SpaDESinAction

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Integrated simulation models: fire, harvesting, birds and caribou

The present toy model is an exercise to understand how SpaDES works when integrating different modules. It is composed of 4 main models (with one to several submodules within each):

1. SCFM (Steve Cumming's fire model): this model is composed of 3 main modules (ignition, escape and spread), and 3 auxiliary modules to establish the landscape, fire drivers, and fire regime. See more information on this model in modules/harvestREADME.Rmd

2. SCSHM (Steve Cumming's Simple Harvest model): this model is composed of 5 main modules: loadYieldTables - loads yield tables necessary for identifying cut blocks, Hanzlik - determines AAC, strataMapFromVegMap - creates a strata map based on the vegetation, scfmHarvest - the harvest component itself, stateVars - a module that updates the state variables (what was cut and what burned). It also has an auxiliary module to establish the landscape. See more information on this model in modules/scfmREADME.Rmd

3. birdsAlberta (bird model based on Vernier's et al., 2008): this model uses coefficients from Vernier et al., 2008 to predict abundance of 2 species of bird (COWA and RBNU) in function of disturbance (fire and harvest).

4. caribouAlberta (caribou model based on Sorensen's et al., 2008): this model uses coefficients from Sorensen et al., 2008 to predict caribou lambda (growth rate) in function of disturbance (fire and harvest).

Running the simulations

1. Setting up all necessary packages, paths and loading all necessary libraries

When setting up the paths using the `SpaDES.core` function `setPaths()`, note that the modules folder should point to where all your modules' *folders* are. SpaDES will find all of these by their names.

```
devtools::install_github("PredictiveEcology/SpaDES.core", ref = "development")
devtools::install_github("PredictiveEcology/SpaDES.tools", ref = "development")
devtools::install_github("PredictiveEcology/reproducible", ref = "development")
devtools::install_github("PredictiveEcology/reproducible", ref = "development")
devtools::install_github("tati-micheletti/usefun")

# Set a few options
options(spades.lowMemory = TRUE)
options(spades.moduleCodeChecks = FALSE)

# Load libraries
  library("SpaDES")
  library("magrittr")
  library("raster")

# Set the directories
```

```
  workDirectory <- getwd()

    SpaDES.core::setPaths(
            modulePath = file.path(workDirectory, "modules"),
            inputPath = file.path(workDirectory, "inputs"),
            outputPath = file.path(workDirectory, "outputs"),
            cachePath = file.path(workDirectory, "cache"))
```

2. Setting up all inputs for the simulation runs

To setup the simulation, we will set 3 'inputs' for the model:

1. **TIME**: start by setting the time for how long you want to run the simulations for. This needs to be a list, in the format of `list(start = 0, end = 10)`.

2. **PARAMETERS**: Next, pass the values of any parameters you would like to change. These values should be a `list()` of the name of the module that contains these. For example, if you want to modify how often the bird model should be run (by default only happening in the beginning and end of the simulation), you can pass inside the parameters list the following: `birdsAlberta = list(.plotInterval = 5)`, for it to run every 5 years. You can find all parameters that can be changed in the metadata of each module, together with a default value and the description of what that parameter does.

3. **OBJECTS**: At last, pass any objects you might want to override from the defaults. One example is the study area. You can load a shapefile in R, and pass it in the form `list(studyArea = shapefile)`. The names of all objects passed need to match the names these have in the modules. These can also be found in the metadata of each module.

It is interesting to note that while **objects are shared** accross modules, **parameters are not**. The modules are in fact integrated by the objects these use as *inputs* and objects these produce as *outputs*. These also have to be defined in the metadata.

Module developers should provide default values for all parameters and objetcs, even if the objects are expected as inputs. This guarantees that anyone running your module, even without any data, is capable of seeing it work.

```
times <- list(start = 0, end = 10)
parameters <- list()
objects <- list()
```

3. Setting up the modules

MODULES: The last step to run the simulation is to identify which modules you want to run together. This should also be passed as a list of the modules names i.e. list("module1", "module2", "module3").

Here, we will mix and match a set of different modules to demonstrate the power of SpaDES. First, we will run a fire model, followed by a harvesting model, and at last, an integrated model that has fire, harvesting, birds and caribous.

```
modulesFire <- list("scfmLandcoverInit", "scfmRegime",
                    "scfmDriver", "scfmIgnition",
                    "scfmEscape", "scfmSpread")

modulesHarvest <- list("scfmLandcoverInit", "loadYieldTables",
```

```
                      "Hanzlik", "strataMapFromVegMap",
                      "scfmHarvest", "stateVars")

allModules <- list("scfmLandcoverInit", "scfmRegime",
                   "scfmDriver", "scfmIgnition",
                   "scfmEscape", "scfmSpread", # Fire model
                   "loadYieldTables", "Hanzlik",
                   "strataMapFromVegMap", "scfmHarvest", # Harvesting
                   "stateVars", # Updating maps and variables
                   "birdsAlberta", # Bird model
                   "caribouAlberta") # Caribou population model
```

4. SpaDES in ACTION!

At last, we will run the simulation calling the `simInitAndSpades()` function. This function needs as inputs the paths, times, parameters, objects, and modules, apart from the *loadOrder* of the modules. If the load order is not provided, the modules might be loaded in a different order than these are supposed to, which might return an error due to missing objects.

