Dispersal Simulation using RangeShiftR

library(RangeShiftR)  
require(sp)  
require(rgdal)  
require(sfheaders)  
require(raster)  
require(SDMSelect)  
require(tidyverse)

# Introduction

The goal is to simulate dispersal of *Cakile edentula* following introductions at the ports of Sydney, Melbourne, Brisbane and Perth.

Steps taken:

1. Using the

* [BCCVL](https://bccvl.org.au/) platform,
* global species occurrence data for *Cakile edentula* in its “native” and “home/invaded” ranges and
* global climate data WorldClim for 1950-2000 at ~5 km resolution

we predict the potential species distribution. The output is a CSV file with the suitability probabilities (0 - 1) for different points.

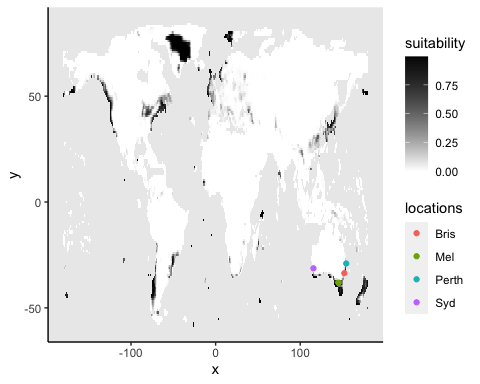
1. Transformed the data on suitability from BCCVL into a landscape map file *land.txt*.

#### suitability map from tif  
  
l = raster("Inputs/proj\_current\_cakile.edentula\_maxent\_unconstrained.tif")  
l2 = raster::resample(l, raster(ext=extent(extent(l)), resolution=1,crs=projection(l)))  
  
raster::writeRaster(l2, format="ascii", filename = "Inputs/climate\_suitability", NAflag = -9, overwrite = T, bylayer = T, datatype = "FLT4S")  
  
  
lp = gplot\_data(raster("Inputs/climate\_suitability.asc")) %>% filter(!is.na(value))

1. Identified the map locations for the ports of “Sydney”, “Melbourne”, “Brisbane” and “Perth” and assigned 100 individuals of *Cakile edentula* introductions in each 1sqkm grid. Transformed this data into a species distribution map file *introduction.txt*

introduction = read.csv("Inputs/aus\_ports3.csv")[, 1:3]  
introduction$Individuals = as.numeric(introduction$Individuals)  
  
a3 = introduction %>% filter(!is.na(Individuals)) %>% mutate("locations" = c("Syd", "Mel", "Mel", "Bris", "Perth")) %>% na.omit()  
  
coordinates(introduction) = ~ lon + lat  
proj4string(introduction)=proj4string(l) # set it to lat-long  
introduction = spTransform(introduction,proj4string(l))  
  
e <- extent(l)  
r <- raster(e, ncols = 720, nrows = 360)  
  
# you need to provide a function 'fun' for when there are multiple points per cell  
introduction2 <- rasterize(introduction, r, fun = mean)  
  
introduction3 = raster::resample(introduction2[[2]], raster(ext=extent(extent(introduction2)), resolution=1,crs=projection(introduction)))  
  
  
raster::writeRaster(introduction3, format="ascii", filename = "Inputs/news\_locations.asc", NAflag = -9, overwrite = T, datatype = "INT2U")

ggplot( ) +   
 geom\_tile(data = lp , aes(x = x, y = y, fill = value)) +   
 scale\_fill\_gradient("suitability", low = "white", high = "black") +  
 theme\_grey() + theme(panel.border = element\_blank(), panel.grid.major = element\_blank(),  
panel.grid.minor = element\_blank(), axis.line = element\_line(colour = "black")) +   
 geom\_point(data = a3, aes(x = lon, y = lat, color = locations))



The chart above displays the climate suitability for *Cakile edentula* in the selected region that overlaps between the native area in the USA and Australia. From the map, we observe that suitability is only relatively high in the native region and very low everywhere else. The introduction points for this simulation are also shown and we note that they are all regions with very low suitability.

