
0.000
0.000
0.000
0
5,000
10,000
15,000
20,000
Distance (m)
Update graph
Dispersal Mortality
Constant
Distance Dependent
Mortality probability
0.0
SETTLEMENT - Dispersal Kernels
If the arrival cell is unsuitable:
Die
Wait
Randomly choose a suitable neigh. cell / die
Randomly choose a suitable neigh. cell / wait
OK
Cancel
Occupied Cells
0
Inbox - Microsoft Ou...
IALE 2013
Palmer_et_al_IALE_20...
RangeShifter_v1.0
RangeShifter_v1.0_Us...
Untitled - Paint
14:17

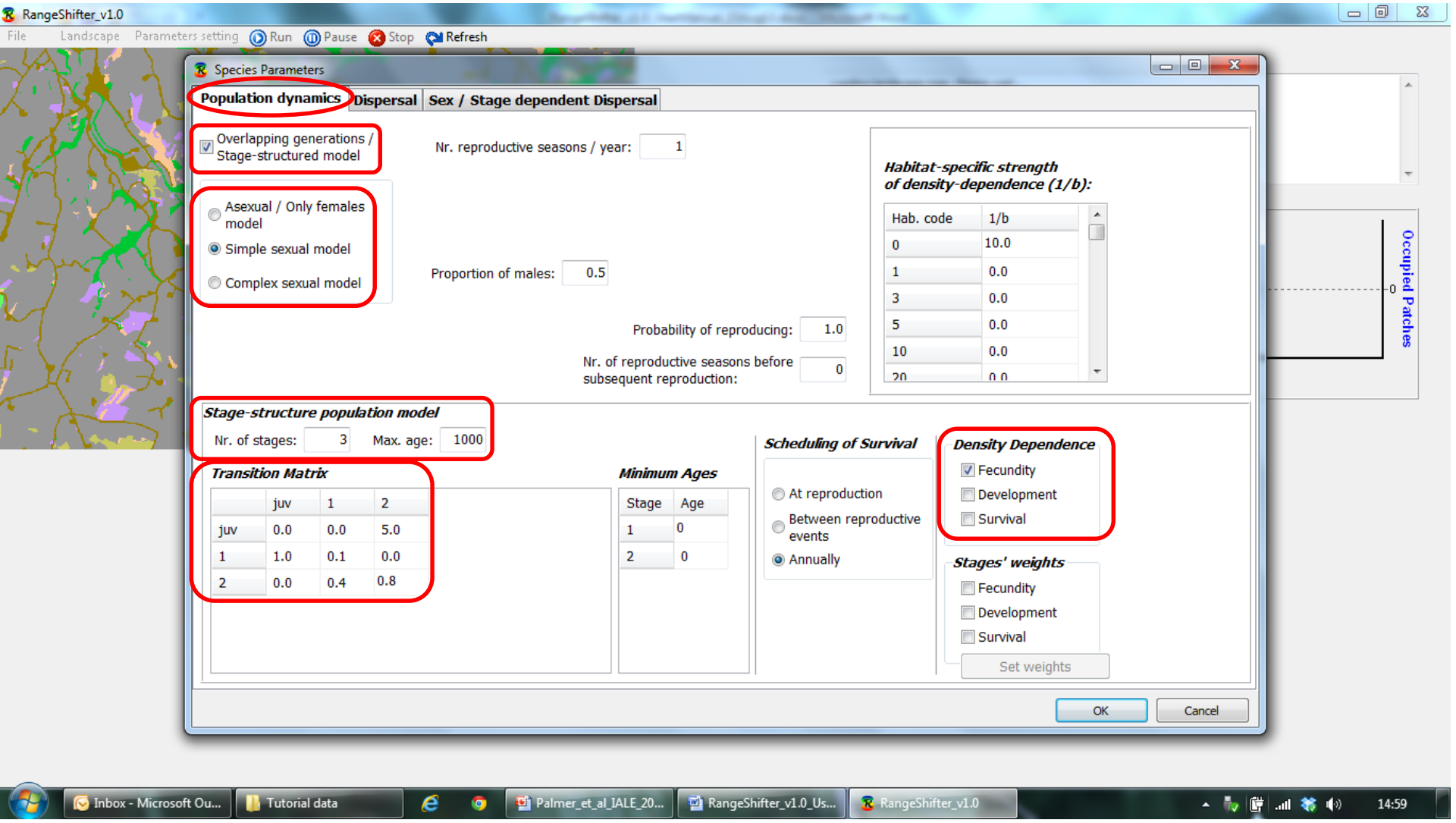

RangeShifter_v1.0
File
Landscape
Parameters setting
Run
Pause
Stop
Refresh
Population Size
0
Running Simulation nr. 124
Initialising simulation...
Running replicate 0...
SIMULATION COMPLETED.
Please Refresh or Close the program.
800,000
700,000
2,400
2,200
2,000
1,800
Occupi
Inbox - Microsof

