Plotting FLR objects with ggplotFL and ggplot2

13 February, 2017

The R package ggplot2 offers a plotting style and tools that are increasingly becoming a data visualization standard. On of the added values of ggplot2 is the ease in displaying highly dimensional data in an intuitive way. For these reasons there are a number of standard methods implemented in the package ggplotFL to plot FLR objects, stock assessment diagnostics and MSE results. In addition standard ggplot2 methods and functions can be used by converting FLR objects into data frames, thus giving an extra flexibility in plotting.

Required packages

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

- CRAN: ggplot2
- FLR: FLCore, ggplotFL

You can do so as follows,

```
# This chunk loads all necessary packages, trims pkg messages
library(FLCore)
library(ggplotFL)
```

```
## Warning: replacing previous import 'ggplot2::%+%' by 'FLCore::%+%' when
## loading 'ggplotFL'
```

```
# Load datasets for tutorial

data("ple4")
data("ple4sex")
data("nsher")
```

SECTION

Using ggplot2 with *FLR* objects

The `ggplot2` package provides a powerful alternative paradigm for creating both simple and complex plots in R using the ideas of Wilkinson's *Grammar of Graphics* [1]

To facilitate the use of `ggplot2` methods in *FLR*, the `ggplotFL` package has been created. The main resources on offer in this package are overloaded versions of the `ggplot()` method that directly accept certaing *FLR* classes, a new set of basic plots for some *FLR* classes, based on `ggplot2` instead of `lattice`, and some examples and documentation on how best make use of `ggplot2`'s powerful paradigm and implementation to obtain high quality plots for even fairly complex data structures.

The overloaded 'ggplot' method

The standard `ggplot` functions expects a `data.frame` for its first argument, `data`. If `ggplot` is called on an *FLR* object, a conversion to `data.frame` takes place before the result, plus any other arguments provided, get passed to the original `ggplot()`. Conversion makes use of `as.data.frame`[2] methods defined in `FLCore`, with the `cohort` argument set to `TRUE`.

[1] Wilkinson, L. 1999. *The Grammar of Graphics*, Springer. doi 10.1007/978-3-642-21551-3_13.

[2] `method?as.data.frame('FLQuant')`

As an example, the FLStock of ple4 is a list containing a number of elements.

```
# summary of the FLStock
summary(ple4)
```

```
## An object of class "FLStock"
##
## Name: Plaice in IV
## Description: Imported from a VPA file. ( N:\Projecten\ICES WG\Demersale werkgroep  [...]
## 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 =  NA
## harvest       : [ 10 52 1 1 1 1 ], units =  f
## harvest.spwn  : [ 10 52 1 1 1 1 ], units =  NA
## m.spwn        : [ 10 52 1 1 1 1 ], units =  NA
```

By calling as.data.frame() on an SLStock, the list is collapsed to a dataframe that than can be plotted by selecting the right dimensions in terms of slot, age, iter, etc.. :

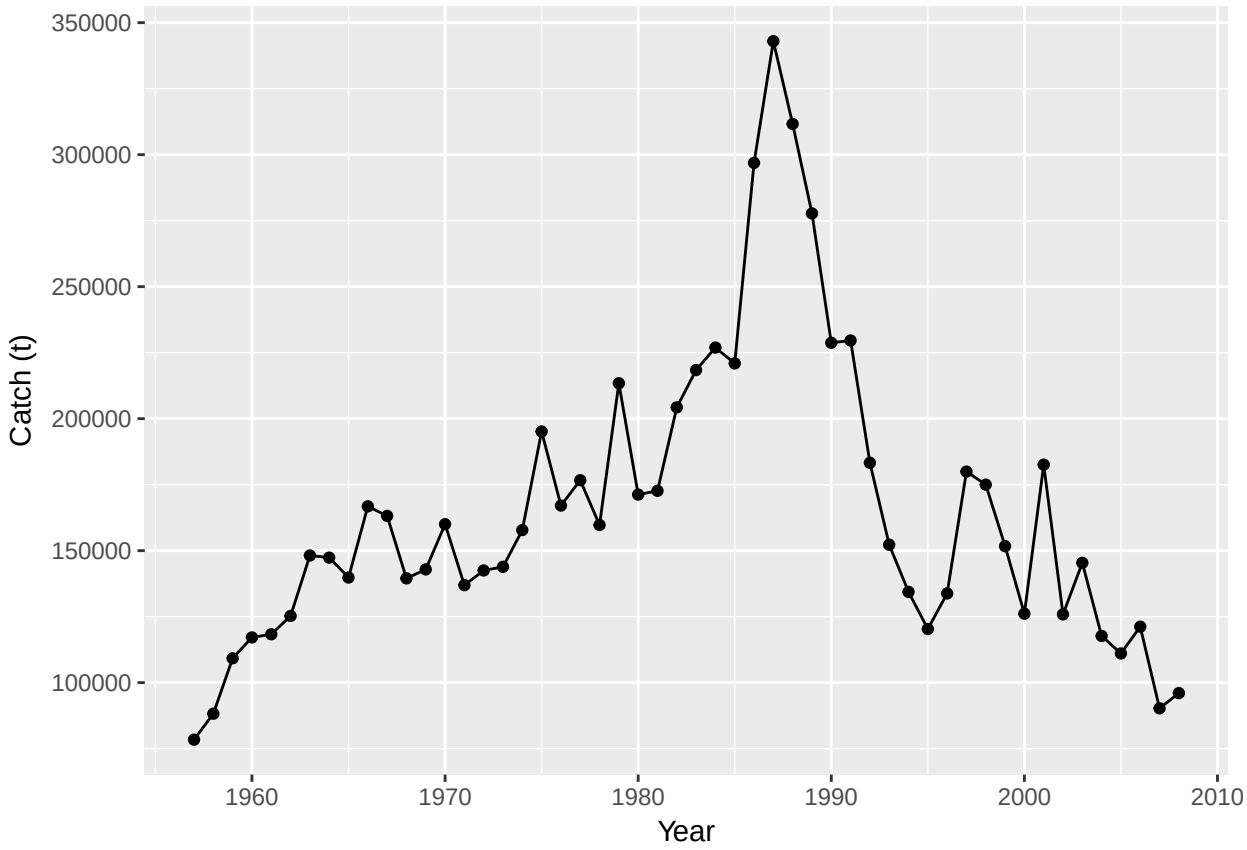
```
head(as.data.frame(ple4))
```

```
##    slot age year   unit season   area iter   data
## 1 catch all 1957 unique    all unique    1  78423
## 2 catch all 1958 unique    all unique    1  88240
## 3 catch all 1959 unique    all unique    1 109238
## 4 catch all 1960 unique    all unique    1 117138
## 5 catch all 1961 unique    all unique    1 118331
## 6 catch all 1962 unique    all unique    1 125272
```

FLQuant

Passing an `FLQuant` object to ggplot, we can specify the names of the dimensions as variables in the plot, where `data` refers to the column storing the actual numeric values. For example, to plot `data` (the `catch` slot from `ple4` in this case) against year, we could use

```
ggplot(data = catch(ple4), aes(year, data)) + geom_point() + geom_line() + ylab("Catch (t)") + xlab("Ye
```



where we pass directly an `FLQuant` object for the `data` argument in `ggplot`, specify an aesthetic mapping (`aes(year, data)`), and add both points (`geom_point()`) and lines (`geom_line()`), together with the appropriate axis labels.

FLQuants

Similarly, we can pass on to `ggplot` an object of class `FLQuants`, and the conversion to `data.frame` will make use of the corresponding method [3]. A new column gives the name of each `FLQuant` in the list, called `qname`. When can then use it to, for example, define a call to `facet_wrap()` to obtain a separate subplot per element.

```
ggplot(data=FLQuants(Yield=catch(ple4), SSB=ssb(ple4), F=fbar(ple4)), aes(year, data)) + geom_line() + f
```

This procedure is particularly useful when plotting information from objects with multiple `FLQuant` slots, as a subset of slots can be selected for plotting, and even transformations or computations can be carried out in the call to the `FLQuants()` creator.