1. Define the *landscape parameter* in RangeShiftR for simulation. We define the resolution at . We set *HabPercent = TRUE* since the data in our suitability map is a probability value between 0 and 1. We set the *K\_or\_DensDep = 1000* to infer that a location with a probability of 1 would have a carrying capacity of 100. The carrying capacities for all locations are calculated based on the probability value and the 100 threshold.

landscapes = ImportedLandscape(LandscapeFile = "climate\_suitability.asc",   
 Resolution = 1,   
 HabPercent = TRUE,   
 K\_or\_DensDep = 1000,   
 SpDistFile = "news\_locations.asc",   
 SpDistResolution = 1)

1. We define the Species parameters which include:

* *demography*: I have made the assumption that the population dynamics are described by a female-only model with non-overlapping generations and defined the *maximum growth rate as 6*

demos <- Demography(Rmax = 6, bc = 0.00001, ReproductionType = 0)  
demos

## Demography:  
## Unstructured population:  
## Rmax : 6   
## bc : 1e-05   
## Reproduction Type : 0 (female only)

* *dispersal*: This contains information on *Emigration* probability, *Transport* modeled with a dispersal kernel and *Settlement* whose default options assume that an individual will die if it arrives in an unsuitable cell and settle if it’s suitable.

We make the assumption that the *Emigration probability = 0.05*

We define *short range* and *long range transfer* at with and with respectively. This suggests that we have a 3rd possible dispersal distance equal to which has a probability of . However, RangeShiftR provides for either a single or double kernel to define distance. To fit this, I considered the odds between the short dispersal distance (20km) and the long distance (100km) and used this to recalculate their probabilities assuming the 3rd option of is not present.

We define settlement parameters to limit self extinction i.e such that if a species emigrates to an unsuitable cell, it can move to one of the eight neighbouring cells in the case that at least one of them is suitable.

dist = matrix(c(20000, 100000, 0.83 ), ncol = 3, byrow = T)  
  
disps <- Dispersal(Emigration = Emigration(EmigProb = 0.05), Transfer = DispersalKernel(DoubleKernel = T, Distances = dist)) + Settlement(MaxSteps = 1, Settle = 2)  
disps

## Dispersal:   
## Emigration:  
## Emigration probabilities:  
## [,1]  
## [1,] 0.05  
##   
## Transfer:  
## Dispersal Kernel  
## DoubleKernel = TRUE   
## Dispersal kernel traits:  
## [,1] [,2] [,3]  
## [1,] 20000 1e+05 0.83  
## Constant mortality prob = 0   
##   
## Settlement:  
## Settlement conditions:  
## [,1]  
## [1,] 2  
## FindMate = FALSE

1. Initialize the parameters for simulation

Introduce 100 individuals in each 1\*1 km grid, in 15 cells around the 4 port locations

inits <- Initialise(InitType = 1, # = initialisation from a loaded species distribution map  
 SpType = 1,# = all suitable cells within all distribution presence cells  
 NrCells = 10,  
 InitDens = 2,  
 IndsHaCell = 100) # = at carrying capacity  
  
inits

## Initialisation:   
## InitType = 1 : Initialisation from loaded species distribution map  
## all presence cells/patches.  
## InitDens = 2 : 100 individuals per cell/hectare

1. Simulation parameters

We will run with simulating the spread of *Cakile edentula* over and record the *population*, *occurrence* and *range* every

sims <- Simulation(Simulation = 1,  
 Years = 1000,  
 Replicates = 100,  
 OutIntRange = 1,  
 OutIntPop = 1,  
 OutIntOcc = 1)  
sims

## Simulation # 1   
## -----------------  
## Replicates = 100   
## Years = 1000   
## Absorbing = FALSE   
## File Outputs:  
## Range, every 1 years  
## Occupancy, every 1 years  
## Populations, every 1 years, starting year 0

1. Combine all the predefined parameters into a master object and run the simulation. We will run two separate simulations, one for the short range dispersal and the other for the long range dispersal.

