Simple MixFishSim Example

This is a simple example of how to use **'MixFishSim'** to generate simulations of dynamics in a mixed fishery.

Load MixFishSim

```
library(MixFishSim)
library(knitr)
opts_chunk$set(tidy = TRUE)
```

Initialise the simulation

Base parameters

First we specify the basic parameters of the simulation. This includes the size of the spatial domain, the number of years to simulate, the number of fleets and vessels per fleet and the number of species for the simulation etc...

The object returned is used internally by MixFishSim a list with two objects:

- sim$idx : The different units of different processes
- sim$brk.idx: breaks for each of the key processes in units of a timestep

```
sim <- init_sim(nrows = 20, ncols = 10, n_years = 10, n_tows_day = 4, n_days_wk_fished = 5,
    n_fleets = 5, n_vessels = 2, n_species = 2, move_freq = 2)

class(sim)
```

```
## [1] "list"
```

```
sim$idx
```

```
##          ntd          ndf           nw          nwm           nt           nm
##     4.000000     5.000000    52.000000     4.333333    26.000000    12.000000
##           ny         ntow      ntow.py        n.spp        ncols        nrows
##    10.000000 10400.000000  1040.000000     2.000000    10.000000    20.000000
##           nf           nv
##     5.000000     2.000000
```

```
names(sim$brk.idx)
```

```
## [1] "tow.breaks"   "day.seq"      "day.breaks"   "trip.breaks"  "week.breaks"
## [6] "month.breaks" "year.breaks"
```

Habitat setup

This function creates the spatial fields which support the fish populations and fisheries. You define the parameters for the mattern covariance function for each population and optionally the location of any

spawning closure areas.

It returns a list of suitable habitat for each species (hab), the habitat as adjusted during the spawning period (spwn_hab) and the binary location of spawning areas (spwn_loc). It also returns the locations as x1,x2,y1,y2 and the multiplier of attractiveness to the spawning area during spawning periods (spwn_mult).

If plot.dist = TRUE, it returns the plots to a file.

```
hab <- create_hab(sim_init = sim, spp.ctrl = list(spp.1 = list(nu = 1/0.015, var = 1,
    scale = 1, Aniso = matrix(nc = 2, c(1.5, 3, -3, 4))), spp.2 = list(nu = 1/0.05,
    var = 2, scale = 12, Aniso = matrix(nc = 2, c(1, 2, -1, 2)))), spawn_areas = list(spp1 = list(area1
    5, 2, 5), area2 = c(6, 8, 6, 8)), spp2 = list(area1 = c(5, 6, 6, 6)), spwn_mult = 10,
    plot.dist = FALSE))

print(hab)
```

```
## $hab
## $hab$spp1
##              [,1]        [,2]        [,3]         [,4]         [,5]        [,6]
##  [1,] 0.000000000 0.000000000 0.000000000 0.0051401459 7.779569e-05 0.000000000
##  [2,] 0.000000000 0.000000000 0.000000000 0.0000000000 5.216751e-03 0.003438088
##  [3,] 0.021091897 0.000000000 0.000000000 0.0000000000 0.000000e+00 0.000000000
##  [4,] 0.001042289 0.000000000 0.029295988 0.0000000000 8.703246e-03 0.000000000
##  [5,] 0.001754513 0.000000000 0.016476590 0.0000000000 0.000000e+00 0.000000000
##  [6,] 0.023229163 0.000000000 0.000000000 0.0040491579 4.480217e-03 0.000000000
##  [7,] 0.006337180 0.011248102 0.000000000 0.0060854766 1.486987e-02 0.000000000
##  [8,] 0.000000000 0.002123207 0.000000000 0.0007432731 5.954530e-03 0.000000000
##  [9,] 0.000000000 0.000000000 0.010535068 0.0124904745 0.000000e+00 0.000000000
## [10,] 0.000000000 0.016913291 0.000000000 0.0278100233 1.553643e-02 0.012422512
## [11,] 0.016548959 0.005845127 0.003425107 0.0000000000 1.351515e-02 0.000000000
## [12,] 0.004940663 0.000000000 0.000000000 0.0000000000 7.481440e-03 0.008199673
## [13,] 0.005446650 0.012103485 0.000000000 0.0134886616 3.262938e-03 0.000000000
## [14,] 0.001521164 0.011939878 0.018528980 0.0000000000 0.000000e+00 0.000000000
## [15,] 0.000000000 0.011174512 0.000000000 0.0000000000 1.838840e-02 0.007029422
## [16,] 0.024163475 0.009370834 0.020520652 0.0138467752 0.000000e+00 0.004108011
## [17,] 0.006841307 0.007537622 0.000000000 0.0000000000 2.958189e-02 0.001448928
## [18,] 0.000000000 0.000000000 0.007828406 0.0000000000 2.087438e-02 0.000000000
## [19,] 0.009385788 0.000000000 0.001709581 0.0023863694 0.000000e+00 0.000000000
## [20,] 0.000000000 0.000000000 0.002930756 0.0000000000 0.000000e+00 0.000000000
##               [,7]        [,8]         [,9]       [,10]
##  [1,] 0.0015930140 0.009501664 0.0142537134 0.000000000
##  [2,] 0.0000000000 0.000000000 0.0000000000 0.017042832
##  [3,] 0.0000000000 0.000000000 0.0000000000 0.000000000
##  [4,] 0.0000000000 0.000000000 0.0438115802 0.000000000
##  [5,] 0.0249512745 0.000000000 0.0000000000 0.000000000
##  [6,] 0.0000000000 0.000000000 0.0040136350 0.000000000
##  [7,] 0.0031494092 0.000000000 0.0086361187 0.015016970
##  [8,] 0.0010684011 0.009231643 0.0000000000 0.001209972
##  [9,] 0.0000000000 0.028473883 0.0069705746 0.010214890
## [10,] 0.0000000000 0.000000000 0.0050251283 0.000000000
## [11,] 0.0195554360 0.010594036 0.0000000000 0.002875530
## [12,] 0.0061936527 0.010457147 0.0008722438 0.000000000
## [13,] 0.0005834516 0.004540992 0.0000000000 0.001263657
## [14,] 0.0000000000 0.000000000 0.0288170356 0.000000000
## [15,] 0.0000000000 0.000000000 0.0000000000 0.000000000
## [16,] 0.0152029429 0.000000000 0.0000000000 0.026968393
```