FLStock

A whole FLStock object can also be used as argument to `ggplot()`, even if the heterogeneity in scale of the data contained makes the plot slightly confusing. For example, we can plot time series of every `FLQuant` slot in `ple4`, with color applied to different `age` dimensions, by calling

```
ggplot(data=ple4, aes(year, data)) + geom_line(aes(group=age, colour=factor(age))) + facet_wrap(~slot, s
```

[3] `method?as.data.frame('FLQuants')`

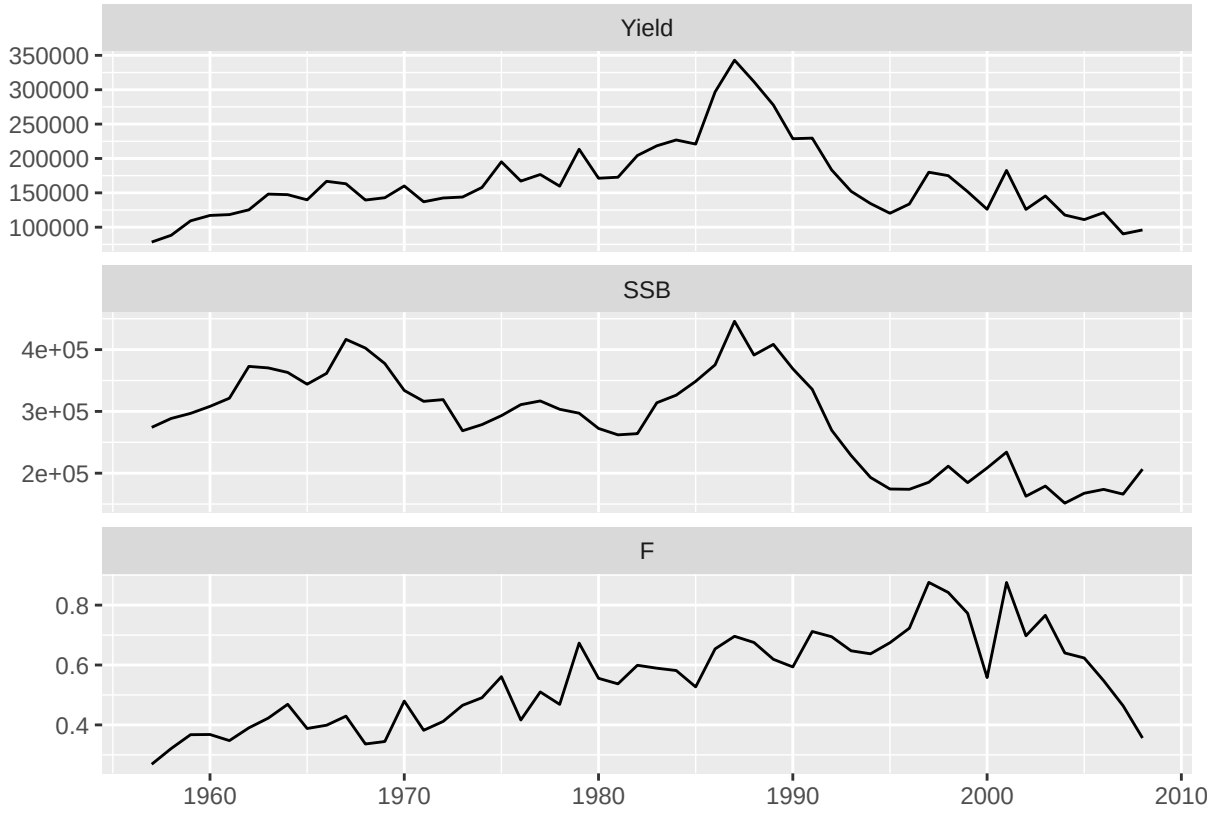


Figure 1: Facet wrap line plot of time series from an FLQuants object.

Figure 2: Overall `ggplot` of an `FLStock` object, faceted by slot.

New `plot()` methods for FLR classes

The `ggplotFL` package also provides new versions of the `plot` method for a number of *FLR* classes. Each S4 class defined in any *FLR* package has a `plot()` method available that provides a quick visual summary of the contents of the object.

FLQuant

The standard `plot()` method for `FLQuant` defined in `ggplotFL` uses the faceting capabilities of `ggplot` to better present some of the multiple dimensions of these objects. If any dimension, other than `year` and `iter`, has length greater than one, it will be added to the formula used by `facet_grid`. For example, an `FLQuant` with dimensions

```
dim(catch.n(ple4))
```

```
## [1] 10 52  1  1  1  1
```

will generate a plot with a time series by year of the data it contains, with horizontal facets for the only dimension, other than `year`, of length greater than 1, `age`.

```
plot(catch.n(ple4))
```

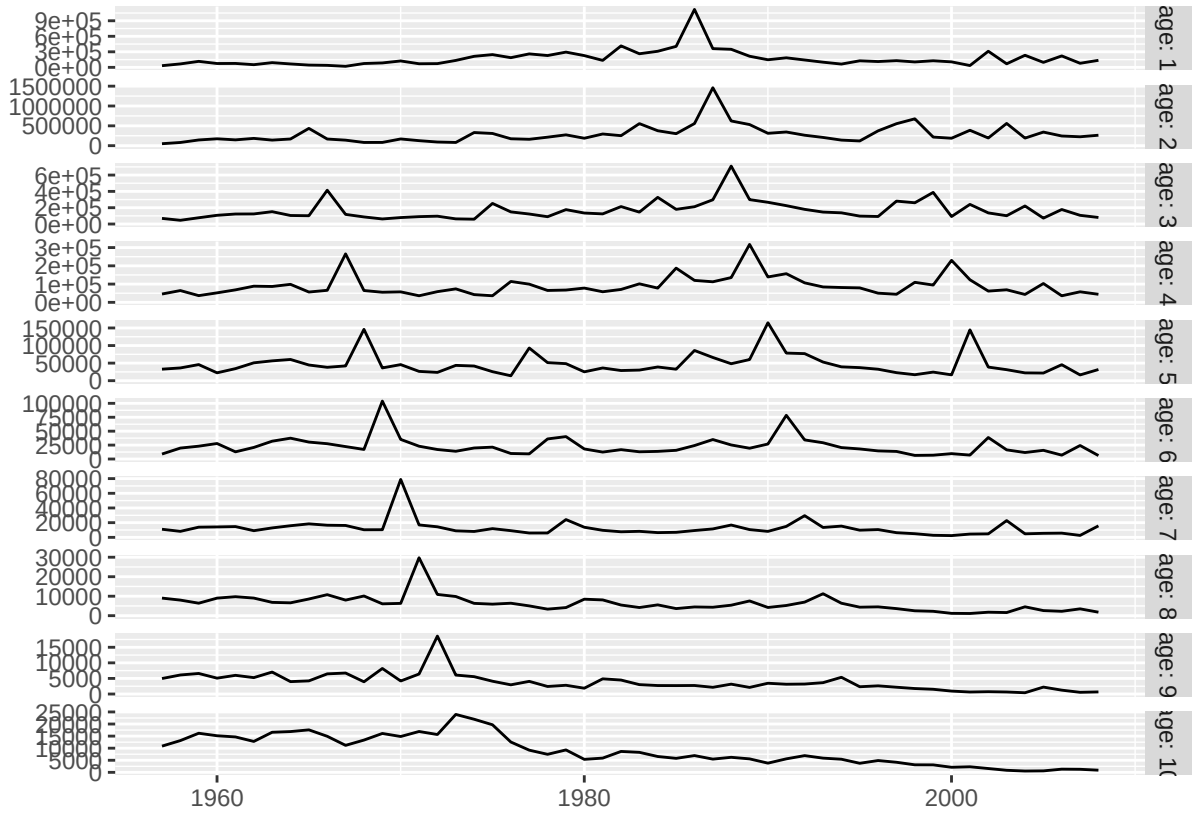


Figure 3: Standard ggplot2-based plot for an FLQuant object with multiple *year*s and *age*s.