FIRE

First, we will run the fire model:

```
FIREinAction <- simInitAndSpades(times = times,
                                 params = parameters,
                                 modules = modulesFire,
                                 objects = objects,
                                 paths = getPaths(),
                                 loadOrder = unlist(modulesFire))
```

```
## [1] "downloading NFDB"
## [1] "2019-08-17 16:33:31 | total elpsd: 0.003 secs | 0 checkpoint init 5"
## [1] "2019-08-17 16:33:31 | total elpsd: 0.005 secs | 0 save init 5"
## [1] "2019-08-17 16:33:31 | total elpsd: 0.008 secs | 0 progress init 5"
## [1] "2019-08-17 16:33:31 | total elpsd: 0.009 secs | 0 load init 5"
## [1] "2019-08-17 16:33:31 | total elpsd: 0.015 secs | 0 scfmLandcoverInit init 5"
## [1] "2019-08-17 16:33:31 | total elpsd: 0.76 secs | 0 scfmRegime init 5"
## [1] "2019-08-17 16:33:31 | total elpsd: 0.83 secs | 0 scfmDriver init 5"
## [1] "2019-08-17 16:33:33 | total elpsd: 2.8 secs | 0 scfmIgnition init 5"
## [1] "2019-08-17 16:33:33 | total elpsd: 2.8 secs | 0 scfmEscape init 5"
## [1] "2019-08-17 16:33:33 | total elpsd: 2.8 secs | 0 scfmSpread init 5"
## [1] "2019-08-17 16:33:33 | total elpsd: 2.8 secs | 0 scfmLandcoverInit plot 5"


## [1] "2019-08-17 16:33:34 | total elpsd: 3.2 secs | 0 scfmIgnition ignite 7.5"
## [1] "2019-08-17 16:33:34 | total elpsd: 3.2 secs | 0 scfmEscape escape 7.5"
## [1] "2019-08-17 16:33:34 | total elpsd: 3.3 secs | 0 scfmSpread burn 7.5"
## [1] "2019-08-17 16:33:34 | total elpsd: 3.9 secs | 1 scfmIgnition ignite 7.5"
## [1] "2019-08-17 16:33:34 | total elpsd: 3.9 secs | 1 scfmEscape escape 7.5"
## [1] "2019-08-17 16:33:35 | total elpsd: 3.9 secs | 1 scfmSpread burn 7.5"
## [1] "2019-08-17 16:33:35 | total elpsd: 4.6 secs | 1 scfmSpread plot 8"


## [1] "2019-08-17 16:33:37 | total elpsd: 6.3 secs | 2 scfmIgnition ignite 7.5"
```

```
## [1] "2019-08-17 16:33:37 | total elpsd: 6.3 secs | 2 scfmEscape escape 7.5"
## [1] "2019-08-17 16:33:37 | total elpsd: 6.3 secs | 2 scfmSpread burn 7.5"
## [1] "2019-08-17 16:33:37 | total elpsd: 6.8 secs | 2 scfmSpread plot 8"
## [1] "2019-08-17 16:33:38 | total elpsd: 7.6 secs | 3 scfmIgnition ignite 7.5"
## [1] "2019-08-17 16:33:38 | total elpsd: 7.6 secs | 3 scfmEscape escape 7.5"
## [1] "2019-08-17 16:33:38 | total elpsd: 7.6 secs | 3 scfmSpread burn 7.5"
## [1] "2019-08-17 16:33:38 | total elpsd: 7.6 secs | 3 scfmSpread plot 8"
## [1] "2019-08-17 16:33:39 | total elpsd: 8.4 secs | 4 scfmIgnition ignite 7.5"
## [1] "2019-08-17 16:33:39 | total elpsd: 8.4 secs | 4 scfmEscape escape 7.5"
## [1] "2019-08-17 16:33:39 | total elpsd: 8.5 secs | 4 scfmSpread burn 7.5"
## [1] "2019-08-17 16:33:40 | total elpsd: 9 secs | 4 scfmSpread plot 8"
## [1] "2019-08-17 16:33:40 | total elpsd: 9.8 secs | 5 scfmIgnition ignite 7.5"
## [1] "2019-08-17 16:33:40 | total elpsd: 9.8 secs | 5 scfmEscape escape 7.5"
## [1] "2019-08-17 16:33:40 | total elpsd: 9.8 secs | 5 scfmSpread burn 7.5"
## [1] "2019-08-17 16:33:41 | total elpsd: 10 secs | 5 scfmSpread plot 8"
## [1] "2019-08-17 16:33:42 | total elpsd: 11 secs | 6 scfmIgnition ignite 7.5"
## [1] "2019-08-17 16:33:42 | total elpsd: 11 secs | 6 scfmEscape escape 7.5"
## [1] "2019-08-17 16:33:42 | total elpsd: 11 secs | 6 scfmSpread burn 7.5"
## [1] "2019-08-17 16:33:42 | total elpsd: 12 secs | 6 scfmSpread plot 8"
## [1] "2019-08-17 16:33:43 | total elpsd: 13 secs | 7 scfmIgnition ignite 7.5"
## [1] "2019-08-17 16:33:43 | total elpsd: 13 secs | 7 scfmEscape escape 7.5"
## [1] "2019-08-17 16:33:43 | total elpsd: 13 secs | 7 scfmSpread burn 7.5"
## [1] "2019-08-17 16:33:44 | total elpsd: 13 secs | 7 scfmSpread plot 8"
## [1] "2019-08-17 16:33:45 | total elpsd: 14 secs | 8 scfmIgnition ignite 7.5"
## [1] "2019-08-17 16:33:45 | total elpsd: 14 secs | 8 scfmEscape escape 7.5"
## [1] "2019-08-17 16:33:45 | total elpsd: 14 secs | 8 scfmSpread burn 7.5"
## [1] "2019-08-17 16:33:45 | total elpsd: 14 secs | 8 scfmSpread plot 8"
## [1] "2019-08-17 16:33:45 | total elpsd: 15 secs | 9 scfmIgnition ignite 7.5"
## [1] "2019-08-17 16:33:45 | total elpsd: 15 secs | 9 scfmEscape escape 7.5"
## [1] "2019-08-17 16:33:45 | total elpsd: 15 secs | 9 scfmSpread burn 7.5"
## [1] "2019-08-17 16:33:46 | total elpsd: 15 secs | 9 scfmSpread plot 8"
## [1] "2019-08-17 16:33:47 | total elpsd: 16 secs | 10 scfmIgnition ignite 7.5"
## [1] "2019-08-17 16:33:47 | total elpsd: 16 secs | 10 scfmEscape escape 7.5"
## [1] "2019-08-17 16:33:47 | total elpsd: 16 secs | 10 scfmSpread burn 7.5"
## [1] "2019-08-17 16:33:47 | total elpsd: 17 secs | 10 scfmSpread plot 8"
```

Note that you can see all events happening, as well as any messages printed during the simulation. Really handy is also to see all plots while the simulation is running. This is really helpful to visually identify potential problems even before the simulation ends.

