A quick introduction to FLR

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The Fisheries Library in R (FLR) is a collection of tools for quantitative fisheries science, developed in the R language, that facilitates the construction of bio-economic simulation models of fisheries systems as well as the application of a wide range of quantitative analysis.

FLR builds on the powerful R environment and syntax to create a domain-specific language for the quantitative analysis of the expected risks and impacts of fisheries management decisions. The classes and methods in FLR consider uncertainty an integral part of our knowledge of fisheries system. [. . .]

Required packages

To follow this tutorial you should have installed the following packages:

- FLR: FLCore

You can do so as follows:

```
install.packages(c("FLCore"), repos = "http://flr-project.org/R")
```

Getting started with the FLCore classes

The main *classes* (i.e. data structures) and *methods* (i.e. procedures) in the FLR system are found in the `FLCore` package. Let's load it first.

```
library(FLCore)
```

We can then inspect an example object.

```
data(ple4)
```

The `ple4` object is of class `FLStock`, used in **FLR** to represent a fish population that is constructed from catch and abundance data through a stock assesssment model. `FLStock` is an S4 class (see `?Classes_Details` for futher details), consisting of a number of slots designed to each of the elements, data or results, needed to construct a view of a fish stock. By calling the `summary` method on the object

```
summary(ple4)
```

```
An object of class "FLStock"

Name: Plaice in IV
```

```
Description: Imported from a VPA file. ( N:\Projecte [...]
Quant: age
Dims:  age  year    unit    season  area    iter
    10  52  1   1   1   1

Range:  min max pgroup  minyear maxyear minfbar maxfbar
    1   10  10  1957    2008    2   6

catch         : [ 1 52 1 1 1 1 ], units =  t
catch.n       : [ 10 52 1 1 1 1 ], units =  10^3
catch.wt      : [ 10 52 1 1 1 1 ], units =  kg
discards      : [ 1 52 1 1 1 1 ], units =  t
discards.n    : [ 10 52 1 1 1 1 ], units =  10^3
discards.wt   : [ 10 52 1 1 1 1 ], units =  kg
landings      : [ 1 52 1 1 1 1 ], units =  t
landings.n    : [ 10 52 1 1 1 1 ], units =  10^3
landings.wt   : [ 10 52 1 1 1 1 ], units =  kg
stock         : [ 1 52 1 1 1 1 ], units =  t
stock.n       : [ 10 52 1 1 1 1 ], units =  10^3
stock.wt      : [ 10 52 1 1 1 1 ], units =  kg
m             : [ 10 52 1 1 1 1 ], units =  m
mat           : [ 10 52 1 1 1 1 ], units =
harvest       : [ 10 52 1 1 1 1 ], units =  f
harvest.spwn  : [ 10 52 1 1 1 1 ], units =
m.spwn        : [ 10 52 1 1 1 1 ], units =
```

we can inspect the slots, dimensions and structure. Most slots in the class (e.g. `catch` or `stock.n`) are themselves of another **FLCore** class, `FLQuant`. This class, the basic element used to assemble all other classes in **FLR**, is a 6-dimensional array that can take advantage of the powerful array algebra capabilities of R. All slots can be accessed and modified using accessors and replacement methods.

```
catch(ple4)
```

```
An object of class "FLQuant"
, , unit = unique, season = all, area = unique

     year
age   1957   1958   1959   1960   1961
  all  78423  88240 109238 117138 118331

      [ ...  42 years]

     year
```

```
age   2004   2005   2006   2007   2008
  all 117702 111060 121205  90283  96040
```

```
m(ple4) <- m(ple4) + m(ple4) * 0.5
```

Other standard R methods have also been defined for these classes in a way that is as intuitive as possible for any R user. For example, subsetting using the [operator works on both FLStock

```
summary(ple4[, 1:10])
```

```
An object of class "FLStock"

Name: Plaice in IV
Description: Imported from a VPA file. ( N:\Projecte [...]
Quant: age
Dims:  age  year    unit    season  area    iter
    10  10  1   1   1   1

Range:  min max pgroup  minyear maxyear minfbar maxfbar
    1   10  10  1957    1966    2   6

catch         : [ 1 10 1 1 1 1 ], units =  t
catch.n       : [ 10 10 1 1 1 1 ], units =  10^3
catch.wt      : [ 10 10 1 1 1 1 ], units =  kg
discards      : [ 1 10 1 1 1 1 ], units =  t
discards.n    : [ 10 10 1 1 1 1 ], units =  10^3
discards.wt   : [ 10 10 1 1 1 1 ], units =  kg
landings      : [ 1 10 1 1 1 1 ], units =  t
landings.n    : [ 10 10 1 1 1 1 ], units =  10^3
landings.wt   : [ 10 10 1 1 1 1 ], units =  kg
stock         : [ 1 10 1 1 1 1 ], units =  t
stock.n       : [ 10 10 1 1 1 1 ], units =  10^3
stock.wt      : [ 10 10 1 1 1 1 ], units =  kg
m             : [ 10 10 1 1 1 1 ], units =  m
mat           : [ 10 10 1 1 1 1 ], units =
harvest       : [ 10 10 1 1 1 1 ], units =  f
harvest.spwn  : [ 10 10 1 1 1 1 ], units =
m.spwn        : [ 10 10 1 1 1 1 ], units =
```