For `FLQuant` objects with iterations, the `plot` method will calculate, by default, the 50% (median), 10%, 25%, 75% and 90% quantiles, to be plotted as a solid line (50%), a dotted line (90%) and a coloured ribbon (75%).

```
plot(rlnorm(200, fbar(ple4), 0.15))
```

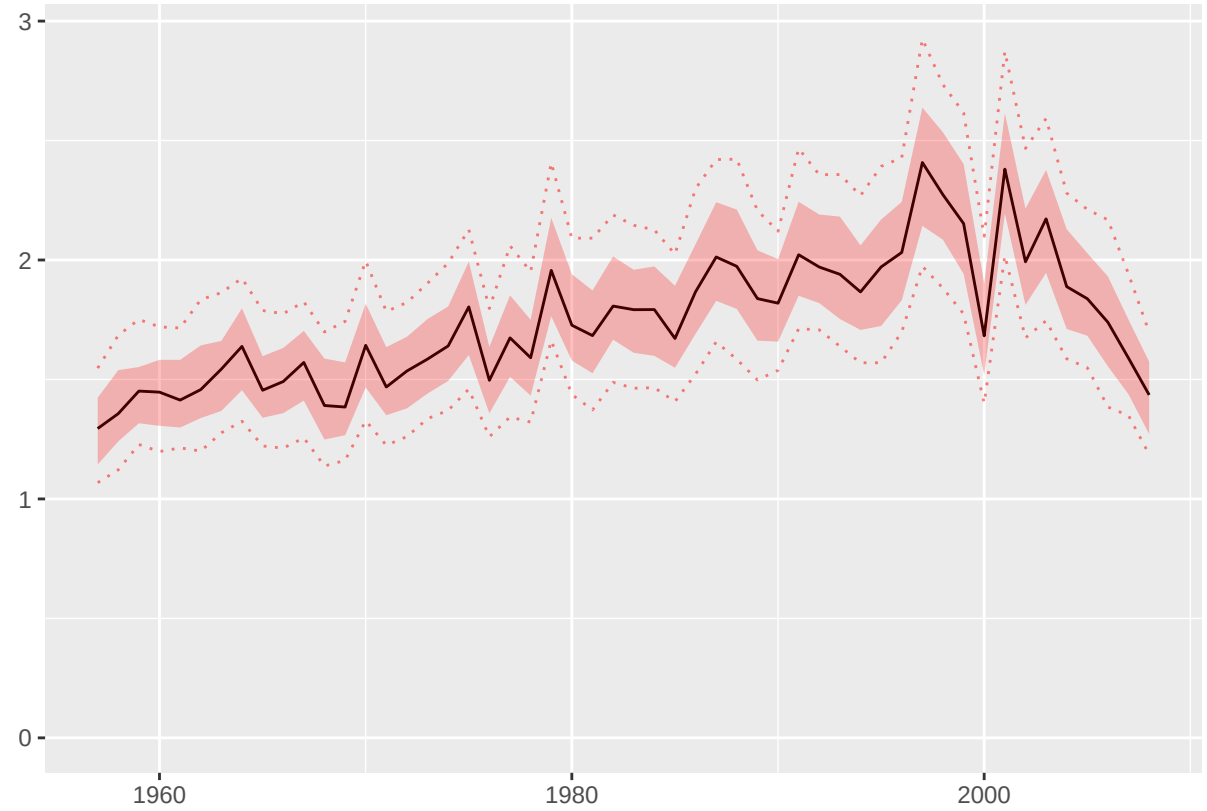


Figure 4: Standard ggplot2-based plot for an FLQuant object with multiple iterations.

Different quantiles can be specified using the `probs` arguments, and the alpha transparency of the ribbon will be proportional to the probability value. A vector of odd length must be passed, and the central point should be 0.50 so the central tendency line represents the median. The most extreme quantiles will be plotted as dotted lines, while all other will show up as ribbons.

```
plot(rlnorm(200, fbar(ple4), 0.15), probs=c(0.05, 0.10, 0.25, 0.50, 0.75, 0.90, 0.95))
```

FLQuants

The `plot` method for `FLQuants` will now by default show each object in a horizontal panel, with indpendent scales, by using `facet_grid`. Objects with iterations will have, as with `plot` for `FLQuant`, their median, 10%, 25%, 75% and 90% quantiles shown as a black line and red ribbons with different levels of transparency, respectively.

```
fqs <- FLQuants(F = rlnorm(200, fbar(ple4), 0.15), SSB = ssb(ple4), Rec = rec(ple4), Catch = catch(ple4)
plot(fqs)
```

Plots of multiple `FLQuant` objects use by default `facet_grid` with multiple plots stack on top of each other. To have the plots on a grid, for example 2x2, you can add a call to `facet_wrap` to change it, for example,

```
fqs <- FLQuants(F = rlnorm(200, fbar(ple4), 0.15), SSB = ssb(ple4), Rec = rec(ple4), Catch = catch(ple4)
plot(fqs) + facet_wrap(~qname, scales="free")
```

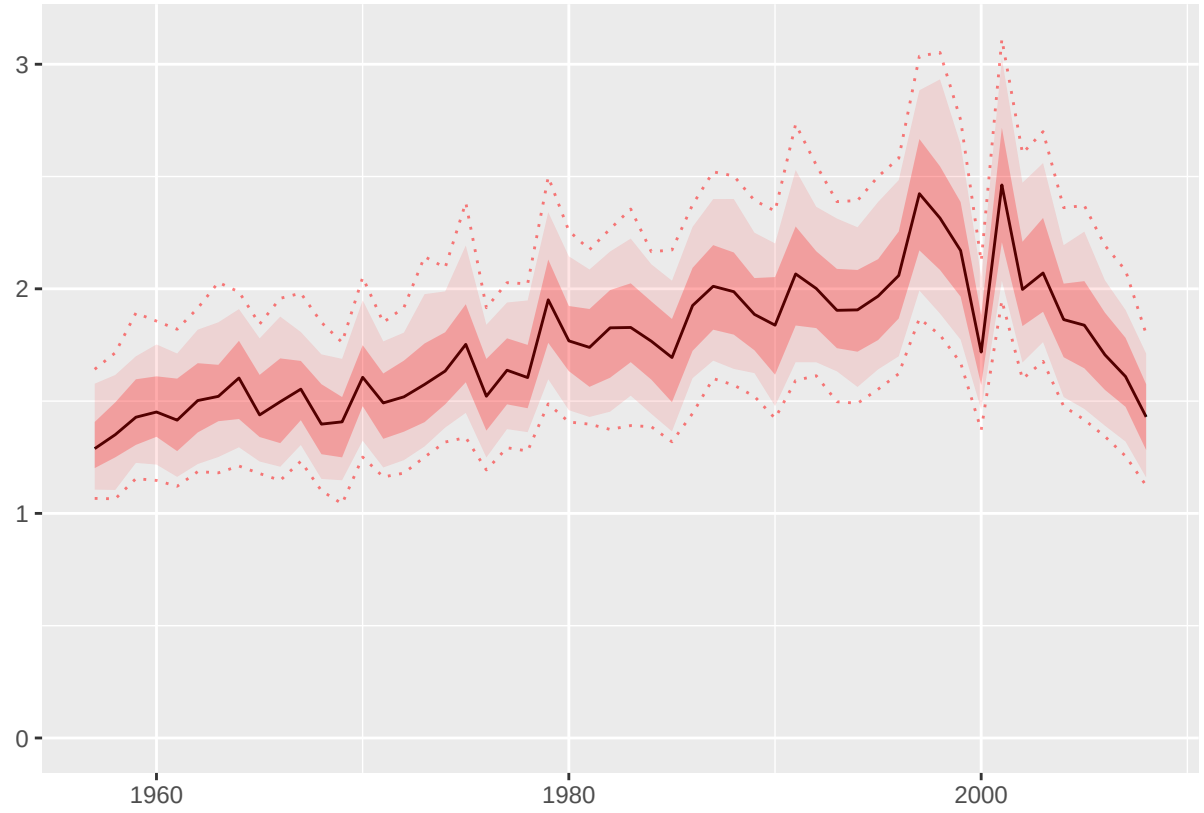


Figure 5: Standard ggplot2-based plot for an FLQuant object with multiple iterations and user-specified quantiles.