Now we will check some of the results from this simulation. First, lets check the age map, flammable map (where fire can burn), the last years' fires and the cummulative fire map:

We can also see some of the fire statistics such as:

1. Summary of burns

```
# Fire Summary
knitr::kable(FIREinAction$burnSummary)
```

igLoc	N	year	areaBurned	polyID
4566	1	0	100	108
4793	1	0	100	108

igLoc	N	year	areaBurned	polyID
4895	1	0	100	108
5229	1	0	100	108
7022	1	0	100	108
8606	1	0	100	108
8721	1	0	100	108
10229	1	0	100	108
10253	1	0	100	108
10288	1	0	100	108
10629	1	0	100	108
10885	26	0	2600	108
11261	1	0	100	108
11502	1	0	100	108
11928	1	0	100	108
12696	1	0	100	108
13188	1	0	100	108
13732	1	0	100	108
16108	1	0	100	108
17266	1	0	100	108
17833	1	0	100	108
19314	1	0	100	108
21895	1	0	100	108
24815	1	0	100	108
26295	1	0	100	108
27795	1	0	100	108
31447	2	0	200	108
6452	1	1	100	108
7013	1	1	100	108
8412	1	1	100	108
8503	1	1	100	108
8818	1	1	100	108
9057	1	1	100	108
11515	1	1	100	108
11971	1	1	100	108
13699	1	1	100	108
15162	53	1	5300	108
17389	1	1	100	108
17426	1	1	100	108
17540	2	1	200	108
18088	1	1	100	108
20113	1	1	100	108
20593	1	1	100	108
22251	1	1	100	108
22457	1	1	100	108
23164	1	1	100	108
23830	1	1	100	108
25509	1	1	100	108
25549	1	1	100	108
26461	1	1	100	108
27351	1	1	100	108
29620	1	1	100	108
1859	1	2	100	108
6565	1	2	100	108

igLoc	N	year	areaBurned	polyID
7716	1	2	100	108
8384	1	2	100	108
8724	1	2	100	108
9382	1	2	100	108
10229	2	2	200	108
10276	1	2	100	108
11525	1	2	100	108
11648	1	2	100	108
11950	1	2	100	108
13336	1	2	100	108
13972	1	2	100	108
14541	1	2	100	108
15477	1	2	100	108
18064	1	2	100	108
18405	1	2	100	108
18585	1	2	100	108
21099	1	2	100	108
21257	2	2	200	108
21353	1	2	100	108
21708	1	2	100	108
21771	1	2	100	108
22676	1	2	100	108
23027	2	2	200	108
26750	1	2	100	108
29883	1	2	100	108
32758	1	2	100	108
33717	1	2	100	108
5343	1	4	100	108
6846	1	4	100	108
8047	1	4	100	108
8224	1	4	100	108
8879	1	4	100	108
12560	1	4	100	108
12694	1	4	100	108
13082	1	4	100	108
13393	1	4	100	108
14285	1	4	100	108
14748	1	4	100	108
14873	1	4	100	108
15038	1	4	100	108
16046	1	4	100	108
16286	1	4	100	108
16635	1	4	100	108
16855	1	4	100	108
17233	1	4	100	108
17980	1	4	100	108
20809	1	4	100	108
21459	1	4	100	108
24628	46	4	4600	108
25323	1	4	100	108
27104	1	4	100	108
31699	1	4	100	108

igLoc	N	year	areaBurned	polyID
3770	1	5	100	108
4598	1	5	100	108
7568	1	5	100	108
8052	1	5	100	108
8209	1	5	100	108
9162	1	5	100	108
9171	1	5	100	108
9521	2	5	200	108
10859	1	5	100	108
13416	1	5	100	108
14508	1	5	100	108
15411	1	5	100	108
17640	1	5	100	108
18141	94	5	9400	108
18344	1	5	100	108
19900	1	5	100	108
20112	1	5	100	108
21230	1	5	100	108
22154	1	5	100	108
31675	1	5	100	108
5734	1	6	100	108
6241	1	6	100	108
6484	1	6	100	108
7117	1	6	100	108
7708	1	6	100	108
12273	1	6	100	108
12734	1	6	100	108
13237	1	6	100	108
13809	1	6	100	108
14077	1	6	100	108
14272	1	6	100	108
14452	1	6	100	108
14989	1	6	100	108
15775	1	6	100	108
16222	4	6	400	108
17605	1	6	100	108
18732	1	6	100	108
20552	1	6	100	108
21953	1	6	100	108
22607	1	6	100	108
25260	1	6	100	108
27539	1	6	100	108
27562	1	6	100	108
29885	1	6	100	108
29886	1	6	100	108
30108	1	6	100	108
31029	1	6	100	108
5021	34	7	3400	108
5939	1	7	100	108
6679	1	7	100	108
6930	1	7	100	108
9085	1	7	100	108