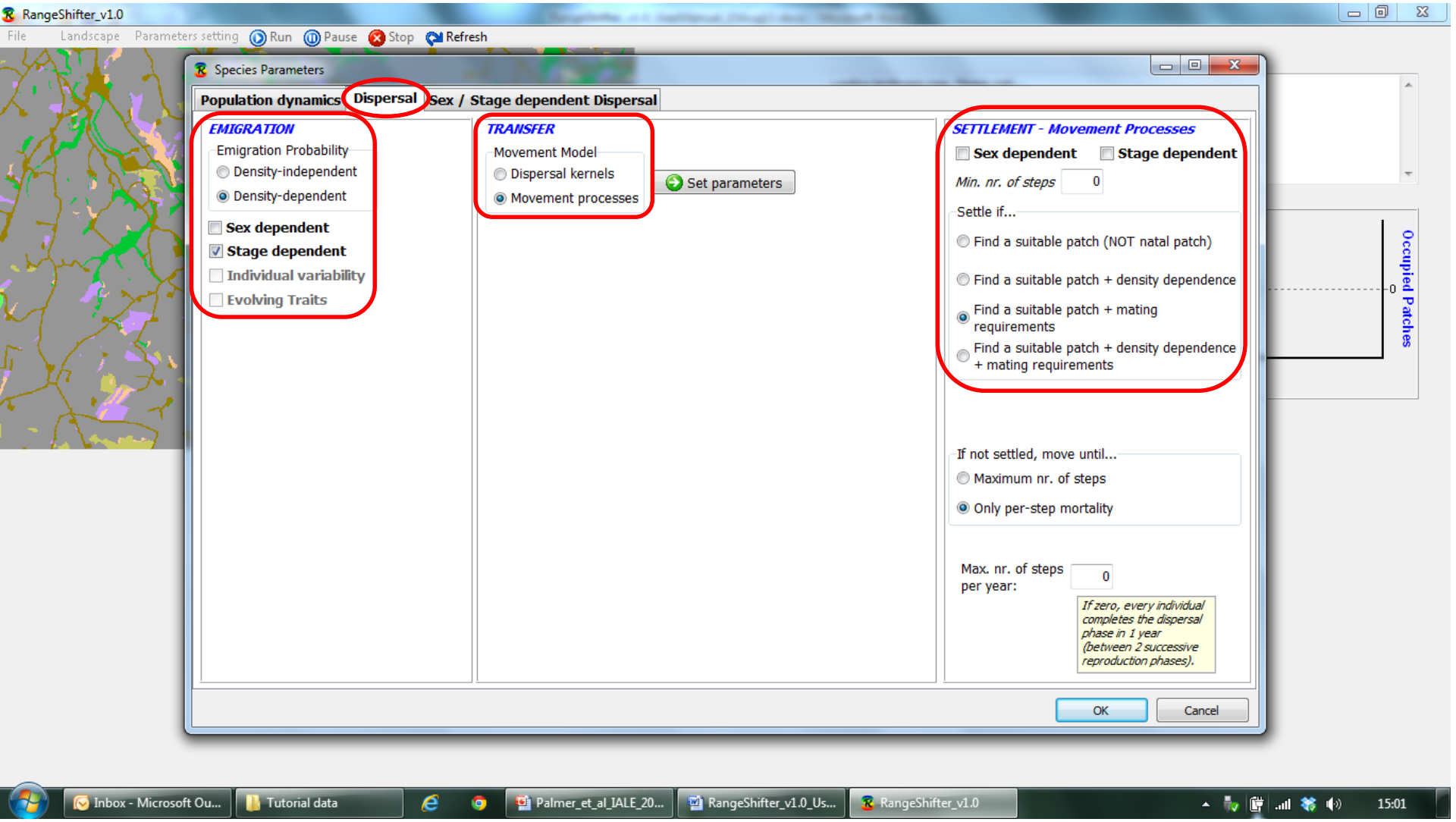
Example 2: landscape-scale connectivity

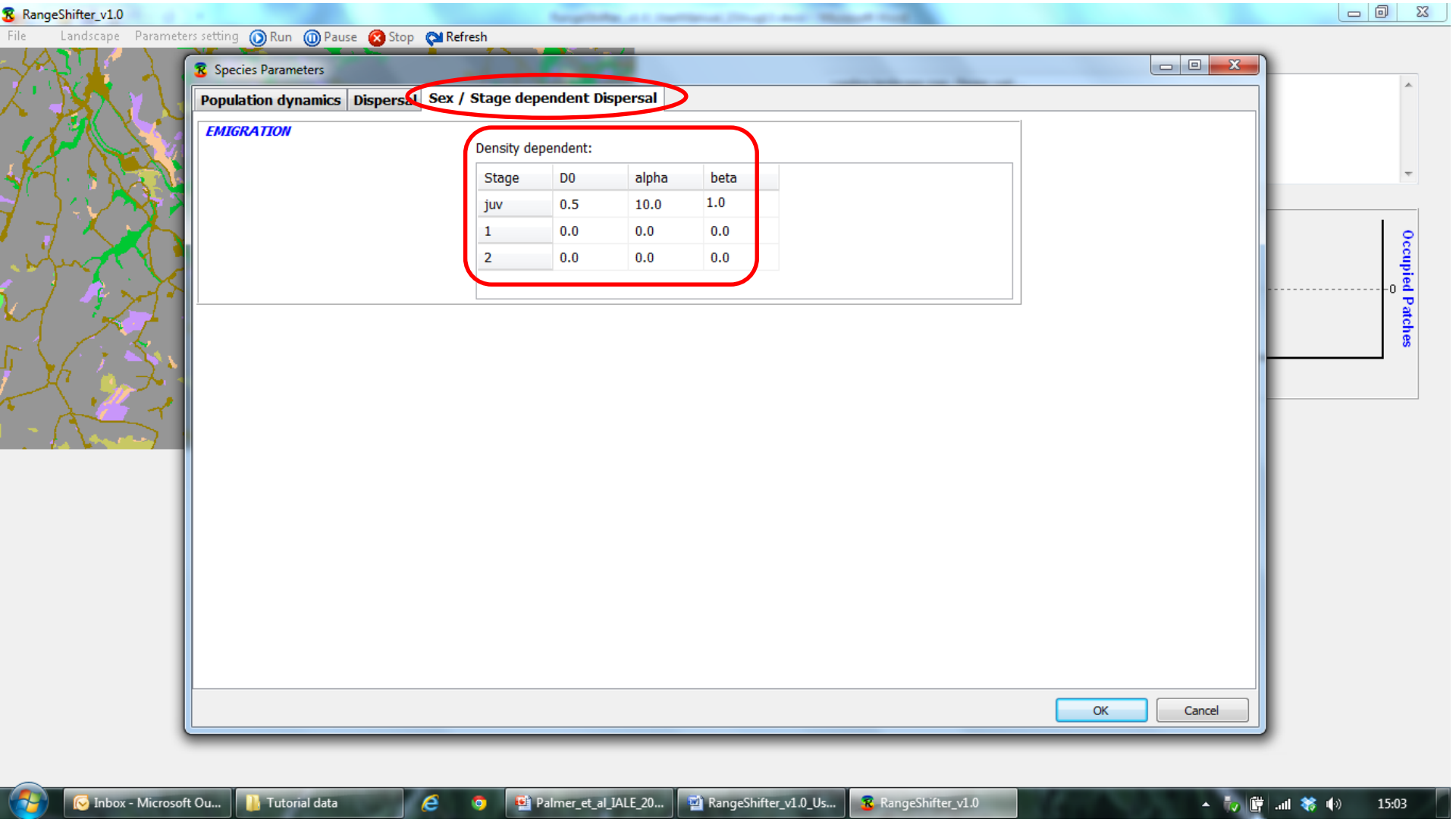


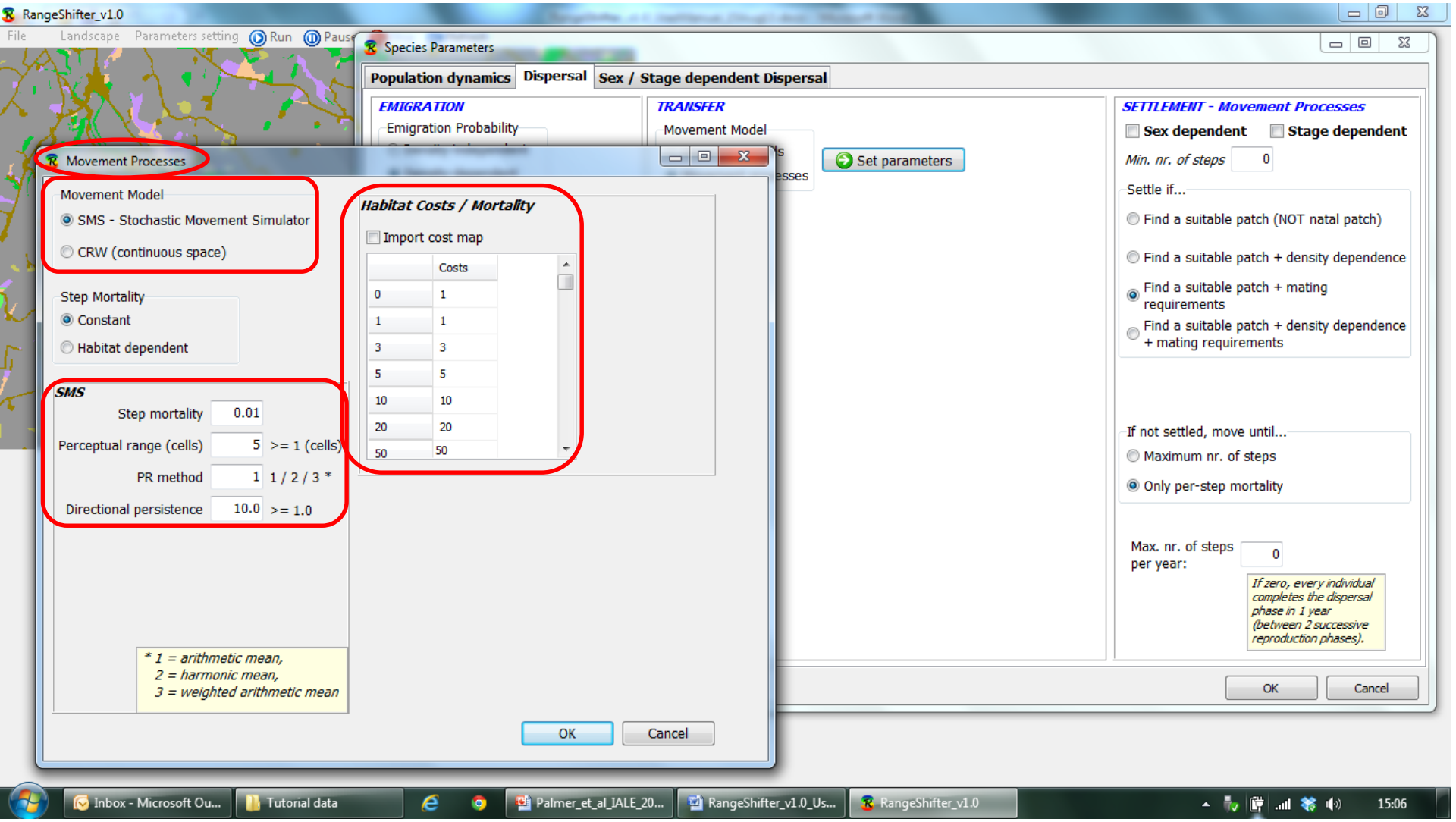

RangeShifter_v1.0
File
Landscape
Parameters setting
Run
Pause
Stop
Refresh
Landscape
Raster Type
habitat codes
% cover
habitat quality
Model Type
Cell-based
Patch-based
Visualise patch landscape
Resolution (m):
10
Nr. of habitat types:
7
Hab. Code
R
G
B
1 0 0 200 50
2 1 250 200 150
3 3 200 200 100
4 5 100 250 100
5 10 200 150 250
6 20 150 150 150
7 50 153 128 0
Import Landscape
Import Patch IDs
SPECIES' DISTRIBUTION
Resolution (m):
0
Import Species Distribution
Cancel
Loading landscape map. Please wait...
Habitats loaded - now specify patch IDs file ...
Population size
Occupied Patches
0
0
0
Years
Inbox - Microsoft Ou...
Tutorial data
Palmer_et_al_IALE_20...
RangeShifter_v1.0_Us...
RangeShifter_v1.0
14:56

