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Bioeconomic Modelling Applied to Fisheries with R/FLR/FLBEIA

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Abstract

The main objectives of the study presented in this report were to test the `FLBEIA` API, condition an operating model for the North Sea mixed fisheries and provide feedback on bioeconomic modelling limitations. Additionally, `Fishrent` and `Fcube` were also tested. `FLR`, `FLBEIA`, `Fishrent` and `Fcube` are software packages implemented by the scientific community studying fisheries to run bioeconomic models. A large test was carried out on `FLBEIA` by both running existing examples and trying to implement a bioeconomic model for the North Sea. In general the group felt `FLBEIA` is on the correct path to provide a bioeconomic modelling framework, although some work is still required. `FLBEIA` is not ready yet for production. A list of bugs and improvements was assembled. Conditioning a bioeconomic operating model for the North Sea showed the difficulties of merging economic and biological information. Inconsistencies on the effort definition seem to create additional problems when relating both sources of information. This subject must be further explored. The exercise was successful but data problems prevented the performance of a full economic analysis, although trend analysis on economic indicators for each scenario tested was possible. Nevertheless, these results must be taken carefully.

Contents

1 Introduction

In the scientific community working on fisheries advice, there's a long standing claim, from biologists that economic models don't take into account the full complexity of the stocks' dynamics, and from economists that biological models don't take into account the economic effects of management and the fleet's adaptive strategies. The final outcome is the lack of an integrated bioeconomic modelling platform that takes into account the full complexity and dynamics of stocks and fisheries, as well as the interaction between the availability of resources and their exploitation.

The STECF Expert Working Group (EWG) 12-02, dealing with Baltic and Cod multi-annual management plans (STECF, 2012b) requested JRC to assess the possibility of extending `Fcube` (Ulrich et al., 2011), a multi-species multi-fleet projection algorithm for scenario testing of TAC and effort management options, and merging it with `Fishrent` (Salz et al., 2010, 2011), a bioeconomic model that aims at optimizing the long term rent from fisheries.

After assessing the workload required and its objectives, JRC replied: *Extending Fcube and making the software ready for production in the short term (2 to 3 month) is not possible due to other commitments. However, JRC is interested in developing a mixed fishery bioeconomic model based on Fishrent and Fcube algorithms in FLR.*

To progress along these lines, JRC organized a workshop on bioeconomic modelling using `FLR`, `FLBEIA`, `Fishrent` and `Fcube` (WKBEM) in Ispra, Italy, on the 19th-23rd of November of 2012, with the following ToR:

- Test `FLBEIA` API
- Condition a model based on North Sea mixed fisheries
- Provide feedback on software limitations and further work

`FLBEIA` is an `FLR`[1] package that implements a framework for bioeconomic modelling. The package is being developed by AZTI Fundazioa (Spain) and it was considered as a promising platform to merge `Fishrent` and `Fcube` ideas. One of the tasks of WKBEM was to test `FLBEIA`, in particular with regards to its capacity of delivering bioeconomic analysis in a production environment, like the one found in STECF EWG meetings.

Parallel to testing `FLBEIA`, WKBEM explored the possibility of building a dataset containing both biological and economic information. Such dataset would allow the inclusion of economic dynamics in an operating model, a major step forward to integrated bioeconomic MSEs. On the other hand, it would expose shortfalls and limitations of the data and methodologies.

To carry out this exercise the group used two datasets:

- the STECF economic dataset published in the Annual Economic Report (STECF, 2012a);
- the ICES WGMIXFISH dataset with stock assessment results for the major demersal stocks in the North Sea and `Fcube` projections for distinct management scenarios (Anon., 2012).

[1] http://flr-project.org

The AER dataset is available online[2] to be used for scientific analysis. The WGMIXFISH dataset is the only known attempt to aggregate biomasses, catches, fishing mortality, fishing effort and prices using fleet segments similar to those defined for economic variables under the DCF[3]. The dataset was requested from ICES, which replied positively.

2 Testing the FLBEIA framework

Two different procedures were used to test `FLBEIA`:

- running a set of examples provided by AZTI researchers,
- parameterizing `FLBEIA` to simulate the Scottish fleets operating in the North Sea.