simulate <- RSsim() + landscapes + demos + disps + sims + inits  
validateRSparams(simulate) ## check parameter validity

## [1] TRUE

1. Run simulations

RunRS(RSparams = simulate, dirpath = paste0(getwd(), "/"))

## Checking Control parameters   
##   
## Control Parameters checked  
##   
## Run Simulation(s) with random seed ...  
## LandscapeFile headers OK: /Users/kwizera.jvk/Desktop/RangeShiftR/Simulation\_cakile\_Australia/2. Climate suitability Simulation/results/Updates/Inputs/climate\_suitability.asc  
## Species Distribution map headers OK: /Users/kwizera.jvk/Desktop/RangeShiftR/Simulation\_cakile\_Australia/2. Climate suitability Simulation/results/Updates/Inputs/news\_locations.asc  
##   
## Running simulation nr. 1  
##   
## starting replicate 0  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
##   
## starting replicate 1  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
## starting year 200...  
## starting year 300...  
##   
## starting replicate 2  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
## starting year 200...  
##   
## starting replicate 3  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
##   
## starting replicate 4  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
##   
## starting replicate 5  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
## starting year 200...  
## starting year 300...  
##   
## starting replicate 6  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
##   
## starting replicate 7  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
## starting year 200...  
## starting year 300...  
##   
## starting replicate 8  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
## starting year 200...  
## starting year 300...  
##   
## starting replicate 9  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
##   
## starting replicate 10  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
## starting year 200...  
## starting year 300...  
##   
## starting replicate 11  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
## starting year 200...  
## starting year 300...  
##   
## starting replicate 12  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
## starting year 200...  
## starting year 300...  
##   
## starting replicate 13  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
## starting year 200...  
##   
## starting replicate 14  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
## starting year 200...  
##   
## starting replicate 15  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
## starting year 200...  
##   
## starting replicate 16  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
## starting year 200...  
##   
## starting replicate 17  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
## starting year 200...  
##   
## starting replicate 18  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
##   
## starting replicate 19  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
##   
## starting replicate 20  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
##   
## starting replicate 21  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
## starting year 200...  
## starting year 300...  
##   
## starting replicate 22  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
##   
## starting replicate 23  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
##   
## starting replicate 24  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
## starting year 200...  
## starting year 300...  
##   
## starting replicate 25  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
## starting year 200...  
## starting year 300...  
##   
## starting replicate 26  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
##   
## starting replicate 27  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
##   
## starting replicate 28  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
##   
## starting replicate 29  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
## starting year 200...  
## starting year 300...  
##   
## starting replicate 30  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
##   
## starting replicate 31  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
##   
## starting replicate 32  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
##   
## starting replicate 33  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
##   
## starting replicate 34  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
## starting year 200...  
## starting year 300...  
##   
## starting replicate 35  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
## starting year 200...  
##   
## starting replicate 36  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
##   
## starting replicate 37  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
## starting year 200...  
##   
## starting replicate 38  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
## starting year 200...  
## starting year 300...  
##   
## starting replicate 39  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
## starting year 200...  
## starting year 300...  
##   
## starting replicate 40  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
## starting year 200...  
##   
## starting replicate 41  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
## starting year 200...  
## starting year 300...  
##   
## starting replicate 42  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
## starting year 200...  
##   
## starting replicate 43  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
## starting year 200...  
## starting year 300...  
##   
## starting replicate 44  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
## starting year 200...  
## starting year 300...  
##   
## starting replicate 45  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
##   
## starting replicate 46  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
## starting year 200...  
## starting year 300...  
##   
## starting replicate 47  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
## starting year 200...  
## starting year 300...  
##   
## starting replicate 48  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
## starting year 200...  
## starting year 300...  