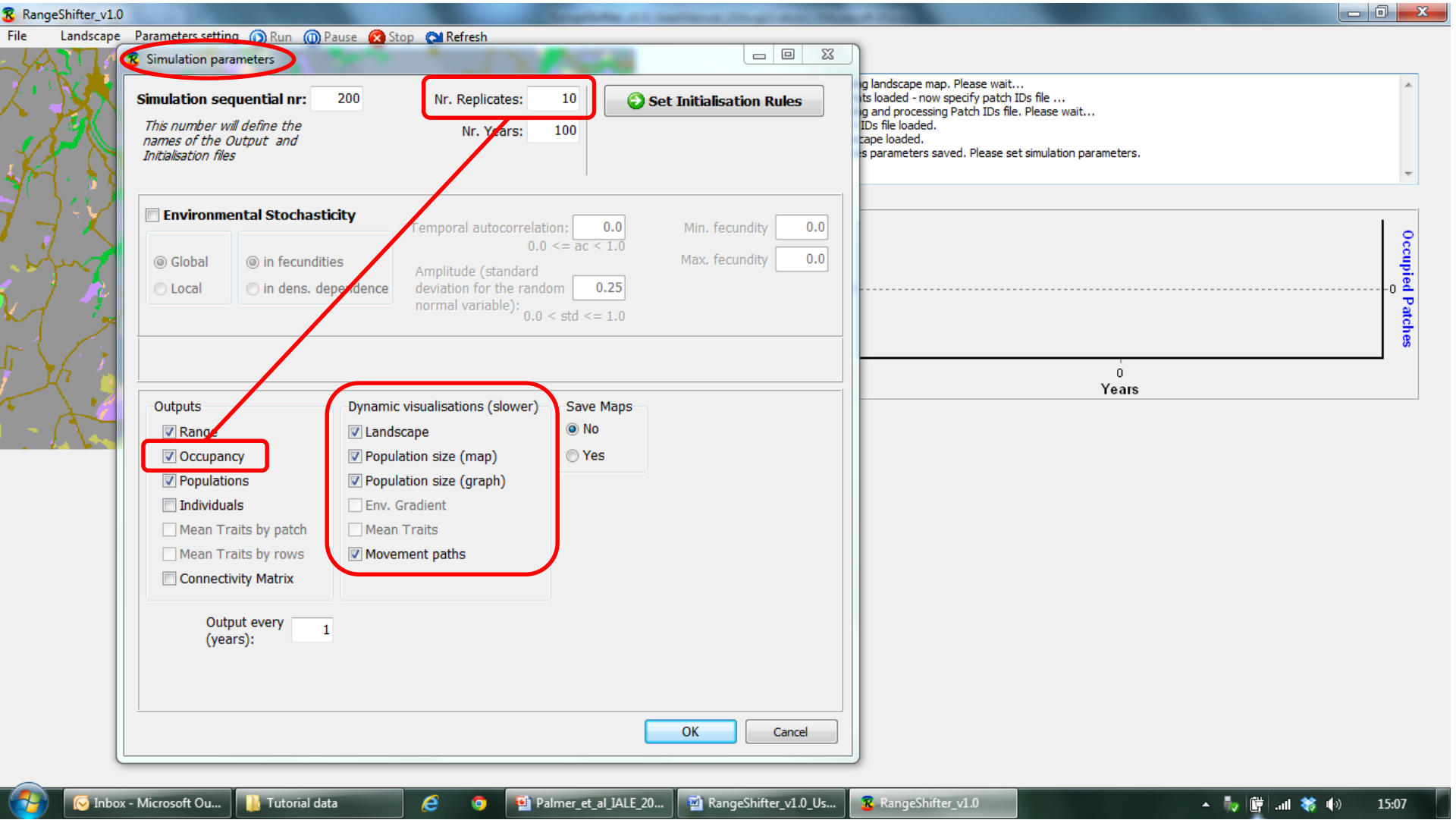

RangeShifter_v1.0
File
Landscape
Parameters setting
Run
Pause
Stop
Refresh
Loading landscape map. Please wait...
Habitats loaded - now specify patch IDs file ...
Loading and processing Patch IDs file. Please wait...
Patch IDs file loaded.
Landscape loaded.
Patch Landscape
Occupied Patches
0
0
Years
Inbox - Microsoft Ou...
Tutorial data
Palmer_et_al_IALE_20...
RangeShifter_v1.0_Us...
RangeShifter_v1.0
14:57