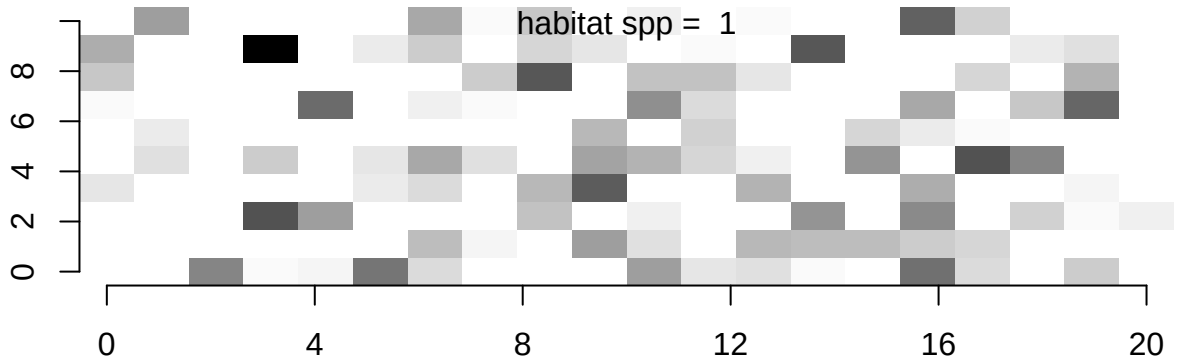
```
## [17,] 0.0000000000 0.007607356 0.0004498937 0.008246010
## [18,] 0.0099361855 0.000000000 0.0042065516 0.000000000
## [19,] 0.0258900594 0.013206606 0.0059278480 0.000000000
## [20,] 0.0000000000 0.000000000 0.0000000000 0.000000000
##
## $hab$spp2
##               [,1]          [,2]          [,3]          [,4]          [,5]
##  [1,] 0.0185567054 0.0175380218 0.0159868547 0.0141641496 0.0123407090
##  [2,] 0.0174177959 0.0157840061 0.0138605251 0.0119478596 0.0102977434
##  [3,] 0.0154976183 0.0135192688 0.0115385209 0.0098379229 0.0086138770
##  [4,] 0.0131169678 0.0110912951 0.0093274292 0.0080574333 0.0074126542
##  [5,] 0.0106190838 0.0087764395 0.0074037455 0.0066793752 0.0066724018
##  [6,] 0.0082495193 0.0067165773 0.0058139018 0.0056714740 0.0062877803
##  [7,] 0.0061136062 0.0049428757 0.0045357772 0.0049617197 0.0061192533
##  [8,] 0.0042206362 0.0034449433 0.0035372938 0.0044703209 0.0060080827
##  [9,] 0.0025623015 0.0022235404 0.0027933636 0.0041073521 0.0057860588
## [10,] 0.0011668434 0.0013005385 0.0022736519 0.0037715120 0.0053096655
## [11,] 0.0001044034 0.0006984293 0.0019297184 0.0033671683 0.0045051163
## [12,] 0.0000000000 0.0004084340 0.0016894627 0.0028236640 0.0033893027
## [13,] 0.0000000000 0.0003596192 0.0014554419 0.0021040728 0.0020605251
## [14,] 0.0000000000 0.0004081824 0.0011188088 0.0012175137 0.0006849908
## [15,] 0.0000000000 0.0003731054 0.0006060733 0.0002479081 0.0000000000
## [16,] 0.0000000000 0.0001198164 0.0000000000 0.0000000000 0.0000000000
## [17,] 0.0000000000 0.0000000000 0.0000000000 0.0000000000 0.0000000000
## [18,] 0.0000000000 0.0000000000 0.0000000000 0.0000000000 0.0000000000
## [19,] 0.0000000000 0.0000000000 0.0000000000 0.0000000000 0.0008799386
## [20,] 0.0000000000 0.0000000000 0.0000000000 0.0006429482 0.0027128505
##               [,6]         [,7]         [,8]         [,9]        [,10]
##  [1,] 0.0107267209 0.009438113 0.008492527 0.007822893 0.007301920
##  [2,] 0.0090659964 0.008297408 0.007929953 0.007812562 0.007736272
##  [3,] 0.0079513997 0.007816258 0.008058839 0.008435644 0.008656530
##  [4,] 0.0074052494 0.007915242 0.008693540 0.009399424 0.009681341
##  [5,] 0.0073154411 0.008385892 0.009523340 0.010304848 0.010369003
##  [6,] 0.0074930051 0.008942040 0.010172140 0.010730140 0.010325266
##  [7,] 0.0077083842 0.009263953 0.010271645 0.010335609 0.009320678
##  [8,] 0.0077166581 0.009058637 0.009559593 0.008976733 0.007383842
##  [9,] 0.0073051104 0.008146572 0.007978937 0.006776359 0.004816751
## [10,] 0.0063620511 0.006536801 0.005718662 0.004102452 0.002107058
## [11,] 0.0049227797 0.004435921 0.003160194 0.001454105 0.000000000
## [12,] 0.0031591151 0.002183615 0.000762419 0.000000000 0.000000000
## [13,] 0.0013303110 0.000163960 0.000000000 0.000000000 0.000000000
## [14,] 0.0000000000 0.000000000 0.000000000 0.000000000 0.000000000
## [15,] 0.0000000000 0.000000000 0.000000000 0.000000000 0.000577040
## [16,] 0.0000000000 0.000000000 0.000000000 0.001380796 0.003255568
## [17,] 0.0000000000 0.000344623 0.002153559 0.004252397 0.006182425
## [18,] 0.0007547305 0.002726314 0.005040094 0.007217134 0.008758947
## [19,] 0.0029459486 0.005425947 0.007846252 0.009673378 0.010481090
## [20,] 0.0052724909 0.007887057 0.010011110 0.011163478 0.011077278
##
##
## $spwn_hab
## $spwn_hab$spp1
##               [,1]         [,2]         [,3]         [,4]         [,5]
##  [1,] 0.0000000000 0.000000000 0.000000000 0.0030996884 4.691353e-05
```