2.1 Compiling, profiling and parallelization

A number of issues were identified in the package that will require further work. This should be considered as a normal part of the development cycle, as further testing and application of the package will help pushing it towards maturity.

The structure of the package, based around a single function that connects the various elements being simulated, is well thought out, although a detailed review should identify elements ready for improvement.

Some thought needs to be given to the ability of the structure chosen to accommodate the use of the multiple options for parallelization currently available in R. Although the package has already been successfully used in an HPC environment, a grid system, other systems could provide different users with the ability to run complex models efficiently, and `FLBEIA` should ideally work with them too. For example, the ability to run on multiple cores, using the `multicore` package, might be limited by the use of input and output files, that might be accessed and written simultaneously by processes running in parallel.

Some of the operations carried out by the `BEIA` function could benefit from speed improvements. An initial exercise of speed profiling was carried out. There is no single operation greatly slowing down the `BEIA` method, but some functions and methods being called repeatedly were identified. Small improvements in their execution speed could have a significant impact on overall running times.

For analyses of limited complexity, like the ones done during the meeting, memory did not seem to be a limiting factor, but this is likely to become more important once larger and more complex fisheries are modelled. `FLBEIA` could benefit from some of the developments taking place in `FLR` that allow storage of large objects on disk, and an initial test is being carried out on using those facilities with an `FLBEIA` example.

2.2 Running examples

Two examples were put together by AZTI scientists to show how to make use of `FLBEIA`'s flexibility regarding modelling processes and testing alternative management procedures. The

[2] `http://stecf.jrc.ec.europa.eu/data-reports`
[3] Data collection framework (Reg. EC/199/2008; Reg. EC/949/2008)

simplest example, using two stocks and two fleets, was a good starting point for the work to be carried out in the following days. The second example, which was more complex, took too long to run and was not explored any further. In both cases the examples were based around external data and code files.

2.3 Parameterizing FLBEIA to simulate the Scottish fleets operating in the North Sea

`FLBEIA` was applied on a subset of the WGMIXFISH dataset with 2 Scottish fleets (SC_Otter>=24 and SC_Otter<24) and one species, haddock (HAD).

The following problems were found while parameterizing the model:

- The stock recruitment relationship must be defined with internal functions of `FLBEIA` and using the FLSR class is not straightforward. A code fix was developed during the meeting.
- The names of objects could be inconsistent between different steps because they are currently redefined at several times.
- It was hard to know if all objects had to be used and even when obviously not used, they still had to be created (example BD).
- The 2 fleets used didn't had all haddock catches, a third fleet should have been created to include the fishing mortality missing.
- Only 1 stock was used which meant that only part of the revenue was taken into account.

The group has a few suggestions which would make it easier to run the model and make our simulation better:

- A GUI or a suite of scripts would be useful. This has been partially addressed.
- Objects should be defined only once (names of stocks, fleets, metiers, years used for simulation/prediction, age of the stocks)
- For objects and controls that are not necessary, default values should be created in the BEIA call (so that the user doesn't have to make the objects).
- It would be good to create a fleet with the rest of the catch (based on the FLStock and FLFleets objects)
- The fishing revenue from other species should also be included per fleet (per metier?) so that the profit and other economic indicators are calculated from the whole revenue rather than a subset.

2.4 Comparing FLBEIA with Fishrent and Fcube

`Fishrent` (Salz et al., 2011) and `FLBEIA` (Garcia et al., 2012) are two bioeconomic models created to conduct bioeconomic analysis for fisheries. Although both have the same aim the packages differ on the structure, implementation and objectives.

`Fishrent` is a simulation model but it can also optimize a fishery over a number of years for a set of variables (e.g. profit, employment, wages, and landings). This is useful to investigate the potential of the system and has been used to estimate the resource rent of fisheries systems (Salz et al., 2010). This type of optimization is not generally used for impact assessments which are based on forward simulations of the fishery under a set of objectives and constraints.

`FLBEIA` is a simulation model where the MSE (management strategy evaluation) framework is followed. That is, it assesses the consequences of a range of management strategies or options. It does not seek to prescribe an optimal strategy or decision. Instead, it seeks to provide the decision maker with the information on which to base a rational decision, given their own objectives, preferences, and attitudes to risk.