igLoc	N	year	areaBurned	polyID
10158	1	7	100	108
10197	1	7	100	108
13083	1	7	100	108
13433	1	7	100	108
15239	1	7	100	108
15550	1	7	100	108
16047	1	7	100	108
18202	1	7	100	108
20005	1	7	100	108
23034	1	7	100	108
23378	1	7	100	108
23909	1	7	100	108
25306	1	7	100	108
26741	92	7	9200	108
26881	1	7	100	108
27800	1	7	100	108
30518	1	7	100	108
32079	1	7	100	108
1640	1	9	100	108
4351	1	9	100	108
4607	1	9	100	108
5694	1	9	100	108
5907	1	9	100	108
7979	1	9	100	108
9253	1	9	100	108
9623	1	9	100	108
9999	1	9	100	108
14929	1	9	100	108
16188	1	9	100	108
17513	1	9	100	108
18125	1	9	100	108
19339	1	9	100	108
19936	1	9	100	108
20790	1	9	100	108
21508	1	9	100	108
21959	4	9	400	108
22453	1	9	100	108
23254	1	9	100	108
23694	1	9	100	108
25081	1	9	100	108
26047	1	9	100	108
27777	1	9	100	108
28681	1	9	100	108
4899	1	10	100	108
6606	1	10	100	108
6933	1	10	100	108
7460	1	10	100	108
9079	1	10	100	108
12581	1	10	100	108
13216	1	10	100	108
14781	1	10	100	108
15019	1	10	100	108

igLoc	N	year	areaBurned	polyID
16963	1	10	100	108
17051	1	10	100	108
19893	1	10	100	108
20575	1	10	100	108
20907	1	10	100	108
21698	1	10	100	108
22246	1	10	100	108
23020	1	10	100	108
23513	1	10	100	108
24729	1	10	100	108
28680	8	10	800	108

2. Probability of ignition of a pixel

```r
# Fire Summary
print(FIREinAction$pIg)
```

```
## [1] 0.001356465
```

3. Fire driver parameters

```r
# Fire Summary
FIREinAction$scfmDriverPars$`108`
```

```
## $pSpread
## [1] 0.2142647
##
## $p0
## [1] 0.007253892
##
## $naiveP0
## [1] 0.006775093
##
## $pIgnition
## [1] 0.001356465
##
## $maxBurnCells
## [1] 9589
##
## $calibModel
##
## Family: gaussian
## Link function: identity
##
## Formula:
## finalSize ~ s(p, bs = "micx", k = 20)
## <environment: 0x000000004a728d80>
##
## Estimated degrees of freedom:
## 3.84  total = 4.84
```

```
##
## GCV score: 73388180
##
##
## $uniroot.Res
## $uniroot.Res$root
## [1] 0.2142647
##
## $uniroot.Res$f.root
##             1
## -0.009185319
##
## $uniroot.Res$iter
## [1] 7
##
## $uniroot.Res$init.it
## [1] NA
##
## $uniroot.Res$estim.prec
## [1] 5e-06
```

HARVEST

Now, we will run the harvest model:

```
HARVESTinAction <- simInitAndSpades(times = times,
                                    params = parameters,
                                    modules = modulesHarvest,
                                    objects = objects,
                                    paths = getPaths(),
                                    loadOrder = unlist(modulesHarvest))
```

```
## [1] "2019-08-17 16:33:55 | total elpsd: 0.002 secs | 0 checkpoint init 5"
## [1] "2019-08-17 16:33:55 | total elpsd: 0.003 secs | 0 save init 5"
## [1] "2019-08-17 16:33:55 | total elpsd: 0.006 secs | 0 progress init 5"
## [1] "2019-08-17 16:33:55 | total elpsd: 0.007 secs | 0 load init 5"
## [1] "2019-08-17 16:33:55 | total elpsd: 0.012 secs | 0 scfmLandcoverInit init 5"
## [1] "2019-08-17 16:33:56 | total elpsd: 1.3 secs | 0 loadYieldTables init 5"
## [1] "2019-08-17 16:33:56 | total elpsd: 1.3 secs | 0 Hanzlik init 5"
## [1] "2019-08-17 16:33:56 | total elpsd: 1.3 secs | 0 strataMapFromVegMap init 5"
## [1] "2019-08-17 16:33:56 | total elpsd: 1.6 secs | 0 scfmHarvest init 5"
## [1] "2019-08-17 16:33:56 | total elpsd: 1.6 secs | 0 stateVars init 5"
## [1] "2019-08-17 16:33:56 | total elpsd: 1.6 secs | 0 scfmLandcoverInit plot 5"
## [1] "2019-08-17 16:33:57 | total elpsd: 1.9 secs | 0 Hanzlik plan 5"
## [1] "2019-08-17 16:33:57 | total elpsd: 1.9 secs | 0 strataMapFromVegMap plot 5"


## [1] "2019-08-17 16:33:57 | total elpsd: 2.5 secs | 0 scfmHarvest plot 5"
## [1] "2019-08-17 16:33:57 | total elpsd: 2.5 secs | 0 stateVars update 5"
## [1] "2019-08-17 16:33:57 | total elpsd: 2.6 secs | 0 stateVars plot 5"
## [1] "2019-08-17 16:33:57 | total elpsd: 2.6 secs | 1 scfmHarvest harvest 5"
## [1] "2019-08-17 16:33:58 | total elpsd: 3.1 secs | 1 scfmHarvest plot 5"
## [1] "2019-08-17 16:33:58 | total elpsd: 3.1 secs | 1 stateVars update 5"
## [1] "2019-08-17 16:33:58 | total elpsd: 3.2 secs | 1 stateVars plot 5"
```

```
## [1] "2019-08-17 16:33:58 | total elpsd: 3.2 secs | 2 scfmHarvest harvest 5"
## [1] "2019-08-17 16:33:58 | total elpsd: 3.6 secs | 2 scfmHarvest plot 5"
## [1] "2019-08-17 16:33:58 | total elpsd: 3.6 secs | 2 stateVars update 5"
## [1] "2019-08-17 16:33:58 | total elpsd: 3.7 secs | 2 stateVars plot 5"
## [1] "2019-08-17 16:33:58 | total elpsd: 3.7 secs | 3 scfmHarvest harvest 5"
## [1] "2019-08-17 16:33:59 | total elpsd: 4.1 secs | 3 scfmHarvest plot 5"
## [1] "2019-08-17 16:33:59 | total elpsd: 4.1 secs | 3 stateVars update 5"
## [1] "2019-08-17 16:33:59 | total elpsd: 4.2 secs | 3 stateVars plot 5"
## [1] "2019-08-17 16:33:59 | total elpsd: 4.2 secs | 4 scfmHarvest harvest 5"
## [1] "2019-08-17 16:33:59 | total elpsd: 4.6 secs | 4 scfmHarvest plot 5"
## [1] "2019-08-17 16:33:59 | total elpsd: 4.6 secs | 4 stateVars update 5"
## [1] "2019-08-17 16:33:59 | total elpsd: 4.6 secs | 4 stateVars plot 5"
## [1] "2019-08-17 16:33:59 | total elpsd: 4.7 secs | 5 scfmHarvest harvest 5"
## [1] "2019-08-17 16:34:00 | total elpsd: 5.1 secs | 5 scfmHarvest plot 5"
## [1] "2019-08-17 16:34:00 | total elpsd: 5.1 secs | 5 stateVars update 5"
## [1] "2019-08-17 16:34:00 | total elpsd: 5.1 secs | 5 stateVars plot 5"
## [1] "2019-08-17 16:34:00 | total elpsd: 5.1 secs | 6 scfmHarvest harvest 5"
## [1] "2019-08-17 16:34:00 | total elpsd: 5.5 secs | 6 scfmHarvest plot 5"
## [1] "2019-08-17 16:34:00 | total elpsd: 5.6 secs | 6 stateVars update 5"
## [1] "2019-08-17 16:34:00 | total elpsd: 5.6 secs | 6 stateVars plot 5"
## [1] "2019-08-17 16:34:00 | total elpsd: 5.6 secs | 7 scfmHarvest harvest 5"
## [1] "2019-08-17 16:34:01 | total elpsd: 6.1 secs | 7 scfmHarvest plot 5"
## [1] "2019-08-17 16:34:01 | total elpsd: 6.1 secs | 7 stateVars update 5"
## [1] "2019-08-17 16:34:01 | total elpsd: 6.1 secs | 7 stateVars plot 5"
## [1] "2019-08-17 16:34:01 | total elpsd: 6.1 secs | 8 scfmHarvest harvest 5"
## [1] "2019-08-17 16:34:01 | total elpsd: 6.6 secs | 8 scfmHarvest plot 5"
## [1] "2019-08-17 16:34:01 | total elpsd: 6.6 secs | 8 stateVars update 5"
## [1] "2019-08-17 16:34:01 | total elpsd: 6.7 secs | 8 stateVars plot 5"
## [1] "2019-08-17 16:34:01 | total elpsd: 6.7 secs | 9 scfmHarvest harvest 5"
## [1] "2019-08-17 16:34:02 | total elpsd: 7.2 secs | 9 scfmHarvest plot 5"
## [1] "2019-08-17 16:34:02 | total elpsd: 7.3 secs | 9 stateVars update 5"
## [1] "2019-08-17 16:34:02 | total elpsd: 7.3 secs | 9 stateVars plot 5"
## [1] "2019-08-17 16:34:02 | total elpsd: 7.3 secs | 10 Hanzlik plan 5"
## [1] "2019-08-17 16:34:02 | total elpsd: 7.4 secs | 10 scfmHarvest harvest 5"
## [1] "2019-08-17 16:34:03 | total elpsd: 7.8 secs | 10 scfmHarvest plot 5"
## [1] "2019-08-17 16:34:03 | total elpsd: 7.9 secs | 10 stateVars update 5"
## [1] "2019-08-17 16:34:03 | total elpsd: 7.9 secs | 10 stateVars plot 5"
```