##   
## starting replicate 49  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
##   
## starting replicate 50  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
##   
## starting replicate 51  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
## starting year 200...  
## starting year 300...  
##   
## starting replicate 52  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
##   
## starting replicate 53  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
## starting year 200...  
## starting year 300...  
##   
## starting replicate 54  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
##   
## starting replicate 55  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
## starting year 200...  
## starting year 300...  
##   
## starting replicate 56  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
##   
## starting replicate 57  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
## starting year 200...  
## starting year 300...  
##   
## starting replicate 58  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
## starting year 200...  
## starting year 300...  
##   
## starting replicate 59  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
## starting year 200...  
## starting year 300...  
##   
## starting replicate 60  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
## starting year 200...  
## starting year 300...  
##   
## starting replicate 61  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
##   
## starting replicate 62  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
## starting year 200...  
## starting year 300...  
##   
## starting replicate 63  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
## starting year 200...  
## starting year 300...  
##   
## starting replicate 64  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
## starting year 200...  
## starting year 300...  
##   
## starting replicate 65  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
## starting year 200...  
## starting year 300...  
##   
## starting replicate 66  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
## starting year 200...  
##   
## starting replicate 67  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
##   
## starting replicate 68  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
## starting year 200...  
## starting year 300...  
##   
## starting replicate 69  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
##   
## starting replicate 70  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
## starting year 200...  
##   
## starting replicate 71  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
## starting year 200...  
## starting year 300...  
##   
## starting replicate 72  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
##   
## starting replicate 73  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
## starting year 200...  
## starting year 300...  
##   
## starting replicate 74  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
##   
## starting replicate 75  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
##   
## starting replicate 76  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
##   
## starting replicate 77  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
## starting year 200...  
## starting year 300...  
##   
## starting replicate 78  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
##   
## starting replicate 79  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
## starting year 200...  
## starting year 300...  
##   
## starting replicate 80  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
## starting year 200...  
##   
## starting replicate 81  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
## starting year 200...  
## starting year 300...  
##   
## starting replicate 82  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
## starting year 200...  
## starting year 300...  
##   
## starting replicate 83  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
##   
## starting replicate 84  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
## starting year 200...  
## starting year 300...  
##   
## starting replicate 85  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
## starting year 200...  
## starting year 300...  
##   
## starting replicate 86  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
##   
## starting replicate 87  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
##   
## starting replicate 88  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
## starting year 200...  
## starting year 300...  
##   
## starting replicate 89  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
##   
## starting replicate 90  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
## starting year 200...  
##   
## starting replicate 91  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
## starting year 200...  
##   
## starting replicate 92  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
##   
## starting replicate 93  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
##   
## starting replicate 94  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
##   
## starting replicate 95  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
## starting year 200...  
## starting year 300...  
##   
## starting replicate 96  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
## starting year 200...  
## starting year 300...  
##   
## starting replicate 97  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
##   
## starting replicate 98  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
## starting year 200...  
## starting year 300...  
##   
## starting replicate 99  
## RunModel(): completed initialisation   
## starting year 0...  
## starting year 1...  
## starting year 2...  
## starting year 3...  
## starting year 10...  
## starting year 20...  
## starting year 30...  
## starting year 100...  
##   
## \*\*\*\*\* Elapsed time: 165 seconds  
##   
## \*\*\*\*\*  
## \*\*\*\*\* Simulation completed   
## \*\*\*\*\* Outputs folder: /Users/kwizera.jvk/Desktop/RangeShiftR/Simulation\_cakile\_Australia/2. Climate suitability Simulation/results/Updates/Outputs/  
## \*\*\*\*\*