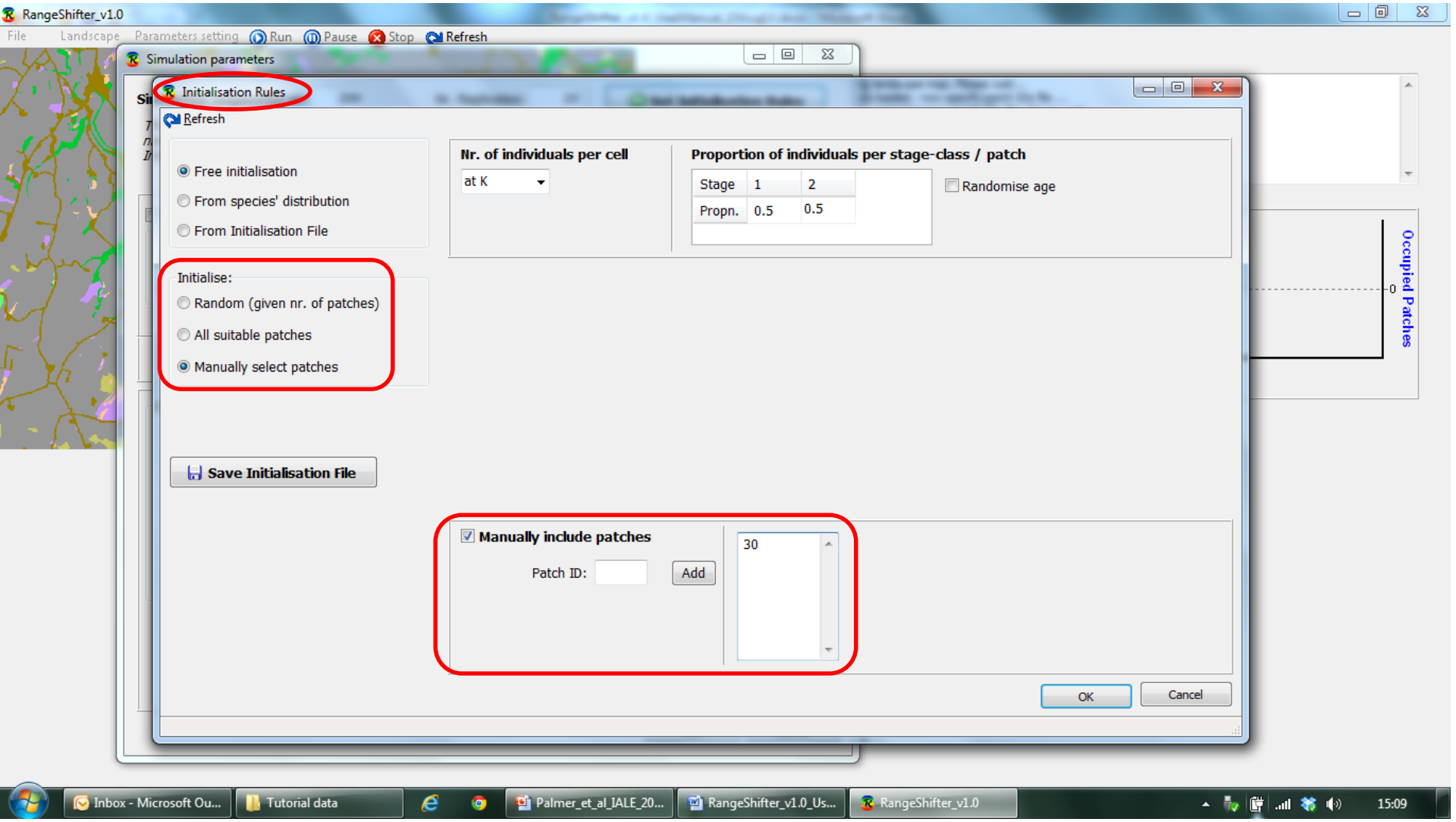

RangeShifter_v1.0
File
Landscape
Parameters setting
Run
Pause
Stop
Refresh
Species Parameters
Population dynamics
Dispersal
Sex / Stage dependent Dispersal
Overlapping generations / Stage-structured model
Nr. reproductive seasons / year:
1
Asexual / Only females model
Simple sexual model
Complex sexual model
Proportion of males:
0.5
Habitat-specific strength of density-dependence (1/b):
Hab. code
1/b
0
10.0
1
0.0
3
0.0
5
0.0
10
0.0
20
0.0
Probability of reproducing:
1.0
Nr. of reproductive seasons before subsequent reproduction:
0
Occupied Patches
Stage-structure population model
Nr. of stages:
3
Max. age:
1000
Transition Matrix
juv
1
2
juv
0.0
0.0
5.0
1
1.0
0.1
0.0
2
0.0
0.4
0.8
Minimum Ages
Stage
Age
1
0
2
0
Scheduling of Survival
At reproduction
Between reproductive events
Annually
Density Dependence
Fecundity
Development
Survival
Stages' weights
Fecundity
Development
Survival
Set weights
OK
Cancel
Inbox - Microsoft Ou...
Tutorial data
Palmer_et_al_IALE_20...
RangeShifter_v1.0_Us...
RangeShifter_v1.0
