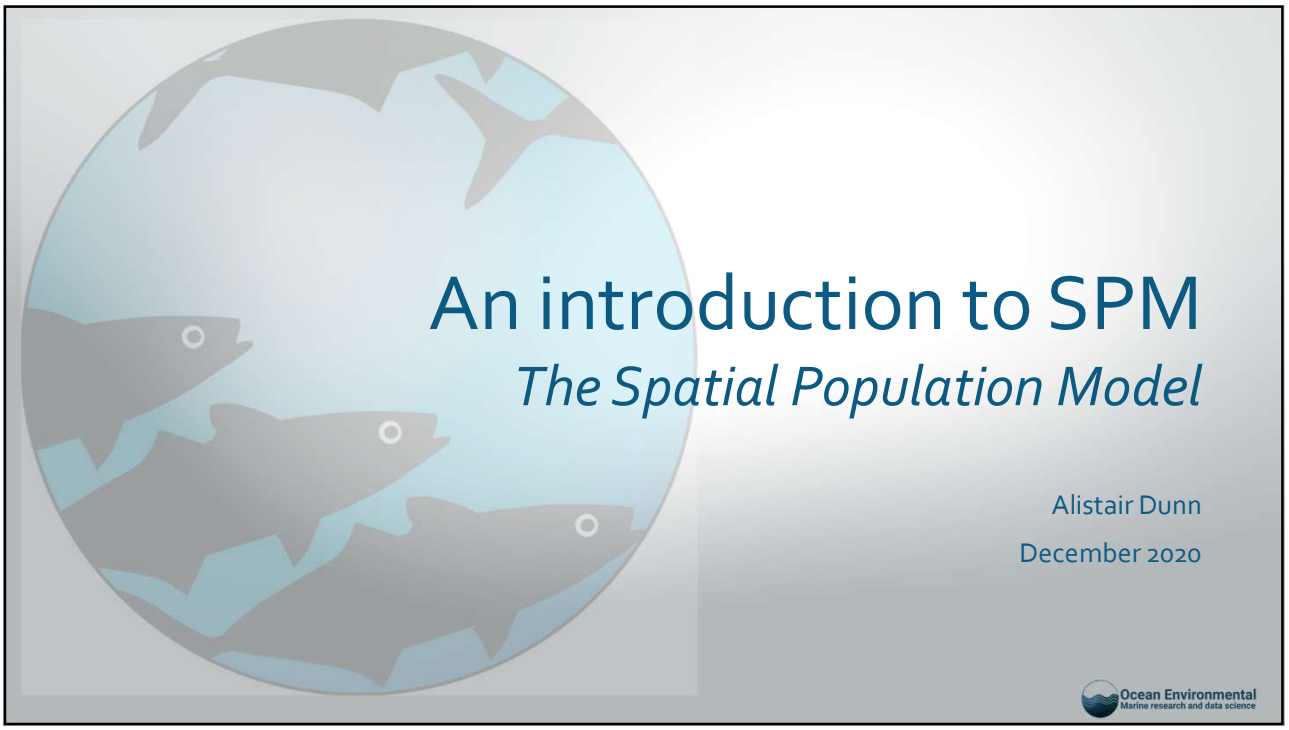

An introduction to SPM

The Spatial Population Model

Alistair Dunn

December 2020

Ocean Environmental
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An introduction to SPM

A short course in using SPM

Two sessions

– 11 December 2020

– 18 December 2020

Dunn, A.; Rasmussen, S.; Mormede, S. (2020). Spatial Population Model User Manual, SPM 2.0.3-2020-08-29. Ocean Environmental Technical Report. Ocean Environmental Ltd. Wellington, New Zealand. 235 p.

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An introduction to SPM
Session 2

The Spatial Population Model

Alistair Dunn

December 2020

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Rcap

- Introduction to SPM
- The config file, commands and subcommands
- The population section
  - Model structure; Initialisation; Time steps and processes; Preference functions; Biological information; Ancillary information (layers, derived parameters, etc.)