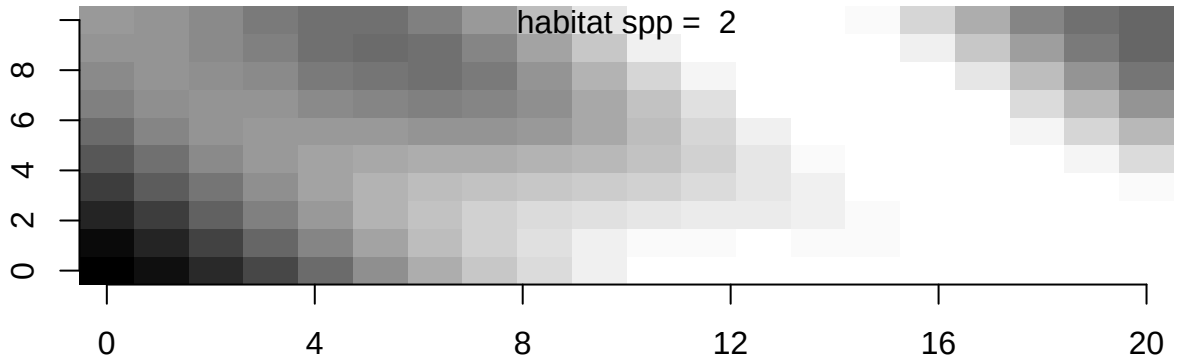
```
##  [2,] 0.0000000000 0.000000000 0.000000000 0.0000000000 3.145884e-02
##  [3,] 0.0127191543 0.000000000 0.000000000 0.0000000000 0.000000e+00
##  [4,] 0.0006285371 0.000000000 0.176665090 0.0000000000 5.248363e-02
##  [5,] 0.0010580327 0.000000000 0.099359621 0.0000000000 0.000000e+00
##  [6,] 0.0140080007 0.000000000 0.000000000 0.0024417844 2.701728e-03
##  [7,] 0.0038215422 0.006783000 0.000000000 0.0036697560 8.967057e-03
##  [8,] 0.0000000000 0.001280368 0.000000000 0.0004482198 3.590790e-03
##  [9,] 0.0000000000 0.000000000 0.006353016 0.0075321946 0.000000e+00
## [10,] 0.0000000000 0.010199308 0.000000000 0.0167704203 9.369012e-03
## [11,] 0.0099796030 0.003524817 0.002065460 0.0000000000 8.150108e-03
## [12,] 0.0029793931 0.000000000 0.000000000 0.0000000000 4.511571e-03
## [13,] 0.0032845210 0.007298826 0.000000000 0.0081341365 1.967666e-03
## [14,] 0.0009173156 0.007200165 0.011173625 0.0000000000 0.000000e+00
## [15,] 0.0000000000 0.006738623 0.000000000 0.0000000000 1.108885e-02
## [16,] 0.0145714235 0.005650942 0.012374674 0.0083500915 0.000000e+00
## [17,] 0.0041255482 0.004545450 0.000000000 0.0000000000 1.783892e-02
## [18,] 0.0000000000 0.000000000 0.004720803 0.0000000000 1.258799e-02
## [19,] 0.0056599599 0.000000000 0.001030937 0.0014390645 0.000000e+00
## [20,] 0.0000000000 0.000000000 0.001767349 0.0000000000 0.000000e+00
##               [,6]         [,7]         [,8]         [,9]         [,10]
##  [1,] 0.0000000000 0.0009606433 0.005729837 0.0085954896 0.0000000000
##  [2,] 0.0020732878 0.0000000000 0.000000000 0.0000000000 0.0102774263
##  [3,] 0.0000000000 0.0000000000 0.000000000 0.0000000000 0.0000000000
##  [4,] 0.0000000000 0.0000000000 0.000000000 0.0264199209 0.0000000000
##  [5,] 0.0000000000 0.0150464945 0.000000000 0.0000000000 0.0000000000
##  [6,] 0.0000000000 0.0000000000 0.000000000 0.0024203628 0.0000000000
##  [7,] 0.0000000000 0.0189920432 0.000000000 0.0052078827 0.0090557603
##  [8,] 0.0000000000 0.0064428336 0.055670045 0.0000000000 0.0007296554
##  [9,] 0.0000000000 0.0000000000 0.017170751 0.0042035012 0.0061599376
## [10,] 0.0074912107 0.0000000000 0.000000000 0.0030303288 0.0000000000
## [11,] 0.0000000000 0.0117926144 0.006388576 0.0000000000 0.0017340454
## [12,] 0.0049446908 0.0037349900 0.006306027 0.0005259936 0.0000000000
## [13,] 0.0000000000 0.0003518418 0.002738378 0.0000000000 0.0007620297
## [14,] 0.0000000000 0.0000000000 0.000000000 0.0173776841 0.0000000000
## [15,] 0.0042389880 0.0000000000 0.000000000 0.0000000000 0.0000000000
## [16,] 0.0024772751 0.0091679083 0.000000000 0.0000000000 0.0162628879
## [17,] 0.0008737545 0.0000000000 0.004587503 0.0002713017 0.0049726335
## [18,] 0.0000000000 0.0059918687 0.000000000 0.0025366983 0.0000000000
## [19,] 0.0000000000 0.0156126147 0.007964047 0.0035747005 0.0000000000
## [20,] 0.0000000000 0.0000000000 0.000000000 0.0000000000 0.0000000000
##
## $spwn_hab$spp2
##               [,1]         [,2]         [,3]         [,4]         [,5]
##  [1,] 1.637439e-02 0.0154755078 0.0141067617 0.0124984112 0.0108894116
##  [2,] 1.536942e-02 0.0139277686 0.0122304937 0.0105427622 0.0090867037
##  [3,] 1.367506e-02 0.0119293699 0.0101815628 0.0086809592 0.0076008641
##  [4,] 1.157438e-02 0.0097869318 0.0082305008 0.0071098595 0.0065409081
##  [5,] 9.370254e-03 0.0077443089 0.0065330470 0.0058938644 0.0058877111
##  [6,] 7.279356e-03 0.0059266915 0.0051301728 0.0050044949 0.0055483221
##  [7,] 5.394631e-03 0.0043615815 0.0040023588 0.0043782094 0.0053996142
##  [8,] 3.724279e-03 0.0030398096 0.0031212995 0.0039446003 0.0053015176
##  [9,] 2.260969e-03 0.0019620466 0.0024648572 0.0036243175 0.0051056042
## [10,] 1.029620e-03 0.0011475920 0.0020062649 0.0033279730 0.0046852360
## [11,] 9.212529e-05 0.0006162923 0.0017027788 0.0029711811 0.0039753037
```