Now we will check some of the results from this simulation. First, lets check the age map, disturbance map (where all the harvest was made), and the strata for harvesting:

We can also see some of the fire statistics such as harvest statistics (total harvested per strata)

Strata1	Strata2	Strata3	Strata4	Strata5	Strata6	Strata7	Strata8
287802	0	0	1169183	44892	391334	204370	0
258937	0	0	1183975	42473	389728	200817	0
267472	0	0	1213583	53020	371242	198521	0
345365	0	0	1248827	52100	366780	218129	0
267415	0	0	1184870	45149	391363	231659	0
256642	0	0	1163227	44245	378083	206462	0
252954	0	0	1160933	43679	377142	205043	0
255508	0	0	1183321	42654	377747	212498	0
320076	0	0	1160783	42084	376102	205254	0
263866	0	0	1081373	39900	348024	189453	0

INTEGRATED MODEL

Now, we will integrate the fire, harvesting, birds and caribou:

```
SpaDESinAction <- simInitAndSpades(times = times,
                                   params = parameters,
                                   modules = allModules,
                                   objects = objects,
                                   paths = getPaths(),
                                   loadOrder = unlist(allModules))
```

```
## [1] "downloading NFDB"
## [1] "2019-08-17 16:34:05 | total elpsd: 0.001 secs | 0 checkpoint init 5"
## [1] "2019-08-17 16:34:05 | total elpsd: 0.004 secs | 0 save init 5"
## [1] "2019-08-17 16:34:05 | total elpsd: 0.008 secs | 0 progress init 5"
## [1] "2019-08-17 16:34:05 | total elpsd: 0.01 secs | 0 load init 5"
## [1] "2019-08-17 16:34:05 | total elpsd: 0.017 secs | 0 scfmLandcoverInit init 5"
## [1] "2019-08-17 16:34:06 | total elpsd: 0.86 secs | 0 scfmRegime init 5"
## [1] "2019-08-17 16:34:06 | total elpsd: 0.89 secs | 0 scfmDriver init 5"
## [1] "2019-08-17 16:34:08 | total elpsd: 3.2 secs | 0 scfmIgnition init 5"
## [1] "2019-08-17 16:34:08 | total elpsd: 3.2 secs | 0 scfmEscape init 5"
## [1] "2019-08-17 16:34:08 | total elpsd: 3.2 secs | 0 scfmSpread init 5"
## [1] "2019-08-17 16:34:08 | total elpsd: 3.2 secs | 0 loadYieldTables init 5"
## [1] "2019-08-17 16:34:08 | total elpsd: 3.2 secs | 0 Hanzlik init 5"
## [1] "2019-08-17 16:34:08 | total elpsd: 3.2 secs | 0 strataMapFromVegMap init 5"
## [1] "2019-08-17 16:34:08 | total elpsd: 3.6 secs | 0 scfmHarvest init 5"
## [1] "2019-08-17 16:34:08 | total elpsd: 3.6 secs | 0 stateVars init 5"
## [1] "2019-08-17 16:34:08 | total elpsd: 3.6 secs | 0 birdsAlberta init 5"
## [1] "2019-08-17 16:34:08 | total elpsd: 3.6 secs | 0 caribouAlberta init 5"
## [1] "2019-08-17 16:34:08 | total elpsd: 3.6 secs | 0 scfmLandcoverInit plot 5"
## [1] "2019-08-17 16:34:09 | total elpsd: 3.9 secs | 0 Hanzlik plan 5"
## [1] "2019-08-17 16:34:09 | total elpsd: 3.9 secs | 0 strataMapFromVegMap plot 5"

## [1] "2019-08-17 16:34:09 | total elpsd: 4.6 secs | 0 scfmHarvest plot 5"
## [1] "2019-08-17 16:34:09 | total elpsd: 4.6 secs | 0 stateVars update 5"
## [1] "2019-08-17 16:34:09 | total elpsd: 4.6 secs | 0 stateVars plot 5"
## [1] "2019-08-17 16:34:09 | total elpsd: 4.7 secs | 0 birdsAlberta model 5"
## [1] "2019-08-17 16:34:13 | total elpsd: 8 secs | 0 birdsAlberta plot 5"

## [1] "2019-08-17 16:34:13 | total elpsd: 8.4 secs | 0 caribouAlberta stats 5"
## [1] "2019-08-17 16:34:13 | total elpsd: 8.5 secs | 0 scfmIgnition ignite 7.5"
## [1] "2019-08-17 16:34:13 | total elpsd: 8.5 secs | 0 scfmEscape escape 7.5"
## [1] "2019-08-17 16:34:13 | total elpsd: 8.5 secs | 0 scfmSpread burn 7.5"
## [1] "2019-08-17 16:34:14 | total elpsd: 9.3 secs | 0 caribouAlberta plot 10"

## [1] "2019-08-17 16:34:15 | total elpsd: 10 secs | 1 scfmHarvest harvest 5"
## [1] "2019-08-17 16:34:15 | total elpsd: 10 secs | 1 scfmHarvest plot 5"
## [1] "2019-08-17 16:34:15 | total elpsd: 10 secs | 1 stateVars update 5"
## [1] "2019-08-17 16:34:15 | total elpsd: 10 secs | 1 stateVars plot 5"
## [1] "2019-08-17 16:34:15 | total elpsd: 11 secs | 1 caribouAlberta stats 5"
## [1] "2019-08-17 16:34:15 | total elpsd: 11 secs | 1 caribouAlberta plot 5"
## [1] "2019-08-17 16:34:16 | total elpsd: 11 secs | 1 scfmIgnition ignite 7.5"
## [1] "2019-08-17 16:34:16 | total elpsd: 11 secs | 1 scfmEscape escape 7.5"
## [1] "2019-08-17 16:34:16 | total elpsd: 11 secs | 1 scfmSpread burn 7.5"
## [1] "2019-08-17 16:34:16 | total elpsd: 12 secs | 1 scfmSpread plot 8"
```