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Partition structure (categories x ages)

Categories	Age=1	Age=2	Age=3	Age=4+
Male_immature	…	…	…	…
Female_immature	…	…	…	…
Male_mature	…	…	…	…
Female_mature	…	…	…	…

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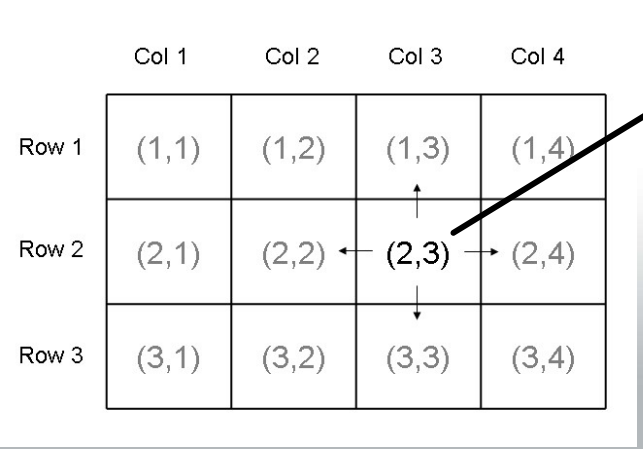
Spatial structure (rows x cols)



Categories	Age=1	Age=2	Age=3	Age=4+
Male_immature	…	…	…	…
Female_immature	…	…	…	…
Male_mature	…	…	…	…
Female_mature	…	…	…	…

Within each spatial cell, we record that cell's population partition

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Homework

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Consider a spatial model of size 10 x 6, with ages 1–50+ and categories male and female.

The @model command may look something like:

```
@model
Nrows 10
ncols 6
layer base
categories male female
min_age 1
max_age 50
age_plus_group True
initialisation_phases initialisation
initial_year 2000
current_year 2020
cell_length 10
time_steps one two three
age_size vonB vonB
```

1. Modify the categories in @ model to allow for tagging of males and females
2. Create an example process that would "tag" fish by using the @category_transition_by_age process
3. Create a new process that applies a tag-loss of 10% per year for the tagged fish
4. What observation type could be used to observe tag-recaptures?
5. Create an example of that observation for the tag-recaptures that occurs in timestep two (a simple example, for one set of recapture observations will suffice).

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Brief overview: Estimation section

- Estimation methods (and associated parameters)
  - Point estimates, profiles, and MCMCs
- Defining estimated parameters
- Constraints and penalties

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Brief overview: Observation section

- Definitions of observations
  - Observed values
  - Likelihoods and variance/sample sizes
- Proportions-at-age
- Proportions-at-length
- Proportions-by-category
- Proportions-by-category-at-length
- Abundance
- Biomass
- Presence/absence

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Brief overview: Report section

- Determines the information that is written to output
  - Defines the file or files where the get written
- WARNING

  If there are NO @report commands, then SPM will produce NO output!

The estimation section

- The role of the estimation section is:
  - Define the objective function
  - Define the parameters to be estimated
  - Calculate a point estimate, i.e., the maximum posterior density estimate (MPD)
  - Calculate a posterior profile selected parameters, i.e., find, for each of a series of values of a parameter, allowing the other estimated parameters to vary, the minimum value of the objective function
  - Generate an MCMC sample from the posterior distribution
  - Calculate the approximate covariance matrix of the parameters as the inverse of the minimizer's approximation to the Hessian, and the corresponding correlation matrix
- The estimation section defines the objective function, parameters of the model, and the method of estimation (point estimates, Bayesian posteriors, profiles, etc.). The objective function is based on a goodness-of-fit measure of the model to observations, priors and penalties.

The objective function

- The objective function (negative log likelihood + priors + penalties)

$$Objective(p) = -\sum_i \log\left[L\left(\mathbf{p}|O_i\right)\right] - \log\left[\pi\left(\mathbf{p}\right)\right]$$

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Estimating parameters

- Use the @estimate command
- To force two parameters to be the same, use the same subcommand

```
@estimate process[MyRecruitment].r0
lower_bound 1000
upper_bound 100000
type uniform


@estimate process[SelectivityOne].a50
same process[SelectivityTwo].a50
process[SelectivityThree].a50
lower_bound 3
upper_bound 15
type uniform
```


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The free parameter file

- SPM command line options to read/write a set of 'free parameters'
- -i file: Input one or more sets of free (estimated) parameter values from file
- -o file: Output a report of the free (estimated) parameter values in a format suitable for –i file
  - Can also be achieved with an @report (**@report[label].type=estimate value)**