```
## [12,] 0.000000e+00 0.0003604012 0.0014907778 0.0024915942 0.0029907124
## [13,] 0.000000e+00 0.0003173271 0.0012842784 0.0018566287 0.0018182023
## [14,] 0.000000e+00 0.0003601792 0.0009872341 0.0010743311 0.0006044342
## [15,] 0.000000e+00 0.0003292273 0.0005347976 0.0002187535 0.0000000000
## [16,] 0.000000e+00 0.0001057257 0.0000000000 0.0000000000 0.0000000000
## [17,] 0.000000e+00 0.0000000000 0.0000000000 0.0000000000 0.0000000000
## [18,] 0.000000e+00 0.0000000000 0.0000000000 0.0000000000 0.0000000000
## [19,] 0.000000e+00 0.0000000000 0.0000000000 0.0000000000 0.0007764557
## [20,] 0.000000e+00 0.0000000000 0.0000000000 0.0005673360 0.0023938127
##               [,6]         [,7]         [,8]        [,9]        [,10]
##  [1,] 0.0094652324 0.0083281681 0.0074937850 0.006902901 0.0064431963
##  [2,] 0.0079998132 0.0073216130 0.0069973711 0.006893786 0.0068264679
##  [3,] 0.0070162957 0.0068970475 0.0071111000 0.007443592 0.0076385007
##  [4,] 0.0065343740 0.0069843903 0.0076711583 0.008294029 0.0085427922
##  [5,] 0.0645512741 0.0073996911 0.0084033718 0.009092973 0.0091495833
##  [6,] 0.0661180952 0.0078904343 0.0089758720 0.009468249 0.0091109900
##  [7,] 0.0068018595 0.0081744900 0.0090636750 0.009120116 0.0082245433
##  [8,] 0.0068091603 0.0079933189 0.0084353620 0.007921048 0.0065154842
##  [9,] 0.0064460117 0.0071885153 0.0070405950 0.005979443 0.0042502893
## [10,] 0.0056138584 0.0057680574 0.0050461338 0.003619993 0.0018592624
## [11,] 0.0043438489 0.0039142458 0.0027885471 0.001283099 0.0000000000
## [12,] 0.0027875955 0.0019268165 0.0006727567 0.000000000 0.0000000000
## [13,] 0.0011738632 0.0001446779 0.0000000000 0.000000000 0.0000000000
## [14,] 0.0000000000 0.0000000000 0.0000000000 0.000000000 0.0000000000
## [15,] 0.0000000000 0.0000000000 0.0000000000 0.000000000 0.0005091787
## [16,] 0.0000000000 0.0000000000 0.0000000000 0.001218411 0.0028727049
## [17,] 0.0000000000 0.0003040945 0.0019002955 0.003752305 0.0054553572
## [18,] 0.0006659724 0.0024056927 0.0044473669 0.006368381 0.0077288732
## [19,] 0.0025994979 0.0047878425 0.0069235137 0.008535766 0.0092484886
## [20,] 0.0046524331 0.0069595202 0.0088337794 0.009850626 0.0097745632
##
##
## $spwn_loc
## $spwn_loc$spp1
##       [,1] [,2] [,3] [,4] [,5] [,6] [,7] [,8] [,9] [,10]
##  [1,]    0    0    0    0    0    0    0    0    0     0
##  [2,]    0    1    1    1    1    0    0    0    0     0
##  [3,]    0    1    1    1    1    0    0    0    0     0
##  [4,]    0    1    1    1    1    0    0    0    0     0
##  [5,]    0    1    1    1    1    0    0    0    0     0
##  [6,]    0    0    0    0    0    1    1    1    0     0
##  [7,]    0    0    0    0    0    1    1    1    0     0
##  [8,]    0    0    0    0    0    1    1    1    0     0
##  [9,]    0    0    0    0    0    0    0    0    0     0
## [10,]    0    0    0    0    0    0    0    0    0     0
## [11,]    0    0    0    0    0    0    0    0    0     0
## [12,]    0    0    0    0    0    0    0    0    0     0
## [13,]    0    0    0    0    0    0    0    0    0     0
## [14,]    0    0    0    0    0    0    0    0    0     0
## [15,]    0    0    0    0    0    0    0    0    0     0
## [16,]    0    0    0    0    0    0    0    0    0     0
## [17,]    0    0    0    0    0    0    0    0    0     0
## [18,]    0    0    0    0    0    0    0    0    0     0
## [19,]    0    0    0    0    0    0    0    0    0     0
```