```
## [1] "2019-08-17 16:34:18 | total elpsd: 13 secs | 2 scfmHarvest harvest 5"
## [1] "2019-08-17 16:34:18 | total elpsd: 14 secs | 2 scfmHarvest plot 5"
## [1] "2019-08-17 16:34:18 | total elpsd: 14 secs | 2 stateVars update 5"
## [1] "2019-08-17 16:34:19 | total elpsd: 14 secs | 2 stateVars plot 5"
## [1] "2019-08-17 16:34:19 | total elpsd: 14 secs | 2 caribouAlberta stats 5"
## [1] "2019-08-17 16:34:19 | total elpsd: 14 secs | 2 caribouAlberta plot 5"
## [1] "2019-08-17 16:34:19 | total elpsd: 14 secs | 2 scfmIgnition ignite 7.5"
## [1] "2019-08-17 16:34:19 | total elpsd: 14 secs | 2 scfmEscape escape 7.5"
## [1] "2019-08-17 16:34:19 | total elpsd: 14 secs | 2 scfmSpread burn 7.5"
## [1] "2019-08-17 16:34:19 | total elpsd: 15 secs | 2 scfmSpread plot 8"
## [1] "2019-08-17 16:34:20 | total elpsd: 16 secs | 3 scfmHarvest harvest 5"
## [1] "2019-08-17 16:34:21 | total elpsd: 16 secs | 3 scfmHarvest plot 5"
## [1] "2019-08-17 16:34:21 | total elpsd: 16 secs | 3 stateVars update 5"
## [1] "2019-08-17 16:34:21 | total elpsd: 16 secs | 3 stateVars plot 5"
## [1] "2019-08-17 16:34:21 | total elpsd: 16 secs | 3 caribouAlberta stats 5"
## [1] "2019-08-17 16:34:21 | total elpsd: 16 secs | 3 caribouAlberta plot 5"
## [1] "2019-08-17 16:34:21 | total elpsd: 16 secs | 3 scfmIgnition ignite 7.5"
## [1] "2019-08-17 16:34:21 | total elpsd: 16 secs | 3 scfmEscape escape 7.5"
## [1] "2019-08-17 16:34:21 | total elpsd: 16 secs | 3 scfmSpread burn 7.5"
## [1] "2019-08-17 16:34:22 | total elpsd: 17 secs | 3 scfmSpread plot 8"
## [1] "2019-08-17 16:34:23 | total elpsd: 18 secs | 4 scfmHarvest harvest 5"
## [1] "2019-08-17 16:34:23 | total elpsd: 18 secs | 4 scfmHarvest plot 5"
## [1] "2019-08-17 16:34:23 | total elpsd: 18 secs | 4 stateVars update 5"
## [1] "2019-08-17 16:34:23 | total elpsd: 18 secs | 4 stateVars plot 5"
## [1] "2019-08-17 16:34:23 | total elpsd: 19 secs | 4 caribouAlberta stats 5"
## [1] "2019-08-17 16:34:23 | total elpsd: 19 secs | 4 caribouAlberta plot 5"
## [1] "2019-08-17 16:34:24 | total elpsd: 19 secs | 4 scfmIgnition ignite 7.5"
## [1] "2019-08-17 16:34:24 | total elpsd: 19 secs | 4 scfmEscape escape 7.5"
## [1] "2019-08-17 16:34:24 | total elpsd: 19 secs | 4 scfmSpread burn 7.5"
## [1] "2019-08-17 16:34:24 | total elpsd: 19 secs | 4 scfmSpread plot 8"
## [1] "2019-08-17 16:34:25 | total elpsd: 20 secs | 5 scfmHarvest harvest 5"
## [1] "2019-08-17 16:34:25 | total elpsd: 21 secs | 5 scfmHarvest plot 5"
## [1] "2019-08-17 16:34:25 | total elpsd: 21 secs | 5 stateVars update 5"
## [1] "2019-08-17 16:34:26 | total elpsd: 21 secs | 5 stateVars plot 5"
## [1] "2019-08-17 16:34:26 | total elpsd: 21 secs | 5 caribouAlberta stats 5"
## [1] "2019-08-17 16:34:26 | total elpsd: 21 secs | 5 caribouAlberta plot 5"
## [1] "2019-08-17 16:34:26 | total elpsd: 21 secs | 5 scfmIgnition ignite 7.5"
## [1] "2019-08-17 16:34:26 | total elpsd: 21 secs | 5 scfmEscape escape 7.5"
## [1] "2019-08-17 16:34:26 | total elpsd: 21 secs | 5 scfmSpread burn 7.5"
## [1] "2019-08-17 16:34:26 | total elpsd: 21 secs | 5 scfmSpread plot 8"
## [1] "2019-08-17 16:34:27 | total elpsd: 22 secs | 6 scfmHarvest harvest 5"
## [1] "2019-08-17 16:34:27 | total elpsd: 22 secs | 6 scfmHarvest plot 5"
## [1] "2019-08-17 16:34:27 | total elpsd: 22 secs | 6 stateVars update 5"
## [1] "2019-08-17 16:34:27 | total