In terms of the simulation of the fleet tactical behavior, both are able to simulate different pre-defined behavior (i.e, Max TAC, Min effort, etc). In the case of `Fishrent` it is done on a fleet basis and in `FLBEIA` on a metier basis. The optimization of the fishing decision of a fleet (optimal allocation of the fishing effort of a fleet to the different metiers) is available in `FLBEIA`.

`FLBEIA` has directly taken the capital dynamics model developed and used in `Fishrent`.

Price dynamics are different in both models but both allow simulations based on fixed or dynamic prices.

To account for all the mortality on a stock, `Fishrent` uses catch shares of the fleets included and if the sum of the catch shares for those fleets is lower than one, the rest of the catch is taken by a non-explicit fleet for which no economic dynamics are included. In `FLBEIA` an additional fleet needs to be defined. It has to be decided if this fleet should be excluded from the economic analysis or if it has to mimic the behavior of some other fleet.

In `Fishrent`, the value of other species is accounted for as a percentage of the value of the included species. It is important to account for this extra revenue because the long term fleet dynamics investigate past profits to project investment and disinvestment in fisheries. In `FLBEIA` is open to the user to decide how to deal with unaccounted revenue.

Stock assessment in `Fishrent` is currently restricted to biomass dynamics model while `FLBEIA` allows the user to choose age structured or biomass dynamics models. The age structured population dynamics are being added to `Fishrent` in FP7 project VECTORS.

Uncertainty is a key issue in impact assessment. `FLBEIA`, following the MSE approach, provides results in terms of risk levels, accounting for the uncertainty derived from the operating model (biologic and economic sub-models) and the management procedure model. `Fishrent` is a deterministic model.

3 Conditioning an operating model for the North Sea mixed demersal fisheries

The aim of this task was to build an operating model for the north sea mixed demersal fishery that includes economic information, which required merging the information contained in the AER dataset (economic) and the WGMIXFISH dataset (stock assessment). Such operating model would allow economic drivers to be taken into account when modelling the dynamics of the fleet, as well as simulating decision making processes that consider the economic outcome of the fleets.

One of the biggest challenges in merging the two datasets is reconciling the mis-match between the different fleet definitions and spatial aggregation used by each group.

This section describes the exercise carried out to build the operating model, that should include: (i) the population dynamics of the major demersal stocks caught in the North Sea, (ii) fishing effort, fishing mortality and costs for the most important fleets operating in the North Sea, and (iii) sales prices of commercial species.

The exercise was split into two tasks:

1. conditioning the populations dynamics, by using stock assessment results to fit stock-recruitment models for each stock and add uncertainty both to fishing mortality and recruitment;
2. computing economic indicators, by linking the AER and WGMIXFISH datasets so that economic information from the AER could be applied to the WGMIXFISH.

Additionally, the analysis performed by the WGMIXFISH can be extended to include some economic indicators. Such analysis is a complex scaling of costs and revenues and would not constitute an integrated bioeconomic analysis, but may help the scenario analysis done for `Fcube` results.

3.1 Conditioning the populations dynamics

In conditioning the biological components of the model we were chiefly interested in how easy was it to develop operating models in `FLBEIA`. In fact the first task was to simplify the code to make it easier to see where and how conditioning could be implemented. In the end it was a relatively easy task. All the `FLBEIA` requires is a list of `FLBiol`[4] objects and a list of `FLSR`[4] like objects.

The `FLBiol`[4] objects were created from a `FLStock`[4] object. To introduce variability in the history of the stock, correlated log-normal error was added to the historical F at age (estimated from the current assessment of the stock, in this example NS haddock) and independent log-normal error to the historical recruitment. Predefined values in the following code are the CVs used in the log-normal errors (i.e. `CV.harvest`), the number of realisations to generate (`niters`) and the final year in the `FLBEIA` projection (`finalyr`).

```
stock.prop <- propagate(stock, niters)
harvest(stock.prop) <- genFLQuant(harvest(stock), method = "ac",
                                  cv = CV.harvest, n = niters)
stock.n(stock.prop) <- genFLQuant(stock.n(stock), method = "ac",
                                  cv = CV.stockn, n = niters)
```