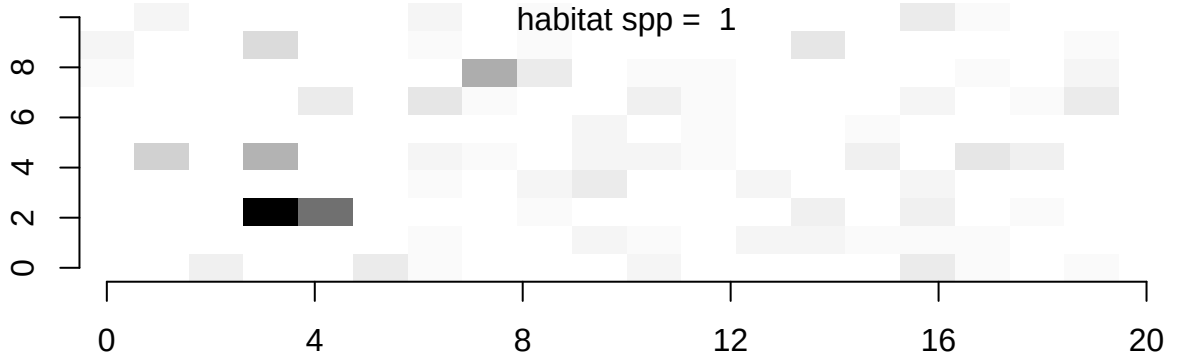
```
## [20,]    0    0    0    0    0    0    0    0    0     0
##
## $spwn_loc$spp2
##       [,1] [,2] [,3] [,4] [,5] [,6] [,7] [,8] [,9] [,10]
##  [1,]    0    0    0    0    0    0    0    0    0     0
##  [2,]    0    0    0    0    0    0    0    0    0     0
##  [3,]    0    0    0    0    0    0    0    0    0     0
##  [4,]    0    0    0    0    0    0    0    0    0     0
##  [5,]    0    0    0    0    0    1    0    0    0     0
##  [6,]    0    0    0    0    0    1    0    0    0     0
##  [7,]    0    0    0    0    0    0    0    0    0     0
##  [8,]    0    0    0    0    0    0    0    0    0     0
##  [9,]    0    0    0    0    0    0    0    0    0     0
## [10,]    0    0    0    0    0    0    0    0    0     0
## [11,]    0    0    0    0    0    0    0    0    0     0
## [12,]    0    0    0    0    0    0    0    0    0     0
## [13,]    0    0    0    0    0    0    0    0    0     0
## [14,]    0    0    0    0    0    0    0    0    0     0
## [15,]    0    0    0    0    0    0    0    0    0     0
## [16,]    0    0    0    0    0    0    0    0    0     0
## [17,]    0    0    0    0    0    0    0    0    0     0
## [18,]    0    0    0    0    0    0    0    0    0     0
## [19,]    0    0    0    0    0    0    0    0    0     0
## [20,]    0    0    0    0    0    0    0    0    0     0
##
##
## $spawn_areas
## $spawn_areas$spp1
## $spawn_areas$spp1$area1
## [1] 2 5 2 5
##
## $spawn_areas$spp1$area2
## [1] 6 8 6 8
##
##
## $spawn_areas$spp2
## $spawn_areas$spp2$area1
## [1] 5 6 6 6
##
##
## $spawn_areas$spwn_mult
## [1] 10
##
## $spawn_areas$plot.dist
## [1] FALSE
```