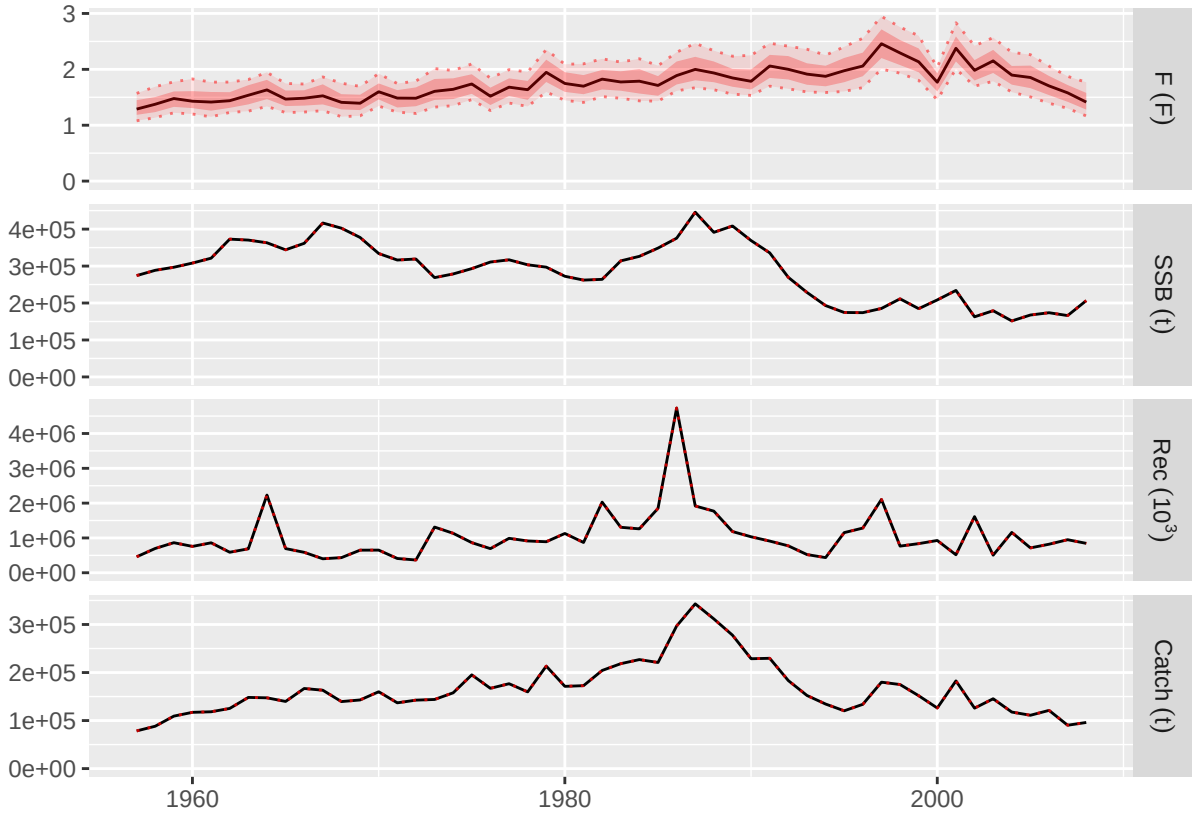


Figure 6: Standard ggplot2-based plot for an FLQuants object with multiple iterations, and consisting of three elements.

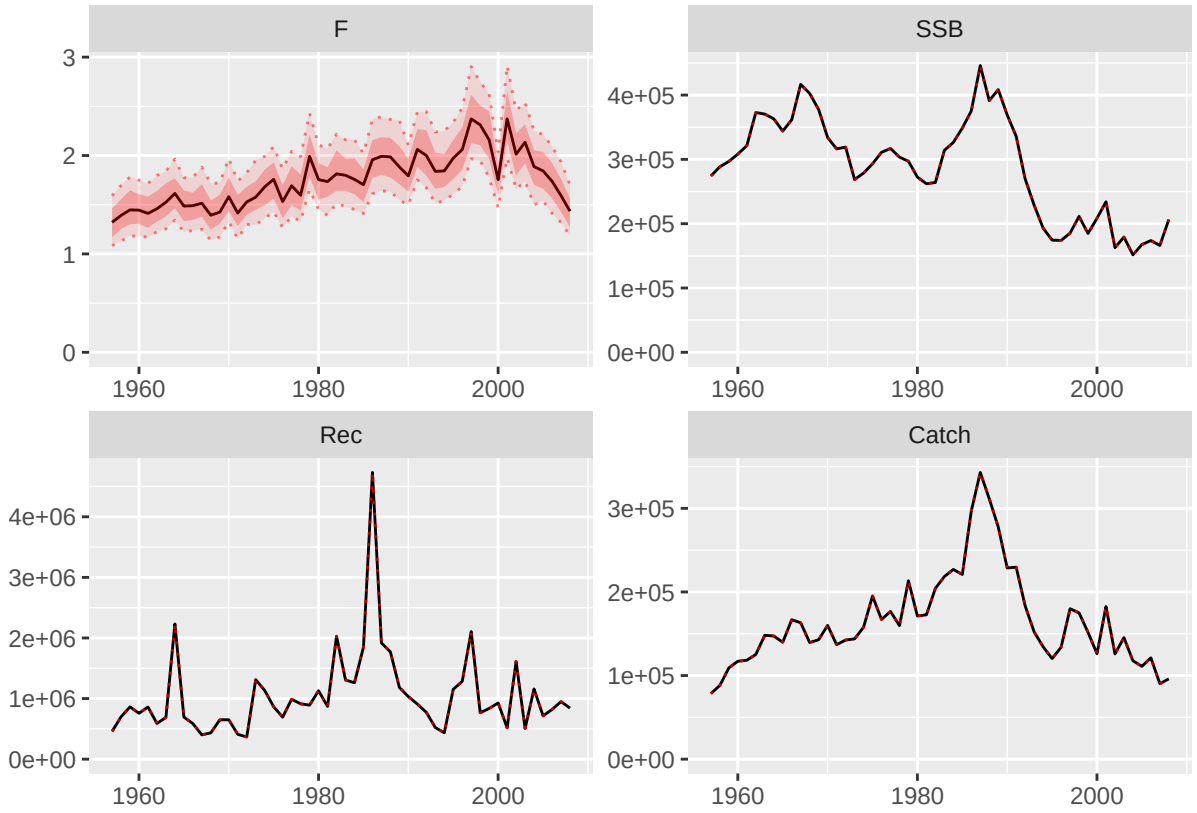


Figure 7: Wrap-based ggplot2-based plot for an FLQuants object with multiple iterations, and consisting of three elements.

FLStock

The `ggplotFL` version of the standard plot for the `FLStock` class, contains the time series of recruitment (obtained by calling `rec()`), SSB (`ssb()`), catch (`catch()`), and fishing morality or harvest for selected ages(`fbar()`). The four panels are now arranged in a 4-row matrix to better display the trends in the time series.

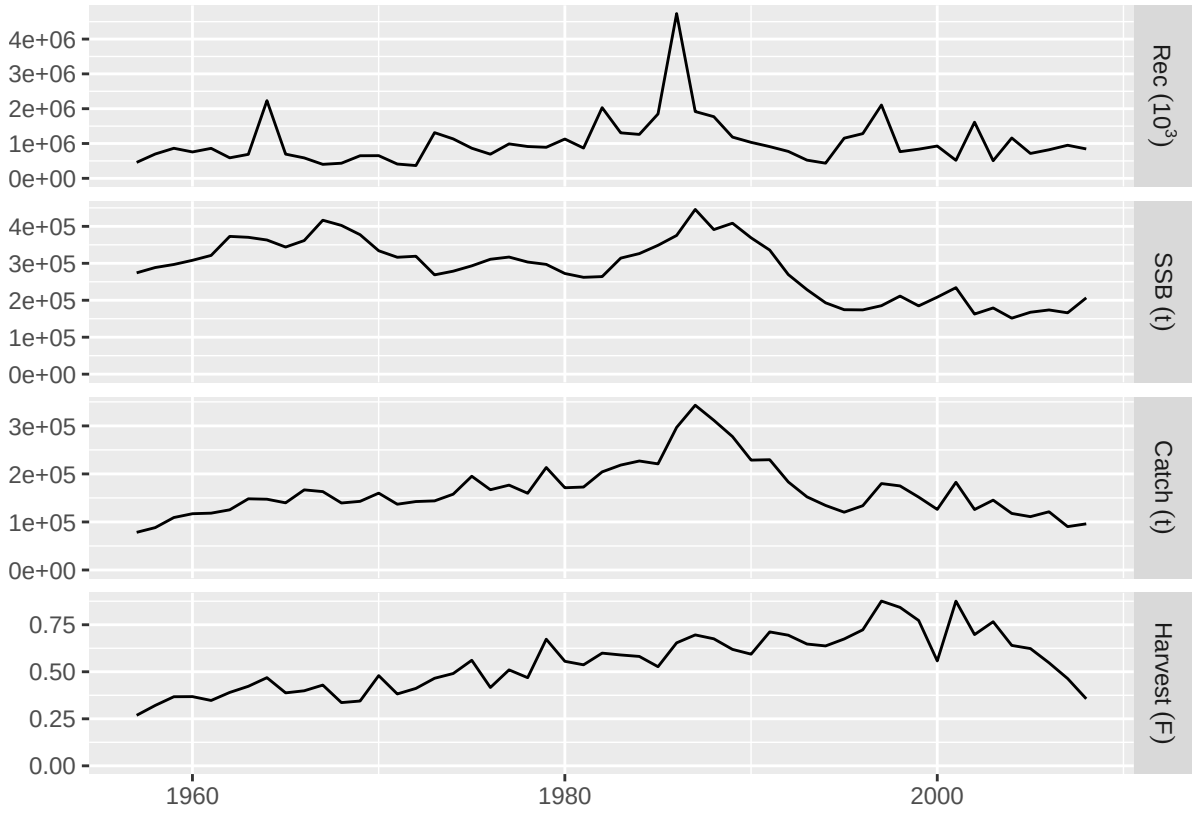


Figure 8: ggplot2 version of the standard plot() for FLStock, as applied to `ple4`

FLStocks

Similarly, the standard `plot()` method for the `FLStocks` class now relies on ggplot. For example, we can create an example `FLStocks` object by splitting the female and male units of `ple4sex` and adding them as separate elements in the list. A call to `plot()` would give us the corresponding plot. Remember the object returned by `ggplot` can always be assigned to a variable in the workspace and modified as required.