and FLQuant

```
stock.n(ple4)[1, ]
```

```
An object of class "FLQuant"
, , unit = unique, season = all, area = unique
```

```
   year
age 1957   1958   1959   1960   1961
  1 457973 698110 863386 757299 860577

      [ ...  42 years]

   year
age 2004    2005    2006    2007    2008
  1 1159019  714344  820006  949341  844041
```

while ensuring that the result are always valid objects of the same class. There are, however, necessary difference. For example, selecting a single element along the first dimension (`age`) did not drop that dimension from the object (`drop=FALSE`), in contrast with the standard behaviour in R for `array`.

In addition to the `summary` method above, a creator method is available for each class

```r
FLQuant(rlnorm(30), dimnames = list(age = 0:5,
    year = 2012:2017))
```

```
An object of class "FLQuant"
An object of class "FLQuant"
, , unit = unique, season = all, area = unique

   year
age 2012    2013    2014    2015    2016
  0 0.60352 1.51710 1.68515 0.59522 0.15654
  1 1.93833 6.16351 0.84972 1.43151 4.84358
  2 0.24826 0.99065 0.61229 5.05653 3.67105
  3 3.14748 3.13919 0.93561 0.69980 0.88436
  4 0.97440 5.28007 1.36443 1.19544 0.69089
  5 2.09946 1.06234 0.53418 0.81529 2.49983
   year
age 2017
  0 0.60352
  1 1.93833
  2 0.24826
  3 3.14748
  4 0.97440
  5 2.09946

units:  NA
```

Other common methods have also been defined for all of them, for example to be able to coerce to and from other classes,

```
head(as.data.frame(ple4))
```

slot	age	year	unit	season	area	iter	data
catch	all	1957	unique	all	unique	1	78423
catch	all	1958	unique	all	unique	1	88240
catch	all	1959	unique	all	unique	1	109238
catch	all	1960	unique	all	unique	1	117138
catch	all	1961	unique	all	unique	1	118331
catch	all	1962	unique	all	unique	1	125272

or plot an object.

```
plot(ple4)
```

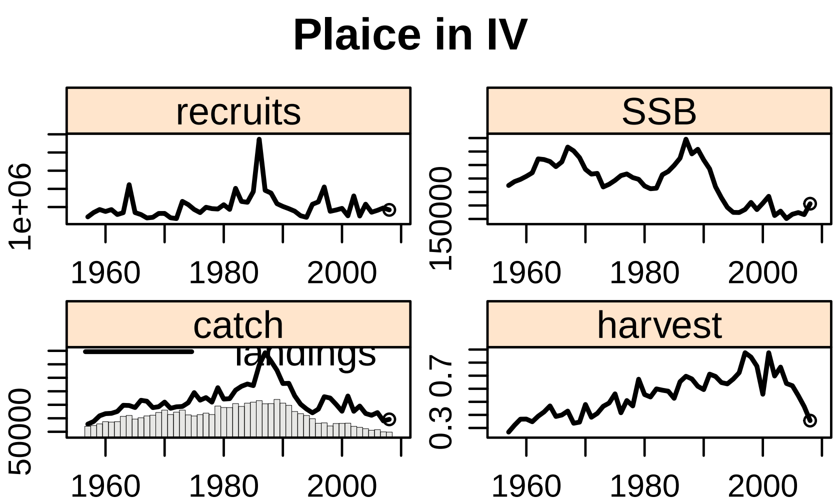


Figure 1: FLStock plot for ple4

A number of fisheries-specific calculations are also available. For example, the estimated spawning stock biomass (SSB), can be obtained from an `FLStock` object using

```
ssb(ple4)
```

```
An object of class "FLQuant"
, , unit = unique, season = all, area = unique

     year
age   1957   1958   1959   1960   1961
  all 274205 288540 296825 308164 321354
```

```
      [ ...  42 years]

     year
age   2004   2005   2006   2007   2008
  all 151508 167531 173783 166061 206480
```

while the mean fishing mortality accross the fully-selected ages ($\bar{F}$) is calculated with

```
fbar(ple4)
```

```
An object of class "FLQuant"
, , unit = unique, season = all, area = unique

     year
age   1957    1958    1959    1960
  all 0.26857 0.32106 0.36734 0.36796
     year
age   1961
  all 0.34756

      [ ...  42 years]

     year
age   2004    2005    2006    2007
  all 0.64015 0.62343 0.54764 0.46392
     year
age   2008
  all 0.35631
```

Class validity

The S4 classes defined in **FLCore** all have validity functions defined that limit what changes can be made to an object for it to remain valid. This ensures that methods do not encounter objects that do not have the required dimensions, differ in dimension names, or are not compatible with each other. For example, the validity requirements for the `FLQuant` class require that

- it is a 6-dimensional array,
- the array is numeric,
- the first dimension is not named 'cohort', and
- dimensions 2:5 are named 'year, 'unit' 'season', 'area' and 'iter'.