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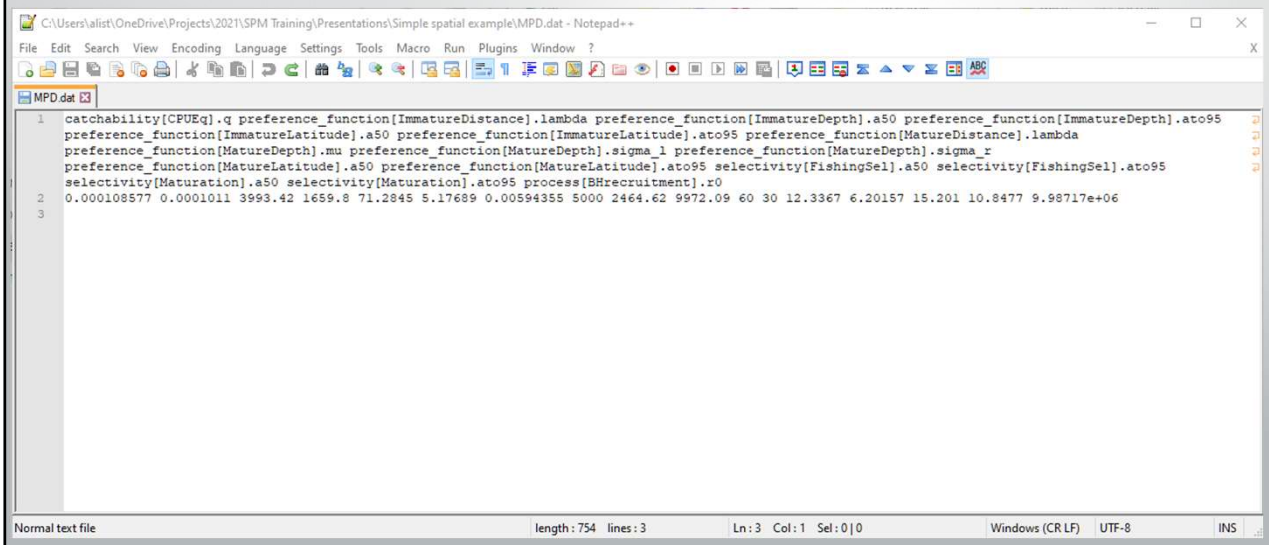

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The –i file is useful in simulations

- E.g., **spm – i myParameters.dat –s 10**
- This simulates 10 sets of observations *for every line* of the file myParameters.dat

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Observation section

- Definitions of observations
  - Observed values
  - Likelihoods and variance/sample sizes
- Types of observation
  - Proportions-at-age
  - Proportions-at-length
  - Proportions-by-category
  - Proportions-by-category-at-length
  - Abundance
  - Biomass
  - Presence/absence

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Observations (1)

- Each observation is an observation of *something* in a year, at a time step, across a number of spatial cells
- Observations can

  contribute to the likelihood, *or*

  be included as pseudo-observations, *or*

  be included as observations for the purposes of simulation

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Observations (2)

- Observations are supplied as observations at an instance in time (possibly over some spatially aggregated area)
- Time series of observations can be supplied as separate observations for each year or point in time
- Observations are evaluated at the end of a time step
  - But the expected values can be inferred at any point in time between the start and the end of a time step. Seep **proportion_method** in each observations class

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Observation section

- Composition frequencies
  - Proportions-at-age: Observations of proportions at age within categories
  - Proportions-at-length: Observations of proportions at length bin within categories
- Proportions between categories (i.e., proportions mature)
  - Proportions-by-category: Observations of proportions by categories within age classes
  - Proportions-by-category-at-length: Observations of proportions by categories within age classes
- Biomass and abundance observations (CPUE, surveys, etc)
  - Abundance: Relative and absolute abundance (number of fish)
  - Biomass: Relative and absolute biomass (biomass of fish)
- Other
  - Presence/absence: relative proportions present