14:59

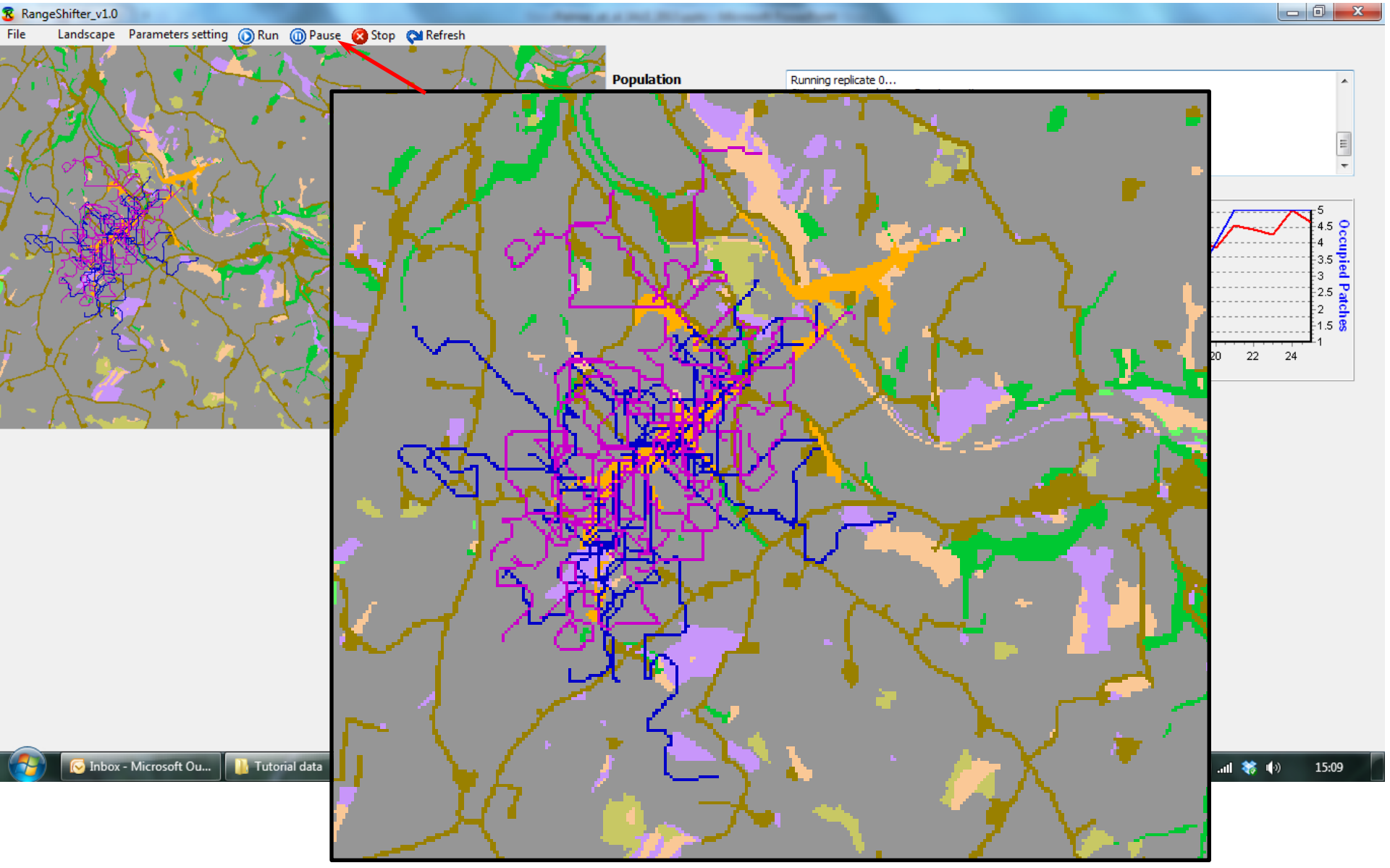

RangeShifter_v1.0
File
Landscape
Parameters setting
Run
Pause
Stop
Refresh
Species Parameters
Population dynamics
Dispersal
Sex / Stage dependent Dispersal
EMIGRATION
Emigration Probability
Density-independent
Density-dependent
Sex dependent
Stage dependent
Individual variability
Evolving Traits
TRANSFER
Movement Model
Dispersal kernels
Movement processes
Set parameters
SETTLEMENT - Movement Processes
Sex dependent
Stage dependent
Min. nr. of steps
0
Settle if...
Find a suitable patch (NOT natal patch)
Find a suitable patch + density dependence
Find a suitable patch + mating requirements
Find a suitable patch + density dependence + mating requirements
If not settled, move until...
Maximum nr. of steps
Only per-step mortality
Max. nr. of steps per year:
0
If zero, every individual completes the dispersal phase in 1 year (between 2 successive reproduction phases).
OK
Cancel
Occupied Patches
0
Inbox - Microsoft Ou...
Tutorial data
Palmer_et_al_IALE_20...
RangeShifter_v1.0_Us...
RangeShifter_v1.0
15:01