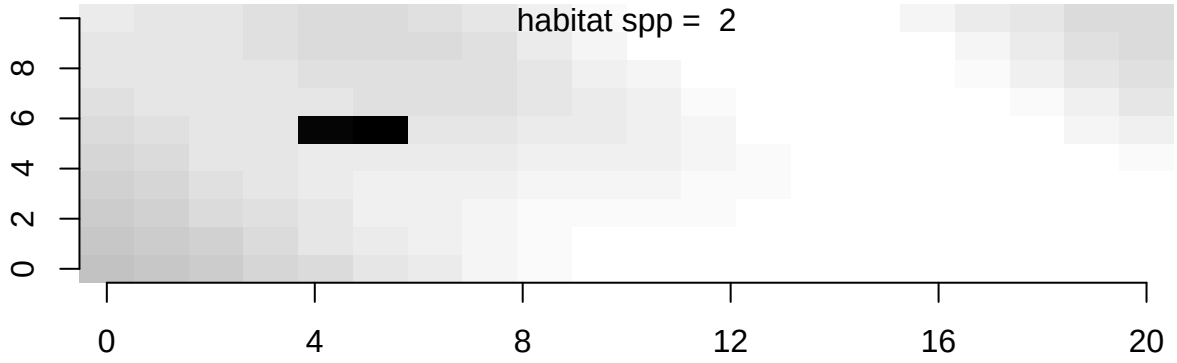
```
## Plot the unadjusted habitat fields
plot_habitat(hab$hab)
```






```
## Plot the adjusted habitat fields
plot_habitat(hab$spwn_hab)
```