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Example observation

```
@observation CAA-1998
type proportions_at_age
year 1998
time_step one
categories immature + mature
selectivities FishingSel FishingSel
min_age 1
max_age 30
tolerance 0.01
age_plus_group True
layer cell
obs r2-c5 0 0 0 0.00409 0.02146 0.00831 0.03836 0.08325 0.06242 0.0854 0.04601 0.11228 0.10244 0.10034 0.05299 0.08555 0.03529 0.02007 0.02677 0.01919 0.01346 0.00775 0.01172 0.01619 0.00961
    0.00835 0.0102 0.00139 0.0051 0.01201
obs r3-c5 0 0 0 0.0106 0.05965 0.06659 0.08638 0.09012 0.05422 0.07038 0.03536 0.07119 0.08309 0.06637 0.05554 0.06758 0.03451 0.02003 0.01972 0.01173 0.0076 0.02246 0.00401 0.01228 0.01052
    0.00861 0.01125 0.00187 0.00479 0.01356
obs r3-c6 0 0 0 0.00292 0.02815 0.02446 0.0929 0.09571 0.05486 0.09705 0.04577 0.07974 0.08562 0.06695 0.05308 0.08523 0.03656 0.03178 0.02135 0.01951 0.01904 0.01915 0.00374 0.00666 0.003
    0.00518 0.01215 0.00148 0 0.00498
obs r4-c3 0 0 0.09996 0.09197 0.19014 0.05221 0.06872 0.09092 0.00622 0.05409 0.05004 0.05407 0.03955 0.04152 0.00656 0.03235 0.00656 0 0 0.00983 0.01748 0.00983 0.00874 0.01967 0.00361
    0.00874 0.00983 0.00361 0 0
obs r4-c4 0 0 0.04694 0.10581 0.23716 0.06041 0.07292 0.09645 0.06859 0.07861 0.03401 0.05064 0.03765 0.02733 0.01321 0.02297 0.0058 0.00757 0.00392 0.00069 0.00262 0.00358 0.00173 0.00116
    0.007 0 0.00153 0 0.00129 0.00095
obs r4-c6 0 0 0 0 0 0.00435 0.00435 0 0 0.00725 0.01812 0.02754 0.05072 0.12319 0.07029 0.11014 0.03551 0.06232 0.07935 0.07645 0.02826 0.05725 0.02029 0.05942 0.02899 0.05072 0.02391 0.0087
    0.02029 0.03261
error_value r2-c5 148
error_value r3-c5 132
error_value r3-c6 119
error_value r4-c3 35
error_value r4-c4 157
error_value r4-c6 58
likelihood multinomial
delta 1e-11
```


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Observations

- Syntax is specific to each type of observations
- There can be some tricky syntax in the sub-commands!

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Proportions-at-age (1)

```
@observation CAA-1998
type proportions_at_age
year 1998
time_step one
categories immature + mature
selectivities FishingSel FishingSel
min_age 1
max_age 30
tolerance 0.01
age_plus_group True
layer cell
obs r2-c5 0 0 0 0.00409 0.02146 0.00831 …
obs r3-c5 0 0 0 0.0106 0.05965 0.06659 …
obs r3-c6 0 0 0 0.00292 0.02815 0.02446 …
obs r4-c3 0 0 0.09996 0.09197 0.19014 …
obs r4-c4 0 0 0.04694 0.10581 0.23716 …
obs r4-c6 0 0 0 0 0 0.00435 0.00435 0 …
error_value r2-c5 148
error_value r3-c5 132
error_value r3-c6 119
error_value r4-c3 35
error_value r4-c4 157
error_value r4-c6 58
likelihood multinomial
delta 1e-11

@report CAA-1998
type observation
observation CAA-1998
```

Note the names of the "spatial cells"

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Proportions-at-age (1)

```
@observation CAA-1998
type proportions_at_age
year 1998
time_step one
categories immature + mature
selectivities FishingSel FishingSel
min_age 1
max_age 30
tolerance 0.01
age_plus_group True
layer cell
obs r2-c5 0 0 0 0.00409 0.02146 0.00831 …
obs r3-c5 0 0 0 0.0106 0.05965 0.06659 …
obs r3-c6 0 0 0 0.00292 0.02815 0.02446 …
obs r4-c3 0 0 0.09996 0.09197 0.19014 …
obs r4-c4 0 0 0.04694 0.10581 0.23716 …
obs r4-c6 0 0 0 0 0 0.00435 0.00435 0 …
error_value r2-c5 148
error_value r3-c5 132
error_value r3-c6 119
error_value r4-c3 35
error_value r4-c4 157
error_value r4-c6 58
likelihood multinomial
delta 1e-11

@report CAA-1998
type observation
observation CAA-1998
```

Note the names of the "spatial cells"

```
# Base cell reference map
@layer cell
type categorical
data r1-c1 r1-c2 r1-c3 r1-c4 r1-c5 r1-c6 r1-c7 r1-c8 r1-c9 r1-c10
data r2-c1 r2-c2 r2-c3 r2-c4 r2-c5 r2-c6 r2-c7 r2-c8 r2-c9 r2-c10
data r3-c1 r3-c2 r3-c3 r3-c4 r3-c5 r3-c6 r3-c7 r3-c8 r3-c9 r3-c10
data r4-c1 r4-c2 r4-c3 r4-c4 r4-c5 r4-c6 r4-c7 r4-c8 r4-c9 r4-c10
data r5-c1 r5-c2 r5-c3 r5-c4 r5-c5 r5-c6 r5-c7 r5-c8 r5-c9 r5-c10
data r6-c1 r6-c2 r6-c3 r6-c4 r6-c5 r6-c6 r6-c7 r6-c8 r6-c9 r6-c10
```