FLSR

The `ggplotFL` version of the class plot for `FLSR` contains the same six panels as before: (1) stock-recruit data, fitted model and lowess smoother, (2) residuals by year, (3) lag 1-correlated residuals, (4) residuals by SSB, (5) residuals qqplot and (6) residuals by fitted values. Blud lines are lo9wess smoothers, to better visualize trends in the data shown.

```
plot(nsher)
```

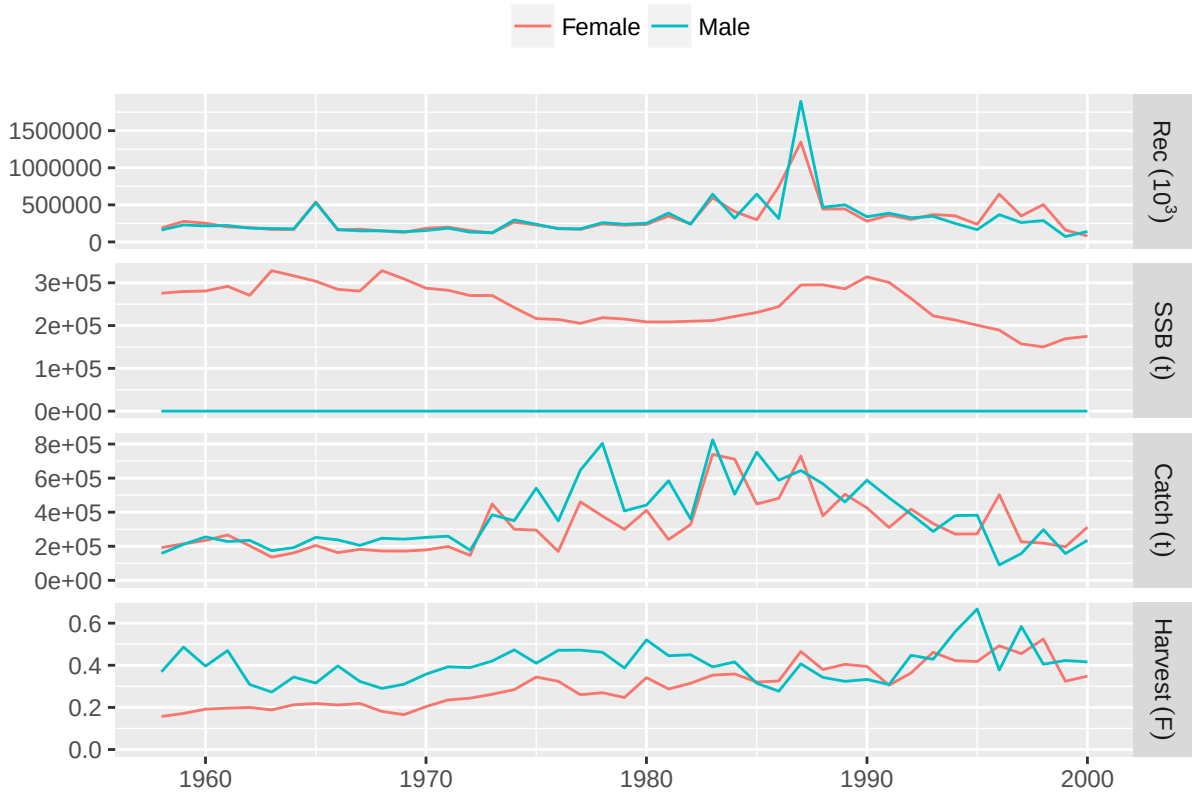


Figure 9: ggplot2 version of the standard plot() for FLStocks, as applied to the sex-separated FLStock object `ple4sex`

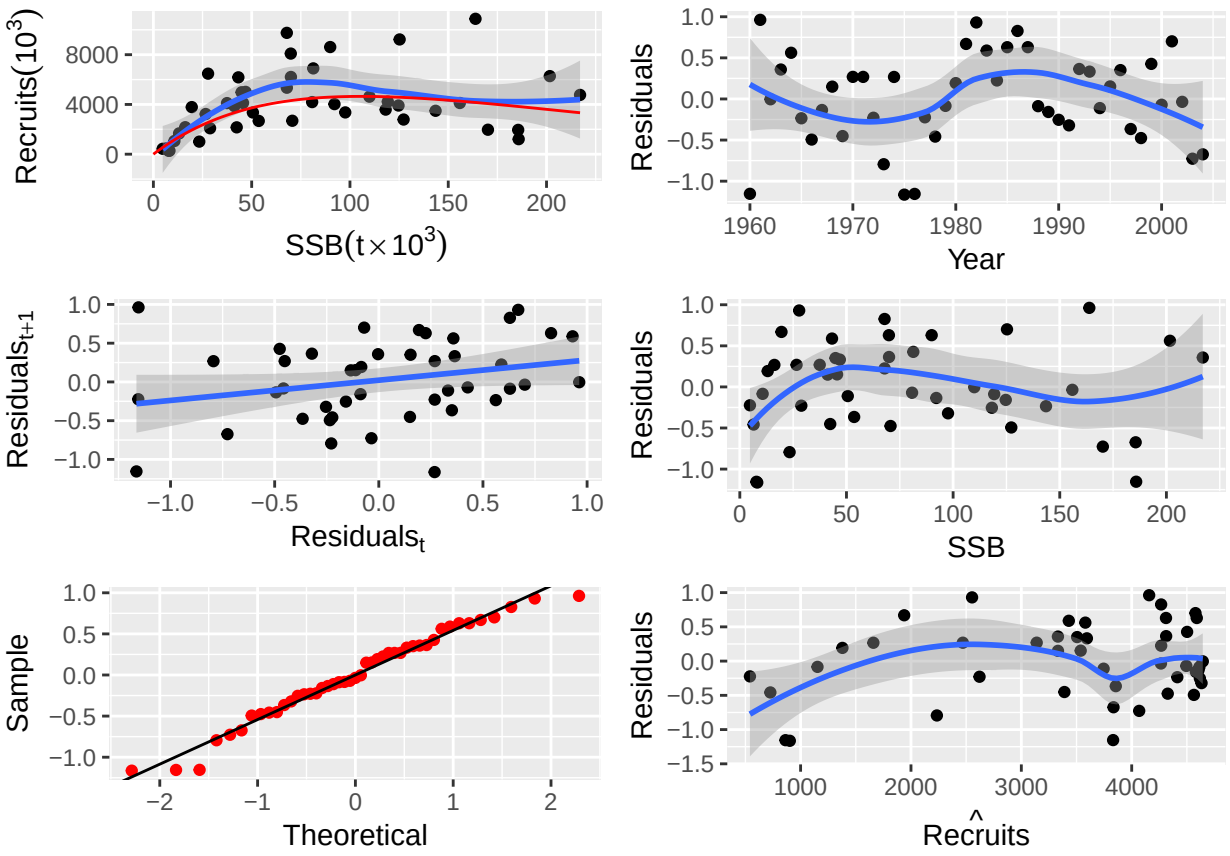


Figure 10: Standard ggplot2-based plot for an object of class FLSR.

FLSRs

A class plot also exists for `FLSRs` objects, lists with `FLSR` elements. The comparison shown involves only the model fit across the different model functions or formulations, but not the residuals diagnostics available for `FLSR`. The default legend contains the formula of each of the fitted models and the parameter values (or the median if multiple iterations exist).

```
srs <- FLSRs(sapply(c('ricker', 'bevholt'), function(x) {
  y <- nsher
  model(y) <- x
  return(fmle(y))
}))
```

```
## Warning in log(x@.Data, ...): NaNs produced

## Warning in log(x@.Data, ...): NaNs produced

## Warning in log(x@.Data, ...): NaNs produced

## Warning in log(x@.Data, ...): NaNs produced
```

```
plot(srs)
```