RangeShifter_v1.0
File
Landscape
Parameters setting
Run
Pause
Stop
Refresh
Species Parameters
Population dynamics
Dispersal
Sex / Stage dependent Dispersal
EMIGRATION
Density dependent:
Stage
D0
alpha
beta
juv
0.5
10.0
1.0
1
0.0
0.0
0.0
2
0.0
0.0
0.0
OK
Cancel
Occupied Patches
0
Inbox - Microsoft Ou...
Tutorial data
Palmer_et_al_IALE_20...
RangeShifter_v1.0_Us...
RangeShifter_v1.0
15:03


RangeShifter_v1.0
File
Landscape
Parameters setting
Run
Pause
Species Parameters
Population dynamics
Dispersal
Sex / Stage dependent Dispersal
EMIGRATION
Emigration Probability
TRANSFER
Movement Model
Set parameters
SETTLEMENT - Movement Processes
Sex dependent
Stage dependent
Min. nr. of steps
0
Settle if...
Find a suitable patch (NOT natal patch)
Find a suitable patch + density dependence
Find a suitable patch + mating requirements
Find a suitable patch + density dependence + mating requirements
If not settled, move until...
Maximum nr. of steps
Only per-step mortality
Max. nr. of steps per year:
0
If zero, every individual completes the dispersal phase in 1 year (between 2 successive reproduction phases).
OK
Cancel
Movement Processes
Movement Model
SMS - Stochastic Movement Simulator
CRW (continuous space)
Step Mortality
Constant
Habitat dependent
SMS
Step mortality
0.01
Perceptual range (cells)
5
>= 1 (cells)
PR method
1
1 / 2 / 3 *
Directional persistence
10.0
>= 1.0
* 1 = arithmetic mean,
2 = harmonic mean,
3 = weighted arithmetic mean
Habitat Costs / Mortality
Import cost map
Costs
0 1
1 1
3 3
5 5
10 10
20 20
50 50
OK
Cancel
Inbox - Microsoft Ou...
Tutorial data
Palmer_et_al_IALE_20...
RangeShifter_v1.0_Us...
RangeShifter_v1.0
15:06

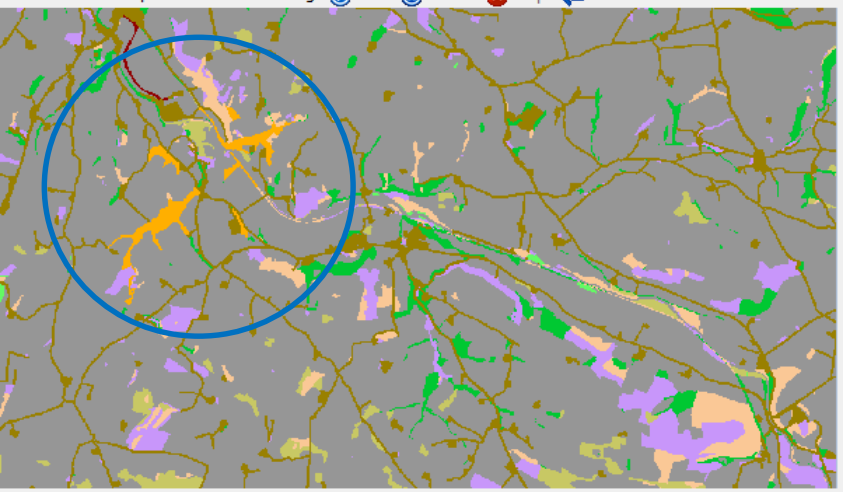

RangeShifter_v1.0
File
Landscape
Parameters setting
Run
Pause
Stop
Refresh
Simulation parameters
Simulation sequential nr: 200
This number will define the names of the Output and Initialisation files
Nr. Replicates: 10
Nr. Years: 100
Set Initialisation Rules
Environmental Stochasticity
Global
Local
in fecundities
in dens. dependence
Temporal autocorrelation: 0.0
0.0 <= ac < 1.0
Amplitude (standard deviation for the random normal variable): 0.25
0.0 < std <= 1.0
Min. fecundity 0.0
Max. fecundity 0.0
Outputs
Range
Occupancy
Populations
Individuals
Mean Traits by patch
Mean Traits by rows
Connectivity Matrix
Dynamic visualisations (slower)
Landscape
Population size (map)
Population size (graph)
Env. Gradient
Mean Traits
Movement paths
Save Maps
No
Yes
Output every (years): 1
OK
Cancel
g landscape map. Please wait...
ts loaded - now specify patch IDs file ...
g and processing Patch IDs file. Please wait...
IDs file loaded.
tape loaded.
s parameters saved. Please set simulation parameters.
Occupied Patches
0
0
Years
Inbox - Microsoft Ou...
Tutorial data
Palmer_et_al_IALE_20...
RangeShifter_v1.0_Us...
RangeShifter_v1.0
15:07