Object validity is checked not only by the class constructor, but also by the replacement methods, for example when calling

```
catch(ple4) <- landings(ple4) + discards(ple4)
```

to assign a new value (the result of adding `landings` and `discards`) to a single slot (`catch`).

A modelling example: the FLSR class

A different type of class defined in **FLCore** is `FLSR`. This class allows for fitting, exploration and prediction of a stock-recruitment relationship. An example dataset is also available, corresponding to the North Sea herring stock.

```
data(nsher)
summary(nsher)
```

```
An object of class "FLSR"

Name:
Description:
Quant: age
Dims:  age  year    unit    season  area    iter
    1   45  1   1   1   1

Range:  min minyear max maxyear
    0   1960    0   2004

rec           : [ 1 45 1 1 1 1 ], units =  10^3
ssb           : [ 1 45 1 1 1 1 ], units =  t*10^3
residuals     : [ 1 45 1 1 1 1 ], units =  NA
fitted        : [ 1 45 1 1 1 1 ], units =  10^3

Model:  rec ~ a * ssb * exp(-b * ssb)
<environment: 0xbac2db8>
Parameters:
    params
iter     a        b
   1 119.4 0.009451

Log-likelihood:  15.862(0)
Variance-covariance:
            a         b
  a 255.33882 1.809e-02
  b   0.01809 1.993e-06
```

The class holds together `FLQuant` slots for inputs (`rec` for recruitment in numbers and `ssb` for spawning stock biomass or any other proxy of stock reproductive potential) and outputs of the fit (`params` for the estimated parameters, `fitted` for the estimated recruitment, and `residuals` for the log residuals). It also contains the necessary elements for the model fit to be carried out using maximum likelihood estimation:

- `logl`: a function that computes the log-likehood from observations and parameter values, to be passed on to `optim`,
- `model`: a formula to calculate the estimated recruitment, and
- `initial`: a function to obtain initial parameter values for the minimization algorithm.

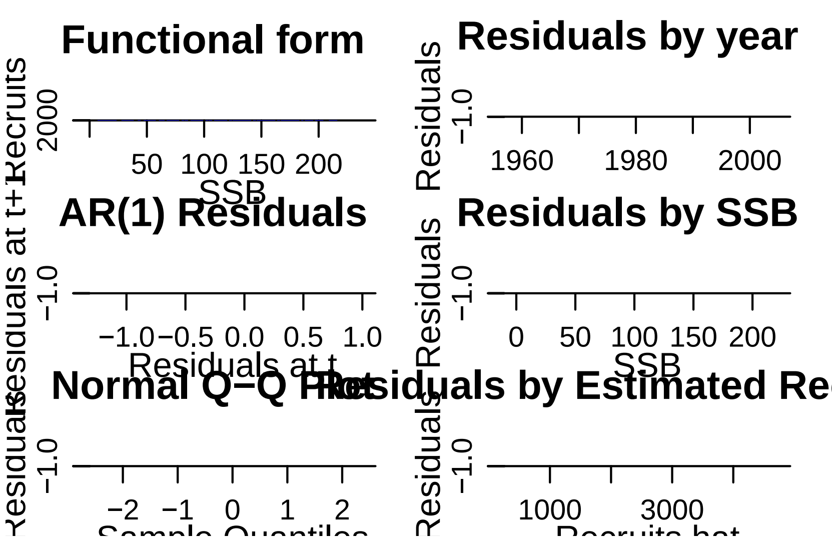
By calling the method that carries out the minimization, `fmle`, we obtain a new object in which the results of the fit are now available:

- `params`: the estimated parameters,
- `logLik`: the log-likelihood and degrees of freedom,
- `covar`: the variance-covariance matrix of the fit, and
- `hessian`: the Hessian matrix of the fit,

as well as some other information returned by the fitting procedure.

Of course we can visualize the result of the model fit, together with a useful set of diagnostics, by simply calling the `plot` method for the class

```
plot(nsher)
```



FLBiol

Packages

References

L. T. Kell, I. Mosqueira, P. Grosjean, J-M. Fromentin, D. Garcia, R. Hillary, E. Jardim, S. Mardle, M. A. Pastoors, J. J. Poos, F. Scott, R. D. Scott; FLR: an open-source framework for the evaluation and development of management strategies. *ICES J Mar Sci* 2007; 64 (4): 640-646. doi: 10.1093/icesjms/fsm012.

More information

- You can submit bug reports, questions or suggestions on this tutorial at `https://github.com/flr/doc/issues`.
- Alternatively, send a pull request to `https://github.com/flr/doc/`.
- For more information on the FLR Project for Quantitative Fisheries Science in R, visit the FLR webpage: `http://flr-project.org`.

Software Versions

- R version 3.4.1 (2017-06-30)
- FLCore: 2.6.3.9006
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License

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