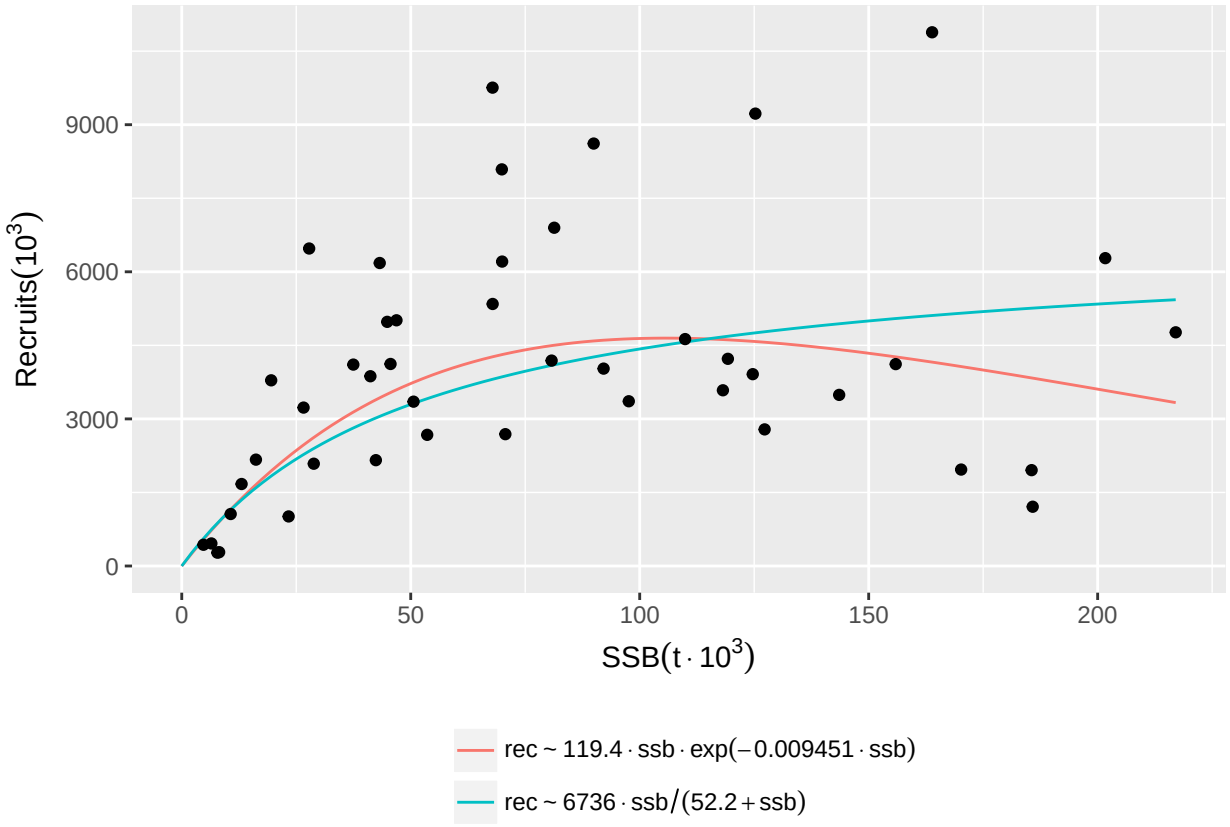


Figure 11: Standard ggplot2-based plot for an FLSRs object, using default legend labels.

An alternative labeller function exists (`modlabel`) that returns the name of the SR model function and the parameter values, by using the *legend_label* argument.

```
plot(srs, legend_label=modlabel)
```

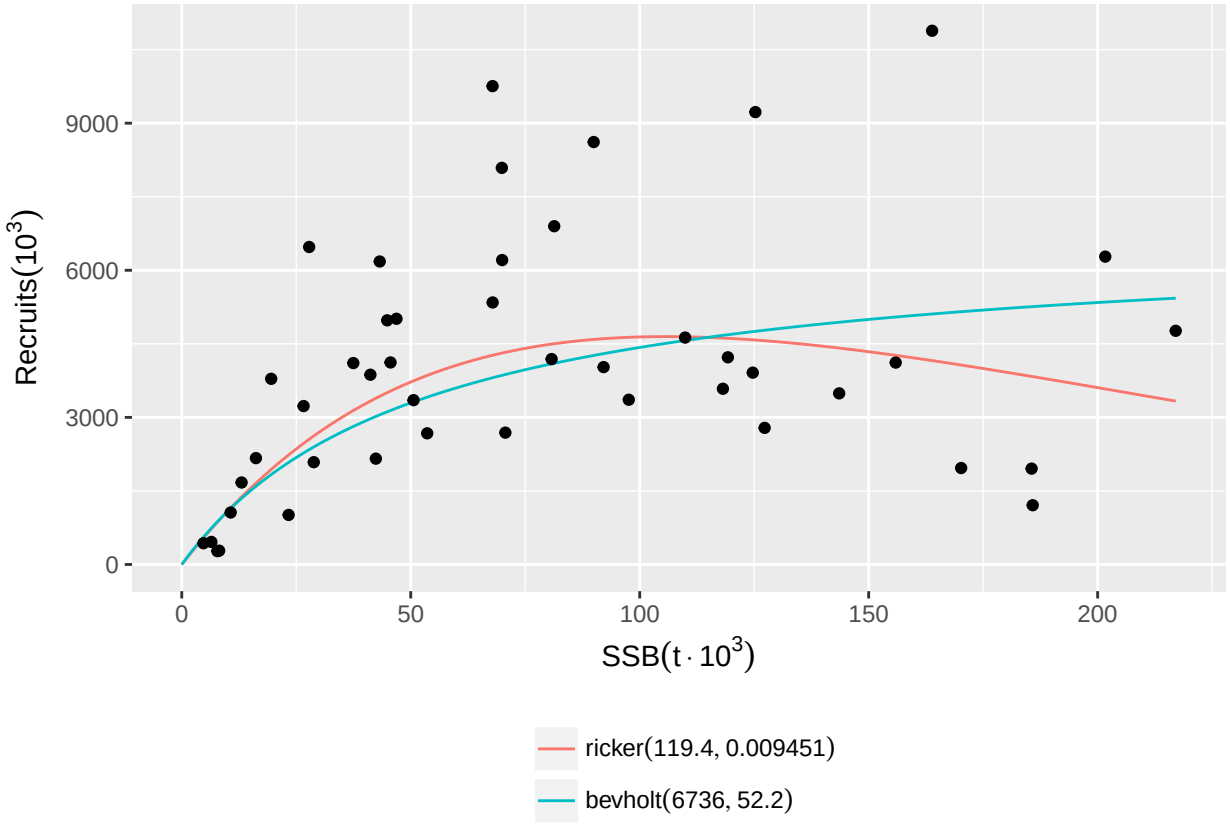


Figure 12: Standard ggplot2-based plot for an FLSRs object, using model names as legend labels.

As is common in `ggplot2`, labels can be specified directly, overwriting those included in the method. You should ignore the warning about scale for *colour* being replaced.

```
plot(srs) + scale_color_discrete(name="SR models", breaks=c('ricker', 'bevholt'),
        labels=c("Ricker", "Beverton & Holt"))
```

```
## Scale for 'colour' is already present. Adding another scale for
## 'colour', which will replace the existing scale.
```

Using ggplot2 directly by converting to data.frame

The methods shown above depend on conversion of *FLR* objects into `data.frame`, which can then be passed to `ggplot()`. Calling `ggplot` on an *FLR* object takes care of this conversion behind the scenes, but to obtain full control and develop certains plots, it is best to explicitely convert the *FLR* objects into a `data.frame`. Different conventions are used in the naming of the data.frame columns created from various *FLR* classes, which need to be used when the plot is specified. For further information, please see the help pages for each `data.frame()` method [4].