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Proportions-at-age (3)

```
@observation CAA-1998
type proportions_at_age
year 1998
time_step one
categories immature + mature
selectivities FishingSel FishingSel
min_age 1
max_age 30
tolerance 0.01
age_plus_group True
layer SSRU
obs 881M 0 0 0 0.00409 0.02146 0.00831 …
obs 881J 0 0 0 0.0106 0.05965 0.06659 …
obs 882A 0 0 0 0.00292 0.02815 0.02446 …
obs 881K 0 0 0.09996 0.09197 0.19014 …
obs 881C 0 0 0.04694 0.10581 0.23716 …
obs 881D 0 0 0 0 0 0.00435 0.00435 0 …
error_value 881M 148
error_value 881J 132
error_value 882A 119
error_value 881K 35
error_value 881C 157
error_value 881D 58
likelihood multinomial
delta 1e-11

@report CAA-1998
type observation
observation CAA-1998
```

```
# SSRUs
@layer SSRU
type categorical
data Other Other Other 881M 881J 881L 882B 882C 882D 882D
data Other Other Other 881M 881J 881K 882A 882B 882C 882D
data Other Other 881F 881H 881H 881I 882A 882B 882B 882C
data Other 881D 881E 881E 881G 881C 882A 882A 882B 882C
data 881A 881A 881A 881A 881B 881C 882A 882A 882B 882B
data Other 881A 881A 881B 881C 881C 882A Other Other
```


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Proportions-at-age (4)

```
@observation CAA-1998
type proportions_at_age
year 1998
time_step one
categories immature + mature
selectivities FishingSel FishingSel
min_age 1
max_age 30
tolerance 0.01
age_plus_group True
layer cell
obs r2-c5 0 0 0 0.00409 0.02146 0.00831 0.03836 0.08325 0.06242 0.0854 0.04601 0.11228 0.10244 0.10034 0.05299 0.08555 0.03529 0.02007 0.02677 0.01919 0.01346 0.00775 0.01172 0.01619 0.00961
                0.00835 0.0102 0.00139 0.0051 0.01201
obs r3-c5 0 0 0 0.0106 0.05965 0.06659 0.08638 0.09012 0.05422 0.07038 0.03536 0.07119 0.08309 0.06637 0.05554 0.06758 0.03451 0.02003 0.01972 0.01173 0.0076 0.02246 0.00401 0.01228 0.01052
                0.00861 0.01125 0.00187 0.00479 0.01356
obs r3-c6 0 0 0 0.00292 0.02815 0.02446 0.0929 0.09571 0.05486 0.09705 0.04577 0.07974 0.08562 0.06695 0.05308 0.08523 0.03656 0.03178 0.02135 0.01951 0.01904 0.01915 0.00374 0.00666 0.003
                0.00518 0.01215 0.00148 0 0.00498
obs r4-c3 0 0 0.09996 0.09197 0.19014 0.05221 0.06872 0.09092 0.00622 0.05409 0.05004 0.05407 0.03955 0.04152 0.00656 0.03235 0.00656 0 0 0.00983 0.01748 0.00983 0.00874 0.01967 0.00361
                0.00874 0.00983 0.00361 0 0
obs r4-c4 0 0 0 0.04694 0.10581 0.23716 0.06041 0.07292 0.09645 0.06859 0.07861 0.03401 0.05064 0.03765 0.02733 0.01321 0.02297 0.0058 0.00757 0.00392 0.00069 0.00262 0.00358 0.00173 0.00116
                0.007 0 0.00153 0 0.00129 0.00095
obs r4-c6 0 0 0 0 0 0.00435 0.00435 0 0 0.00725 0.01812 0.02754 0.05072 0.12319 0.07029 0.11014 0.03551 0.06232 0.07935 0.07645 0.02826 0.05725 0.02029 0.05942 0.02899 0.05072 0.02391 0.0087
                0.02029 0.03261
error_value r2-c5 148
error_value r3-c5 132
error_value r3-c6 119
error_value r4-c3 35
error_value r4-c4 157
error_value r4-c6 58
likelihood multinomial
delta 1e-11
process_error 50
```


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Proportions-at-age (5)

```
@observation CAA-1998a
type proportions_at_age
year 1998
time_step one
categories immature + mature
selectivities FishingSel FishingSel
min_age 1
max_age 30
tolerance 0.01
age_plus_group True


@observation CAA-1998b
…
categories immature  mature
…

@observation CAA-1998c
…
categories male_immature  + male_mature   female_immature + female_immature
…
```