## $Errors  
## [1] 0

# Summary of the output

The table below shows the summary for the outputs for the 100 different replicates simulated for 1000 years. The column *Rep* represents the replicate indicating a hypothetical species. *year* indicates the year the species dies out (if year < 1000) or 1000 if the species survived the entire simulation period. *max\_number* is the maximum number of individuals that were recorded in that replicate. *final\_number* is the number of individuals at the end of the simulation. *max\_range* is the maximum number of occupied cells starting for each replicate. *start\_range* is the original number of occupied cells at year 0

m = read.csv("Outputs/Batch1\_Sim1\_Land1\_Range.txt", sep = "\t")  
n = m %>% group\_by(Rep) %>% summarize(year = max(Year), max\_number = max(NInds), final\_number = tail(NInds, 1), start\_range = head(NOccupCells, 1), max\_range = max(NOccupCells)) %>% as.data.frame()   
  
survived = nrow(n[n$year == 1000,])  
minimum\_survival = min(n$year)

We note from the table (below) that;

* out of the 100 replicates, 6 survived after 1000 years
* the species survived for between 50 and 1000 years

n[order(-n$year),]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **Rep** | **year** | **max\_number** | **final\_number** | **start\_range** | **max\_range** |
| 27 | 26 | 1000 | 497 | 45 | 1 | 123 |
| 48 | 47 | 1000 | 505 | 100 | 1 | 127 |
| 61 | 60 | 1000 | 751 | 499 | 1 | 198 |
| 93 | 92 | 1000 | 918 | 163 | 1 | 234 |
| 94 | 93 | 1000 | 715 | 247 | 1 | 165 |
| 50 | 49 | 893 | 838 | 0 | 1 | 199 |
| 29 | 28 | 884 | 170 | 0 | 1 | 48 |
| 87 | 86 | 878 | 387 | 0 | 1 | 106 |
| 35 | 34 | 866 | 629 | 0 | 1 | 169 |
| 19 | 18 | 851 | 459 | 0 | 1 | 108 |
| 6 | 5 | 830 | 244 | 0 | 1 | 66 |
| 62 | 61 | 781 | 444 | 0 | 1 | 113 |
| 56 | 55 | 774 | 156 | 0 | 1 | 39 |
| 89 | 88 | 759 | 298 | 0 | 1 | 83 |
| 30 | 29 | 615 | 371 | 0 | 1 | 86 |
| 1 | 0 | 580 | 289 | 0 | 1 | 66 |
| 82 | 81 | 532 | 182 | 0 | 1 | 57 |
| 22 | 21 | 505 | 284 | 0 | 1 | 67 |
| 72 | 71 | 495 | 512 | 0 | 1 | 126 |
| 13 | 12 | 478 | 218 | 0 | 1 | 63 |
| 67 | 66 | 467 | 227 | 0 | 1 | 58 |
| 55 | 54 | 413 | 180 | 0 | 1 | 42 |
| 86 | 85 | 409 | 200 | 0 | 1 | 55 |
| 97 | 96 | 374 | 336 | 0 | 1 | 85 |
| 3 | 2 | 373 | 313 | 0 | 1 | 64 |
| 5 | 4 | 365 | 201 | 0 | 1 | 44 |
| 44 | 43 | 349 | 148 | 0 | 1 | 41 |
| 63 | 62 | 333 | 203 | 0 | 1 | 55 |
| 98 | 97 | 331 | 180 | 0 | 1 | 41 |
| 24 | 23 | 306 | 180 | 0 | 1 | 37 |
| 70 | 69 | 297 | 216 | 0 | 1 | 54 |