[4] For example `method?as.data.frame('FLQuants')`

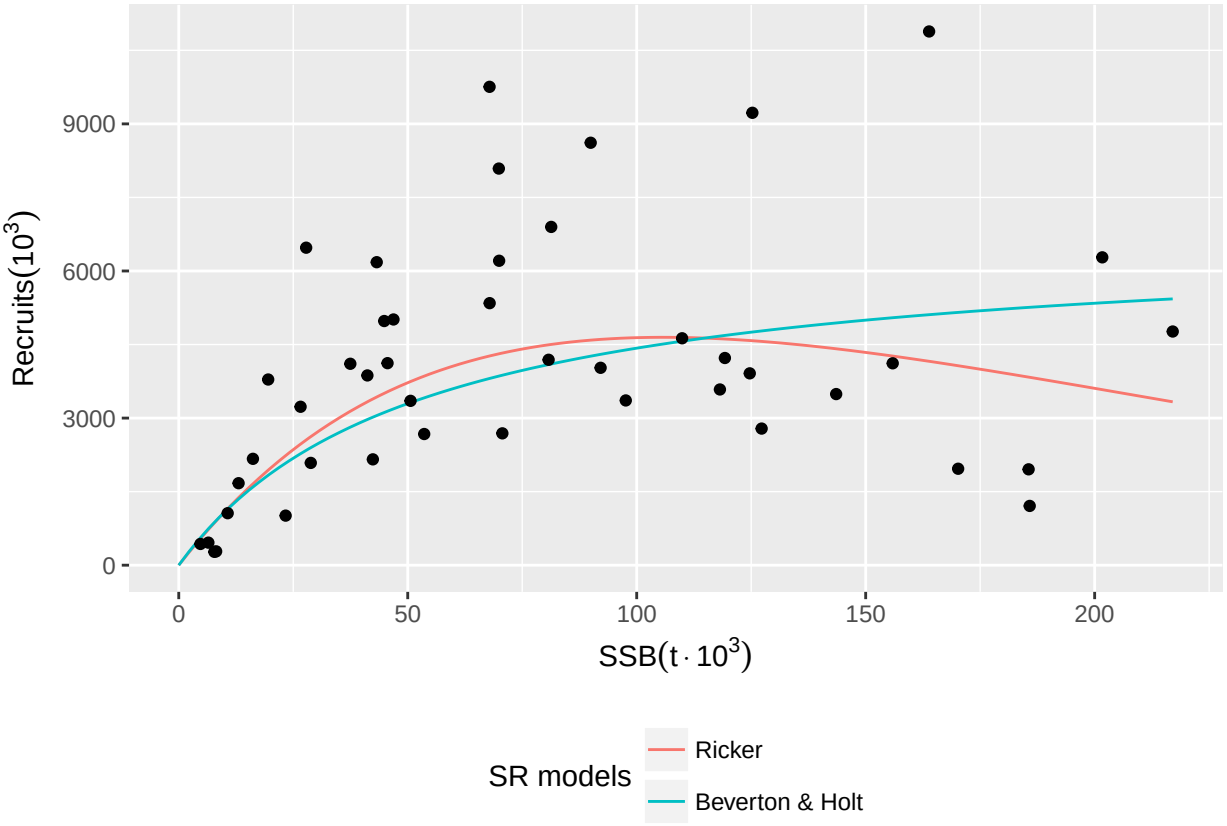


Figure 13: Standard ggplot2-based plot for an FLSRs object, using model names as legend labels.

Some examples

Example: plot quantiles of a simulation

To have full control over a plot of the median (or mean) and the confidence or probability intervals of a simulated or randomized time series, i.e. an `FLQuant` object with iters, we need to arrange the different values computed from the object in separate columns of a `data.frame`.

If we start with some random `FLQuant` object, such as

```
fla <- rlnorm(100, FLQuant(exp(cumsum(rnorm(25, 0, 0.1)))), 0.1)
ggplot(fla, aes(factor(year), data)) + geom_boxplot() + xlab("")
```

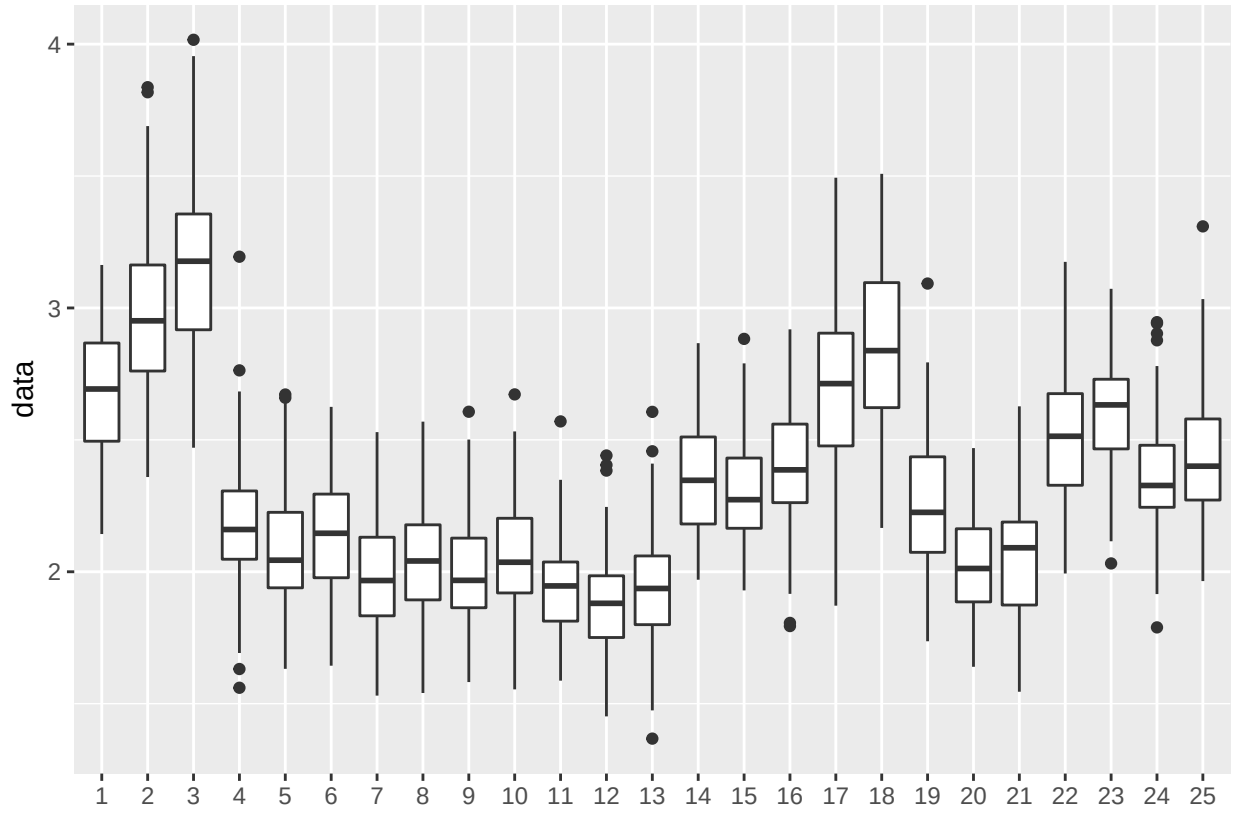


Figure 14: Distribution of values of a simulated time series plotted using geom_boxplot()

we can first compute the necessary statistics on the object itself, as these operations are very efficient on an array. `quantile()` on an `FLQuant` will return the specified quantiles along the `iter` dimension. Let's extract the 10th, 25th, 50th, 75th and 90th quantiles.

```
flq <- quantile(fla, c(0.10, 0.25, 0.50, 0.75, 0.90))
```

The object can now be coerced to a `data.frame`

```
fdf <- as.data.frame(flq, drop=TRUE)
```

and inspected to see how the 100 `iters` have been now turned into the five requested quantiles in the iter column

```
##   year iter  data
## 1    1  10% 2.339
```

```
## 2    2  10% 2.613
## 3    3  10% 2.725
```

The long format `data.frame` can be reshaped into a wide format one so that we can instruct `ggplot` to use the quantiles, now in separate columns, to provide limits for the shaded areas in `geom_ribbon`. To do this we can use `reshape`, as follows

```
fdw <- reshape(fdf, timevar = "iter", idvar = c("year"), direction = "wide")
```

This creates a wide `data.frame` in which the `iter` column is spread into five columns named as the levels of its conversion into factor

```
levels(fdf[,'iter'])
```

```
## [1] "10%" "25%" "50%" "75%" "90%"
```

We can now use those five quantile columns when plotting shaded areas using `geom_ribbon`. Please note that the column names returned by `quantile()` need to be quoted using backticks.

```
p <- ggplot(data=fdw, aes(x=year, y=`data.50%`)) +
    geom_ribbon(aes(x=year, ymin = `data.10%`, ymax = `data.90%`), fill="red", alpha = .15) +
    geom_ribbon(aes(x=year, ymin = `data.25%`, ymax = `data.75%`), fill="red", alpha = .25) +
    geom_line() + ylab("data")
print(p)
```

Figure 15: Time series with 75% and 90% credibility intervals plotted using geom_ribbon.

Assigning the result of the call to `ggplot()` to a variable, as done above, will allow us to reuse the plot later on by modifying or adding components.

Example: Simulation trajectories plot

If the result of an stochastic simulation is summarised by showing credibility intervals, it is very informative to plot as well some of the individual iterations (in this case we want iteration 1, 4 and 23) as a way of showing the fact that individual trajectories are generally not as smooth as, for example, the median shown in the figure above.

```
fds  <- as.data.frame(iter(fla, c(1, 4, 23)))

p + geom_line(data=fds, aes(year, data, colour=iter), size=0.5) +
  theme(legend.position = "none")
```

Figure 16: Spaghetti plot of an stochastic simulation, by calling geom_line on top of the stored ribbon plot.

This is easy to do in `ggplot2` by adding an extra element on top of the previous plot, stored in the `p` object from the code above.