elpsd: 22 secs | 6 stateVars plot 5"
## [1] "2019-08-17 16:34:27 | total elpsd: 22 secs | 6 caribouAlberta stats 5"
## [1] "2019-08-17 16:34:27 | total elpsd: 22 secs | 6 caribouAlberta plot 5"
## [1] "2019-08-17 16:34:27 | total elpsd: 22 secs | 6 scfmIgnition ignite 7.5"
## [1] "2019-08-17 16:34:27 | total elpsd: 22 secs | 6 scfmEscape escape 7.5"
## [1] "2019-08-17 16:34:27 | total elpsd: 22 secs | 6 scfmSpread burn 7.5"
## [1] "2019-08-17 16:34:28 | total elpsd: 23 secs | 6 scfmSpread plot 8"
## [1] "2019-08-17 16:34:29 | total elpsd: 24 secs | 7 scfmHarvest harvest 5"
## [1] "2019-08-17 16:34:29 | total elpsd: 24 secs | 7 scfmHarvest plot 5"
## [1] "2019-08-17 16:34:29 | total elpsd: 24 secs | 7 stateVars update 5"
## [1] "2019-08-17 16:34:29 | total elpsd: 24 secs | 7 stateVars plot 5"
```

```
## [1] "2019-08-17 16:34:29 | total elpsd: 24 secs | 7 caribouAlberta stats 5"
## [1] "2019-08-17 16:34:29 | total elpsd: 24 secs | 7 caribouAlberta plot 5"
## [1] "2019-08-17 16:34:29 | total elpsd: 25 secs | 7 scfmIgnition ignite 7.5"
## [1] "2019-08-17 16:34:29 | total elpsd: 25 secs | 7 scfmEscape escape 7.5"
## [1] "2019-08-17 16:34:29 | total elpsd: 25 secs | 7 scfmSpread burn 7.5"
## [1] "2019-08-17 16:34:30 | total elpsd: 25 secs | 7 scfmSpread plot 8"
## [1] "2019-08-17 16:34:31 | total elpsd: 26 secs | 8 scfmHarvest harvest 5"
## [1] "2019-08-17 16:34:31 | total elpsd: 27 secs | 8 scfmHarvest plot 5"
## [1] "2019-08-17 16:34:31 | total elpsd: 27 secs | 8 stateVars update 5"
## [1] "2019-08-17 16:34:31 | total elpsd: 27 secs | 8 stateVars plot 5"
## [1] "2019-08-17 16:34:32 | total elpsd: 27 secs | 8 caribouAlberta stats 5"
## [1] "2019-08-17 16:34:32 | total elpsd: 27 secs | 8 caribouAlberta plot 5"
## [1] "2019-08-17 16:34:32 | total elpsd: 27 secs | 8 scfmIgnition ignite 7.5"
## [1] "2019-08-17 16:34:32 | total elpsd: 27 secs | 8 scfmEscape escape 7.5"
## [1] "2019-08-17 16:34:32 | total elpsd: 27 secs | 8 scfmSpread burn 7.5"
## [1] "2019-08-17 16:34:32 | total elpsd: 28 secs | 8 scfmSpread plot 8"
## [1] "2019-08-17 16:34:33 | total elpsd: 28 secs | 9 scfmHarvest harvest 5"
## [1] "2019-08-17 16:34:34 | total elpsd: 29 secs | 9 scfmHarvest plot 5"
## [1] "2019-08-17 16:34:34 | total elpsd: 29 secs | 9 stateVars update 5"
## [1] "2019-08-17 16:34:34 | total elpsd: 29 secs | 9 stateVars plot 5"
## [1] "2019-08-17 16:34:34 | total elpsd: 29 secs | 9 caribouAlberta stats 5"
## [1] "2019-08-17 16:34:34 | total elpsd: 29 secs | 9 caribouAlberta plot 5"
## [1] "2019-08-17 16:34:34 | total elpsd: 29 secs | 9 scfmIgnition ignite 7.5"
## [1] "2019-08-17 16:34:34 | total elpsd: 29 secs | 9 scfmEscape escape 7.5"
## [1] "2019-08-17 16:34:34 | total elpsd: 29 secs | 9 scfmSpread burn 7.5"
## [1] "2019-08-17 16:34:35 | total elpsd: 30 secs | 9 scfmSpread plot 8"
## [1] "2019-08-17 16:34:36 | total elpsd: 31 secs | 10 Hanzlik plan 5"
## [1] "2019-08-17 16:34:36 | total elpsd: 31 secs | 10 birdsAlberta model 5"
## [1] "2019-08-17 16:34:46 | total elpsd: 42 secs | 10 birdsAlberta plot 5"
## [1] "2019-08-17 16:34:46 | total elpsd: 42 secs | 10 scfmHarvest harvest 5"
## [1] "2019-08-17 16:34:47 | total elpsd: 42 secs | 10 scfmHarvest plot 5"
## [1] "2019-08-17 16:34:47 | total elpsd: 42 secs | 10 stateVars update 5"
## [1] "2019-08-17 16:34:47 | total elpsd: 42 secs | 10 stateVars plot 5"
## [1] "2019-08-17 16:34:47 | total elpsd: 42 secs | 10 caribouAlberta stats 5"
## [1] "2019-08-17 16:34:47 | total elpsd: 42 secs | 10 caribouAlberta plot 5"
## [1] "2019-08-17 16:34:47 | total elpsd: 43 secs | 10 scfmIgnition ignite 7.5"
## [1] "2019-08-17 16:34:47 | total elpsd: 43 secs | 10 scfmEscape escape 7.5"
## [1] "2019-08-17 16:34:47 | total elpsd: 43 secs | 10 scfmSpread burn 7.5"
## [1] "2019-08-17 16:34:48 | total elpsd: 43 secs | 10 scfmSpread plot 8"
```