Population models

Now we need to set up the population models for the simulations. We do this with the init_pop function. We set the initial population biomasses, movement rates, recruitment parameter and growth and natural mortality rates.

The object created stores all the starting conditions and containers for the changes in the populations during the simulations.

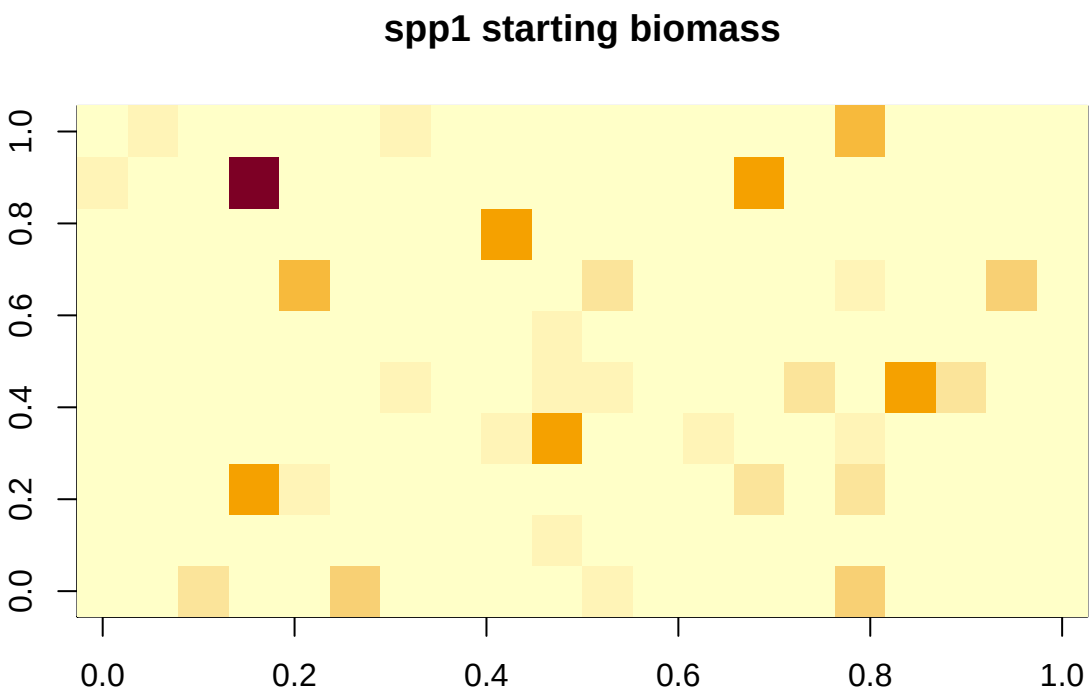
```
Pop <- init_pop(sim_init = sim, Bio = c(spp1 = 1e+05, spp2 = 1000), hab = hab[["hab"]],
    start_cell = c(5, 5), lambda = c(spp1 = 0.1, spp2 = 0.1), init_move_steps = 20,
    rec_params = list(spp1 = c(model = "BH", a = 4, b = 2, cv = 0.7), spp2 = c(model = "BH",
        a = 27, cv = 0.3)), rec_wk = list(spp1 = 3:6, spp2 = 4:8), spwn_wk = list(spp1 = 4:8,
        spp2 = 4:8), M = c(spp1 = 0.2, spp2 = 0.2), K = c(spp1 = 0.3, spp2 = 0.3))

names(Pop)
```

```
## [1] "Pop_record" "Start_pop"  "dem_params"
```