Combined categories

Separate categories

Combined & separate categories

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Proportions-by-category

```
# Proportions mature (2002)
@observation mature-2002
type proportions_by_category
year 2002
time_step one
categories mature
categories2 immature
selectivities FishingSel
selectivities2 FishingSel
min_age 1
max_age 30
age_plus_group True
layer cell
obs r1-c6 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
obs r1-c7 0 0 0 0 0 0 0 0 0 0 0 0 1 0 1 1 1 1 1 1 1 0 1 1 1 0 0 1 0 1
error_value r1-c6 0 0 0 0 0 0 0 0 0 0 0 0 0.787321602766333 0.34561403690674 1.13656511836189 0.339598241696144 1.97260446913269
        1.63108455705452 2.61832196981598 1.89204376675641 0.617082446534434 1.01619406867846 0.506579197325262 1.04978500403117
        1.35523207671698 0.26735423045293 0.313148903242939 1.25399868831737 0.363334993774255 0.303227308894021
        0.312798722780255
error_value r1-c7 0 0 0 0 0 0 0 0 0 0 0 0 0.351374171679312 0.00564558759137334 0.895055623231706 0.87507361556791 0.928122482467766
        1.53171257719831 0.695603300220298 0.903583975480345 1.68662506324844 0.0348463028891523 0.53670383340713
        0.430556416668389 0.478921468852145 0 0 0.333738157718646 0 0.410913872452334
likelihood binomial
delta 1e-11
```


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Likelihoods

- Different likelihoods available (and depending the observation)
- Does allow likelihood modifiers
  - Likelihood (defines the likelihood for the observation)
  - process_error (modifies the c.v.s or the N)
  - likelihood_multiplier (scaler on the likelihood)
  - simulation_likelihood (define the likelihood for simulations, if different)

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Other observations

- Other observations
  - Proportions-at-length
  - Proportions-by-category-at-length
  - Abundance
  - Biomass
  - Presence/absence
- Slightly different syntax (as required for the different types)

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The report section

- Determines the information that is written to output
- A wide range of reports available
  - Print the map (i.e., row and column labels of each spatial cell) of the spatial structure
  - Print the partition at a specific time-step for any number of years
  - Print the biomass of the partition at a specific time-step for any number of years
  - Print the partition at the end of an initialisation
  - Print a summary of a process
  - Print a summary of a preference function
  - Print a derived quantity
  - Print a derived quantity by cell
  - Print a summary of the estimated parameters
  - Print the estimated parameters in a vector format (suitable for use with spm -i)
  - Print the objective function values
  - Print the covariance matrix
  - Print an observation values, fits, and residuals
  - Print a simulated observation suitable for use in a SPM input configuration file.
  - Print the ageing error misclassification matrix
  - Print a layer
  - Print a derived view via a categorical layer
  - Print a selectivity's values
  - Print the random number seed
  - Print the age-size relationship
  - Print the age-weight relationship
  - Print the size-weight relationship
  - Print the results of an MCMC
  - Print the MCMC samples as they are calculated
  - Print the MCMC objective function values as they are calculated

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@reports

```
@report random_seed
type random_number_seed

@report spatial-map
type spatial_map

@report SSRU-2002
type layer_derived_view
years 2002
time_step one
layer SSRU

@report initialisation-phase1
type initialisation
initialisation_phase Phase1

@report initialisation-phase2
type initialisation
initialisation_phase Phase2
```

```
@report state-2
type partition
time_step two
years 1995-2007

@report SSB
type derived_quantity
derived_quantity SSB

@report Abundance
type layer
years 2000
time_step one
layer Abundance

@report ImmatureLatitude
type preference_function
preference_function ImmatureLatitude
```

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@reports

```
@report random_seed
type random_number_seed

@report spatial-map
type spatial_map

@report SSRU-2002
type layer_derived_view
years 2002
time_step one
layer SSRU

@report initialisation-phase1
type initialisation
initialisation_phase Phase1

@report initialisation-phase2
type initialisation
initialisation_phase Phase2
```

```
@report state-2
type partition
time_step two
years 1995-2007

@report SSB
type derived_quantity
derived_quantity SSB

@report Abundance
type layer
years 2000
time_step one
layer Abundance

@report ImmatureLatitude
type preference_function
preference_function ImmatureLatitude
```