RangeShifter_v1.0
File
Landscape
Parameters setting
Run
Pause
Stop
Refresh
Simulation parameters
Initialisation Rules
Refresh
Free initialisation
From species' distribution
From Initialisation File
Nr. of individuals per cell
at K
Proportion of individuals per stage-class / patch
Stage 1 2
Propn. 0.5 0.5
Randomise age
Initialise:
Random (given nr. of patches)
All suitable patches
Manually select patches
Save Initialisation File
Manually include patches
Patch ID:
Add
30
OK
Cancel
Occupied Patches
0
Inbox - Microsoft Ou...
Tutorial data
Palmer_et_al_IALE_20...
RangeShifter_v1.0_Us...
RangeShifter_v1.0
15:09


RangeShifter_v1.0
File
Landscape
Parameters setting
Run
Pause
Stop
Refresh
Population
Running replicate 0...
Occupied Patches
5
4.5
4
3.5
3
2.5
2
1.5
1
20
22
24
Inbox - Microsoft Ou...
Tutorial data
15:09

RangeShifter_v1.0

File Landscape Parameters setting Run Pause Stop Refresh

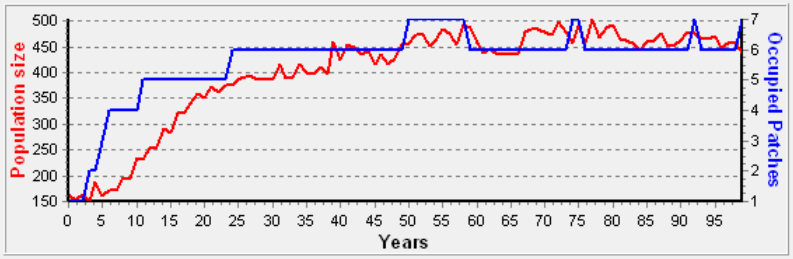


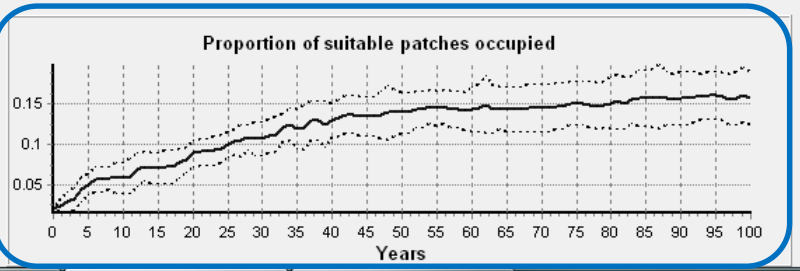
Population Size

0

10 ind / ha

Initialising simulation...
Running replicate 9...
Writing final output...
SIMULATION COMPLETED.
Please Refresh or Close the program.





Inbox - Microsoft Ou... | Tutorial data | Palmer_et_al_IALE_20... | RangeShifter_v1.0_Us... | RangeShifter_v1.0 | Untitled - Paint | 15:12

Recent applications of RangeShifter to conservation and landscape ecology issues

Factors controlling range expansion rates

Barros C, Palmer SCF, Bocedi G and Travis JMJ (2016). Spread rates on fragmented landscapes: the interacting roles of demography, dispersal and habitat availability. *Diversity and Distributions*, 22, 1266-1275.

Evaluation of management scenarios for Afrotropical forest bird species

Aben, J., et al. (2016) The importance of realistic dispersal models in conservation planning: application of a novel modelling platform to evaluate management scenarios in an Afrotropical biodiversity hotspot. *Journal of Applied Ecology,* 53, 1055-1065.

Recovery of Asian Crested Ibis *Nipponia nippon* in China

Sun, Y., et al. (2016) Predicting and understanding spatio-temporal dynamics of species recovery: implications for crested ibis conservation in China. *Diversity and Distributions*, 22, 893-904.

Potential response of terrestrial mammals to climate change

Santini, L, Cornulier, T, Bullock, JM, Palmer, SCF, White, SM, Hodgson, JA, Bocedi, G and Travis, JMJ (2016). A trait-based approach for predicting species responses to environmental change from sparse data: how well might terrestrial mammals track climate change? *Global Change Biology*, 22, 2415-2424.

Climate change mitigation strategies

Synes NW, Watts K, Palmer SCF, Bocedi G, Bartoń KA, Osborne PE and Travis JMJ (2015). A multi-species modelling approach to examine the impact of alternative climate change adaptation strategies on range shifting ability in a fragmented landscape. *Ecological Informatics*, 30, 222-229.

Range expansion of an invasive mammal – American mink *Neovison vison*

Fraser, E. J., et al. (2015) Range expansion of an invasive species through a heterogeneous landscape - the case of American mink in Scotland. *Diversity and Distributions*, 21, 888-900.

Introducing ***RangeShifter*** a new tool for Landscape Ecology

Now it is your turn!...