Now we will check some of the results from this simulation. First, lets check the birds:

We can even make some cool analysis with these results, such as answering how many birds were lost in the 10 years of the simulation:
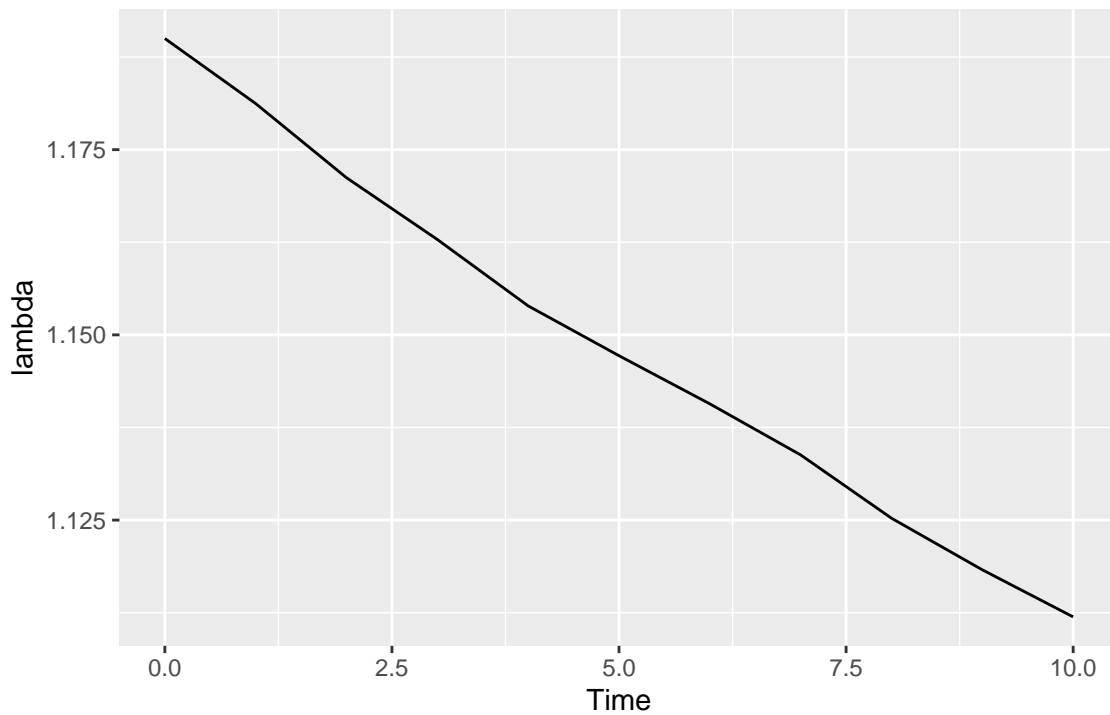
COWA Delta presence probability from year 0 to 10

RBNU Delta presence probability from year 0 to 10

We can also see some of the caribou outputs:

1. Lambda through time

Caribou lambda through time

2. Lambda and population size through time

Lambda	Nt
1.190000	105102
1.181219	105102
1.171210	105102
1.162872	105102
1.153908	105102
1.147184	105102
1.140688	105102
1.133792	105102
1.125252	105102
1.118287	105102
1.111933	105102

Hands-on

Are you ready to start on SpaDES? You can either play around with these modules (change parameters or change the study the area) or you can start you very own module. For that, you can simply type:

```
newModule("ModuleName", path = getPaths()$modulePath)
```

Happy SpaDESing!!!