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@report.type=spatial_map

- Spatial_map is a special report that prints the spatial co-ordinates of each spatial cell (i.e., row and column labels of each spatial cell) of the spatial structure
  - Written to help me remember what I'm doing 😵. Note the r1-c1 cell is in the top right!

```
[spatial-map]
report.type: spatial_map
r1-c1 r1-c2 r1-c3 r1-c4 r1-c5 r1-c6 r1-c7 r1-c8 r1-c9 r1-c10
r2-c1 r2-c2 r2-c3 r2-c4 r2-c5 r2-c6 r2-c7 r2-c8 r2-c9 r2-c10
r3-c1 r3-c2 r3-c3 r3-c4 r3-c5 r3-c6 r3-c7 r3-c8 r3-c9 r3-c10
r4-c1 r4-c2 r4-c3 r4-c4 r4-c5 r4-c6 r4-c7 r4-c8 r4-c9 r4-c10
r5-c1 r5-c2 r5-c3 r5-c4 r5-c5 r5-c6 r5-c7 r5-c8 r5-c9 r5-c10
r6-c1 r6-c2 r6-c3 r6-c4 r6-c5 r6-c6 r6-c7 r6-c8 r6-c9 r6-c10
*end
```


Example @report

```
[Recruitment]
report.type: process
age: 1
b0: Phase2
categories: immature
label: BHrecruitment
proportions: 1.0
r0: 9.98717e+06
ssb: SSB
ssb_offset: 1
standardise_ycs_years: 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006
steepness: 0.75
type: bh_recruitment
ycs_values: 1 1 1 1 1 1 1 1 1 1 1 1 1
b0_value: 1.39537e+07
ycs_years: 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006
ssb_values: 1.39537e+07 1.39537e+07 1.39537e+07 1.39537e+07 1.39528e+07 1.39481e+07 1.39382e+07 1.3929e+07
                  1.3905e+07 1.38665e+07 1.38349e+07 1.37992e+07 1.37707e+07
recruitment_values: 9.98717e+06 9.98717e+06 9.98717e+06 9.98717e+06 9.98712e+06 9.98684e+06 9.98625e+06
                  9.98569e+06 9.98426e+06 9.98194e+06 9.98003e+06 9.97786e+06 9.97612e+06
true_ycs_values: 1 1 1 1 0.999995 0.999967 0.999908 0.999852 0.999709 0.999477 0.999285 0.999068 0.998894
*end
```

Putting it all together

- SPM config files can be very long!
- Output can be huge ☹
  - But you can re-direct specific output to different files if required
- Read and write the output using the R library

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The R library

- Mostly works!
- Read SPM output
  - `extract(file, path = "", ignore.unknown=FALSE)`
  - A simple R function that will read SPM output
  - Creates a single object as a 'list' with each block of output as a sperate item
  - SPM config files can be read and written with

    `read.spm.config(file, path = "")`

    `write.spm.config(object, file, path = "", …)`
  - The format for `write.spm.config()` is tricky – best to read a file in and modify it.

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```
library(spm)
MPD<-extract("../../SPM/estimate.log")

Read 8538 items
Warning: spm and the spm R library versions are different
SPM v2.0.3-2020-08-29
R   v2.0.1-2020-03-25

> summary(MPD)
                    Length Class  Mode
header                5     -none- list
initialisation        2     -none- list
partition            26     -none- list
layer                 7     -none- list
layer_derived_view    1     -none- list
observation          26     -none- list
random_number_seed    1     -none- list
spatial_map           1     -none- list
derived_quantity      1     -none- list
estimate_summary      1     -none- list
estimate_value        2     -none- list
objective_function    1     -none- list
selectivity           2     -none- list
covariance            1     -none- list
process               4     -none- list
age_size              1     -none- list
age_weight            1     -none- list
preference_function   6     -none- list
```


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```
> MPD$header
$call
[1] "Call: spm -e -g 0 -o MPD.dat "
$date
[1] "Date: Sun Dec 06 22:14:53 2020"
$version
[1] "v2.0.3-2020-08-29 (rev. 2020-08-29 03:48:00 UTC). Copyright (c) 2008-2020, NIWA"
$user.name
[1] "User name: alist"
$machine.name
[1] "Machine name: DELL-9020 (Windows_NT, PID=2340)"
```


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```
> names(MPD$layer)
[1] "Abundance-density" "Abundance-density" "Abundance-density" "Abundance-density"
[5] "Abundance-density" "Abundance"         "Abundance-density"

> MPD$layer$Abundance
$layer
[1] "Abundance"

$layer.type
[1] "abundance"