| 10 | 9 | 293 | 209 | 0 | 1 | 52 |
| 20 | 19 | 293 | 242 | 0 | 1 | 54 |
| 16 | 15 | 290 | 161 | 0 | 1 | 40 |
| 53 | 52 | 289 | 206 | 0 | 1 | 56 |
| 32 | 31 | 281 | 123 | 0 | 1 | 32 |
| 7 | 6 | 273 | 242 | 0 | 1 | 56 |
| 54 | 53 | 263 | 151 | 0 | 1 | 39 |
| 73 | 72 | 250 | 176 | 0 | 1 | 41 |
| 96 | 95 | 241 | 367 | 0 | 1 | 87 |
| 78 | 77 | 235 | 231 | 0 | 1 | 52 |
| 33 | 32 | 223 | 172 | 0 | 1 | 42 |
| 58 | 57 | 219 | 123 | 0 | 1 | 37 |
| 25 | 24 | 218 | 153 | 0 | 1 | 42 |
| 83 | 82 | 209 | 252 | 0 | 1 | 62 |
| 90 | 89 | 203 | 249 | 0 | 1 | 65 |
| 28 | 27 | 202 | 205 | 0 | 1 | 47 |
| 41 | 40 | 199 | 116 | 0 | 1 | 25 |
| 36 | 35 | 198 | 167 | 0 | 1 | 43 |
| 45 | 44 | 198 | 156 | 0 | 1 | 36 |
| 31 | 30 | 190 | 166 | 0 | 1 | 46 |
| 39 | 38 | 188 | 133 | 0 | 1 | 27 |
| 76 | 75 | 188 | 101 | 0 | 1 | 27 |
| 66 | 65 | 187 | 141 | 0 | 1 | 32 |
| 71 | 70 | 187 | 213 | 0 | 1 | 57 |
| 12 | 11 | 182 | 114 | 0 | 1 | 30 |
| 92 | 91 | 182 | 206 | 0 | 1 | 56 |
| 26 | 25 | 180 | 135 | 0 | 1 | 35 |
| 59 | 58 | 173 | 163 | 0 | 1 | 36 |
| 23 | 22 | 161 | 125 | 0 | 1 | 23 |
| 46 | 45 | 161 | 170 | 0 | 1 | 38 |
| 81 | 80 | 161 | 113 | 0 | 1 | 27 |
| 18 | 17 | 152 | 124 | 0 | 1 | 30 |
| 77 | 76 | 151 | 128 | 0 | 1 | 36 |
| 8 | 7 | 149 | 169 | 0 | 1 | 38 |
| 34 | 33 | 148 | 147 | 0 | 1 | 24 |
| 57 | 56 | 144 | 121 | 0 | 1 | 24 |
| 88 | 87 | 141 | 209 | 0 | 1 | 55 |
| 21 | 20 | 133 | 126 | 0 | 1 | 34 |
| 17 | 16 | 131 | 139 | 0 | 1 | 31 |
| 4 | 3 | 127 | 193 | 0 | 1 | 51 |
| 14 | 13 | 127 | 131 | 0 | 1 | 34 |
| 85 | 84 | 121 | 100 | 0 | 1 | 15 |
| 99 | 98 | 115 | 149 | 0 | 1 | 43 |
| 51 | 50 | 113 | 112 | 0 | 1 | 21 |
| 43 | 42 | 112 | 112 | 0 | 1 | 28 |
| 47 | 46 | 110 | 122 | 0 | 1 | 29 |
| 68 | 67 | 109 | 100 | 0 | 1 | 24 |
| 11 | 10 | 105 | 116 | 0 | 1 | 15 |
| 49 | 48 | 103 | 153 | 0 | 1 | 29 |
| 95 | 94 | 99 | 100 | 0 | 1 | 23 |
| 60 | 59 | 98 | 116 | 0 | 1 | 26 |
| 80 | 79 | 98 | 140 | 0 | 1 | 26 |
| 84 | 83 | 95 | 109 | 0 | 1 | 14 |
| 75 | 74 | 91 | 120 | 0 | 1 | 23 |
| 65 | 64 | 90 | 129 | 0 | 1 | 20 |
| 38 | 37 | 89 | 162 | 0 | 1 | 33 |
| 42 | 41 | 86 | 100 | 0 | 1 | 23 |
| 79 | 78 | 84 | 103 | 0 | 1 | 17 |
| 37 | 36 | 82 | 139 | 0 | 1 | 22 |
| 2 | 1 | 81 | 128 | 0 | 1 | 19 |
| 100 | 99 | 76 | 115 | 0 | 1 | 33 |
| 74 | 73 | 70 | 127 | 0 | 1 | 29 |
| 64 | 63 | 64 | 120 | 0 | 1 | 20 |
| 15 | 14 | 60 | 128 | 0 | 1 | 19 |
| 52 | 51 | 58 | 129 | 0 | 1 | 19 |
| 91 | 90 | 57 | 119 | 0 | 1 | 25 |
| 40 | 39 | 52 | 114 | 0 | 1 | 18 |
| 9 | 8 | 45 | 107 | 0 | 1 | 21 |
| 69 | 68 | 28 | 104 | 0 | 1 | 18 |