Example: Using FLQuants

Coercion using `as.data.frame`, combined with the use of `reshape`, or `dcast` and `melt` (from the `reshape2` package[5]), provides the *FLR* user with the tools required to create a large range of `ggplots` out of any *FLR* object.

TODO: ADD text & example

[5] http://cran.r-project.org/package=reshape2

Example: Bubble plots

Bubble plots allow us to represent a third continuous dimension in a scatter plot by sizing points according the value of a variable. For example, catch in numbers by age and year can be visualized using

```
ggplot(catch.n(ple4), aes(year, as.factor(age), size=data)) + geom_point(shape=21) + scale_size(range =
```

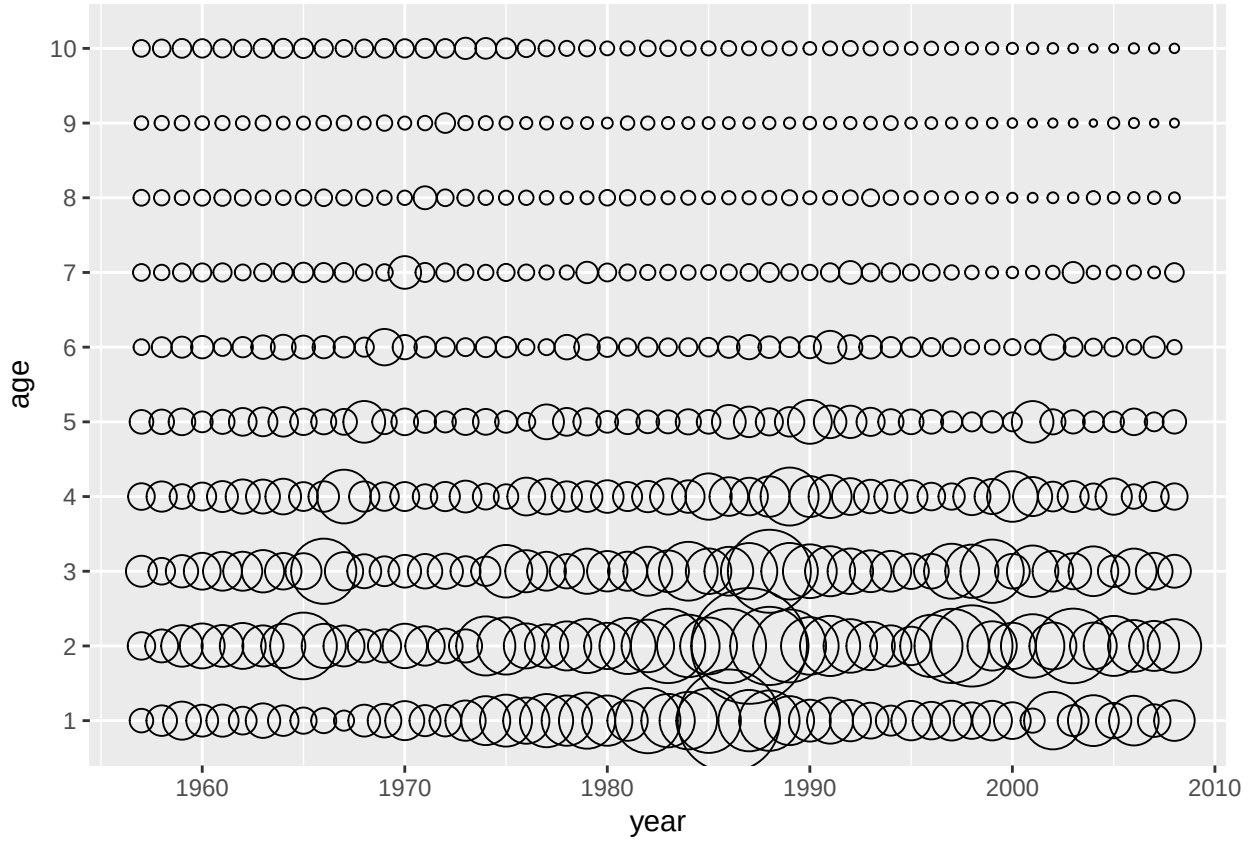


Figure 17: Bubble plot of catch by age in numbners for North Sea plaice.

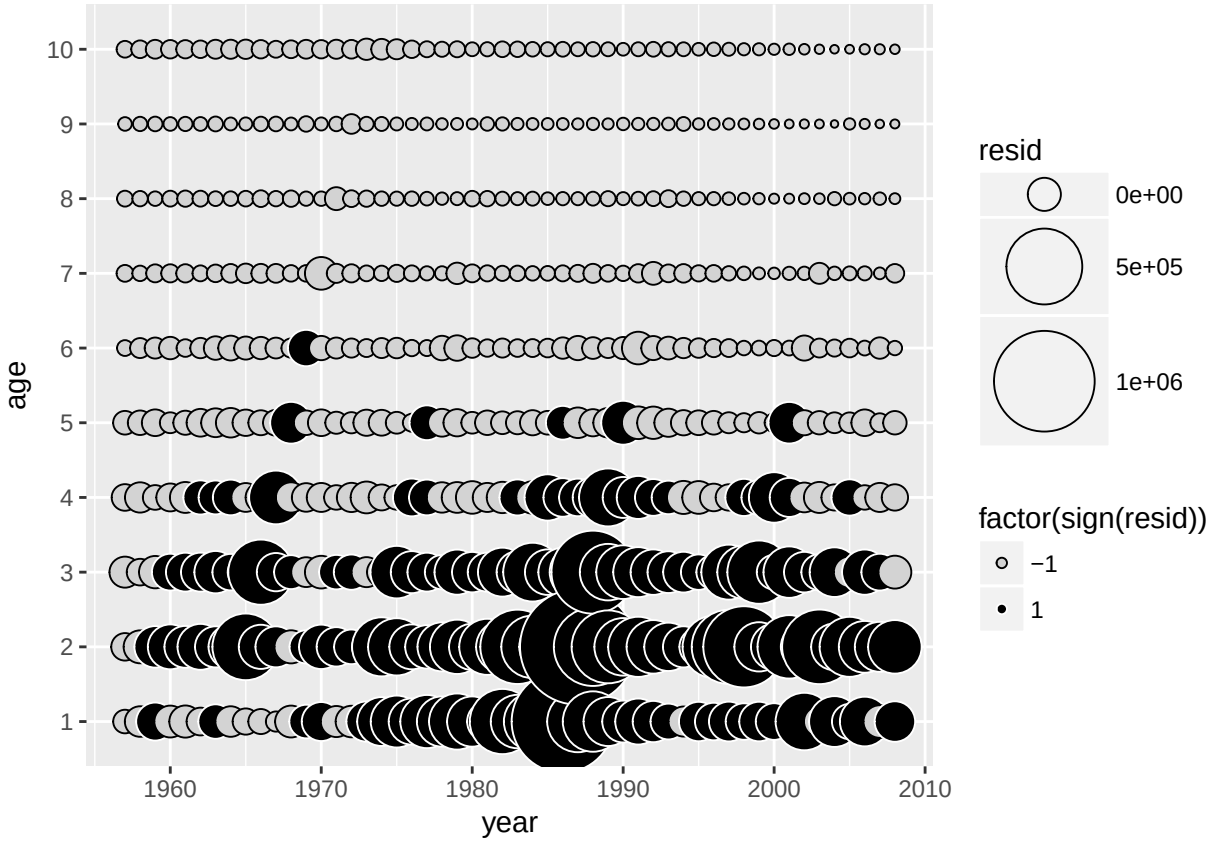
where *data* is used to size the bubbles in the call to *aes()*. This single line of code replaces the functionality offered by the *lattice*-based *bubbles()* method available in *FLCore*.

Example: Residual plots

Residuals plots can be built for example for the numbers at age in the catch FLQuant by subtraction of the computed mean from the data. Then bubble plots can be built in ggplot, with size proportional to the residual and conditional color coding for positive/negative residuals.

```
dat <- as.data.frame(catch.n(ple4))
dat$resid <- dat$data - mean(dat$data)

ggplot(dat, aes(year, as.factor(age), size=resid)) +
    geom_point(shape=21, aes(colour=factor(sign(resid)), fill=factor(sign(resid)))) +
    scale_size(range = c(1, 20)) +
    scale_colour_manual(values=c("black", "white")) +
    scale_fill_manual(values=c("lightgray", "black")) +
     ylab("age")
```



More information

SubSECTION

References

More information

- You can submit bug reports, questions or suggestions on this tutorial at https://github.com/flr/doc/issues.
- Or 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 3.3.2 (2016-10-31)
- FLCore: 2.6.0.20170123
- ggplotFL: 2.5.20161007
- ggplot2: 2.2.0
- **Compiled**: Mon Feb 13 11:21:37 2017

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