$year
[1] "2000"

$time_step
[1] "one"

$label
[1] "Abundance"

$report.type
[1] "layer"

$data
     [,1]     [,2]       [,3]     [,4]     [,5]     [,6]     [,7]     [,8]     [,9]     [,10]
[1,] "0"      "0"        "0"      "183243" "186532" "187089" "185059" "0"      "0"      "0"
[2,] "0"      "0"        "0"      "167002" "174985" "227804" "346118" "320274" "0"      "0"
[3,] "0"      "54498.4"  "83300"  "189129" "238156" "400346" "446183" "420097" "362686" "0"
[4,] "0"      "231137"   "241995" "302151" "439260" "476793" "479499" "472305" "422592" "0"
[5,] "227498" "237829"   "331352" "390567" "461624" "444679" "383664" "366293" "319969" "242572"
[6,] "0"      "0"        "389334" "619213" "631892" "613171" "539347" "500978" "0"      "0"
```


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```
> names(MPD$process)
[1] "Recruitment" "Ageing"      "Maturation"  "M"
> MPD$process$M
$label
[1] "M"

$report.type
[1] "process"

$data
$data$categories
[1] "immature" "mature"

$data$label
[1] "M"

$data$m
[1] 0.13 0.13

$data$selectivities
[1] "One" "One"

$data$type
[1] "constant_mortality_rate"
```


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Simulations

- Simulations create *simulated* observations for a given model
  - The values and parameters in the observation section are used to generate the simulated observations
  - Observations can be used to "fit" data and/or used to "simulate" data
  - SPM will only simulate data for where there is an observation that used to simulate from
- SPM will create an output in a format suitable for use by SPM as an actual observation

Simulations (1)

```
spm -i file -s n_sims > output.log
```

Running a simulation

```
> spm –s 10 –g 0 – i MPD.dat

SPM (Spatial Population Model)
Call: ..\..\Build\windows\spm -s 10 -g 0 –i MPD.dat
Date: Sat Aug 29 11:31:25 2020
v2.0.3-2020-08-26 (rev. 2020-08-26 10:11:36 UTC). Copyright (c) 2008-2020, NIWA
User name: alist
Machine name: HP1040 (Windows_NT, PID=19464)

Completed
```


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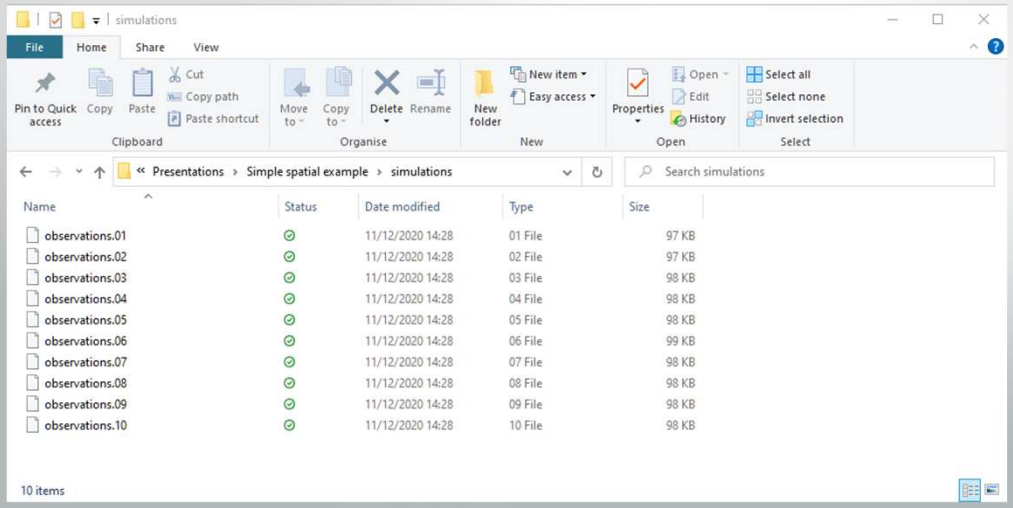

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Example of a simulated observation

```
#[cpue-2006-simulated]
#report.type: simulated_observation
#observation.label: cpue-2006
@observation cpue-2006
catchability CPUEq
categories immature mature
delta 1e-11
layer cell
likelihood lognormal
selectivities FishingSel FishingSel
time_step one
type abundance
year 2006
obs r1-c6 1.3094727046784029
obs r1-c7 0.94334093435631761
error_value r1-c6 0.395844253897014
error_value r1-c7 0.159743484356619
#end
```


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