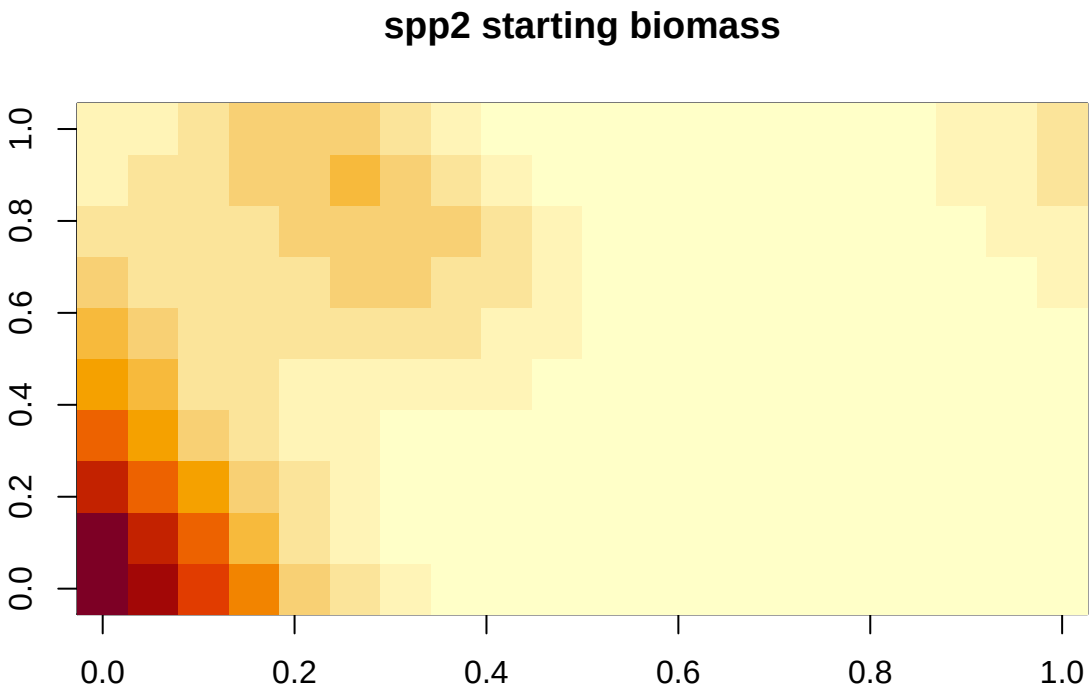
```
Pop$dem_params
```

```
## $spp1
## $spp1$rec_params
## model     a     b    cv
##  "BH"   "4"   "2" "0.7"
##
## $spp1$rec_wk
## [1] 3 4 5 6
##
## $spp1$spwn_wk
## [1] 4 5 6 7 8
##
## $spp1$M
## [1] 0.2
##
## $spp1$K
## [1] 0.3
##
##
## $spp2
## $spp2$rec_params
## model     a    cv
##  "BH"  "27" "0.3"
##
## $spp2$rec_wk
## [1] 4 5 6 7 8
##
## $spp2$spwn_wk
## [1] 4 5 6 7 8
##
## $spp2$M
## [1] 0.2
##
## $spp2$K
## [1] 0.3
```

```
image(Pop$Start_pop[[1]], main = "spp1 starting biomass")
```




```
image(Pop$Start_pop[[2]], main = "spp2 starting biomass")
```



Population movement

Now we set up the population tolerance to different temperatures. We can then plot the combined spatiotemporal suitable habitat.

```
moveCov <- init_moveCov(sim_init = sim, steps = 52, spp_tol = list(spp1 = list(mu = 12,
    va = 8), spp2 = list(mu = 15, va = 7)))

plot_spatiotemp_hab(hab = hab, moveCov = moveCov, spwn_wk = list(spp1 = 4:8, spp2 = 4:8))
```