Then the numbers at age implied by recruitment and F was calculated and the object converted to a list of FLBiols

```
bio <- as.FLBiol( fwdWindow(stock.prop, FLBRP(stock.prop), end = finalyr) )
biols <- FLBiols(bio)
```

We chose to use newly developed methods to add uncertainty to stock histories `genFLQuant` and a combination of `fwdWindow` with `FLBRP`[4] found in `FLash` and `FLAssess`[4] respectively, to deal with the forecast assumptions. These methods are available in a package `FLData` being

[4] See FLR for more information on classes

developed by the JRC as part of the a4a initiative[5]. In short they model the correlation in the data matrix and use this to add noise around the data. Currently two methods are available, one to add multivariate gaussian error (on the log scale) and the other models the trajectories by age as random walks.

To complete the conditioning it is necessary to estimate the stock recruitment relationship implied by each simulation to be used in the operating model projections. Predefined values are the stock reruitment model (`srmodel`).

```
# set up stock recruitment object
SRsim <- FLSRsim(model=srmodel, rec = rec(bio, rec.age=1), ssb = ssb(bio))
SRsim@params[]  <- sr(as.FLSR(bio, model=srmodel))@params
SRsim@timelag[] <- c(1,2) # c(timelag.year,timelag.season)

# uncertainty in SR
# projection uncertainty - multiplicative error CV = 20%
SRsim@uncertainty[] <- rlnorm(dim(SRsim@uncertainty[])[2], 0, 0.2)

# historical uncertainty... not clear what to do...
SRsim@uncertainty[, dimnames(catch.n(stock))$year] <- 1
#or should it be exp(sr.pars @ residuals)[,dimnames(catch.n(stock))$year]
SRs <- list(SRsim)
names(SRs) <- bio@name
```

The objects `biols` and `SRs` were then ready to be passed to the `FLBEIA` function.

3.2 Computing economic indicators

The cornerstone of merging both datasets was linking the different fleet definitions.

In both datasets the fleet definition includes information about the fishing technique and vessel length. However, both data sets are using different definitions and aggregation levels for fishing techniques.

Fleet length classes differ in both data sets. Nevertheless, the length categories used in the WGMIXFISH dataset are aggregations of the ones used by the AER, *e.g.* the <24m used by the WGMIXFISH covers the <10m, 10-12m, 12-18m and 18-24m used in the AER.

Regarding Member States, the AER dataset has information for the UK, while the WGMIXFISH dataset has England and Scottish fleets separated. Additionally, the WGMIXFISH dataset includes Norway which is not included in the AER dataset.

Table 1 shows the links between the WGMIXFISH and the AER fleet definitions.

[5] `https://fishreg.jrc.ec.europa.eu/web/a4a`

Table 1: Link between the AER and the WGMIXFISH fleet definitions

WGMIXFIXH	AER			Description
fleet code	country	gear	vessel length	
BE_Beam<24	BEL	TBB	VL1824	
BE_Beam<24	BEL	TBB	VL1218	
BE_Beam>=24	BEL	TBB	VL2440	
BE_Otter	BEL	DTS	VL1824	
BE_Otter	BEL	DTS	VL2440	
DK_Beam	DNK	TBB	VL1218	
DK_Beam	DNK	TBB	VL1824	
DK_FDF	DNK	FDF	NA	Fully Documented Fishery
DK_OTH	DNK	OTH	NA	Other metier
DK_Otter<24	DNK	DTS	VL0010	
DK_Otter<24	DNK	DTS	VL1012	
DK_Otter<24	DNK	DTS	VL1218	
DK_Otter<24	DNK	DTS	VL1824	
DK_Otter24-40	DNK	DTS	VL2440	
DK_Pelagic	DNK	PEL	NA	No data for TM
DK_Seine	DNK	DTS	VL1012	
DK_Static	DNK	PGP	VL0010	polyvalent passive gears only
DK_Static	DNK	PGP	VL1012	polyvalent passive gears only
DK_Static	DNK	PGP	VL1218	polyvalent passive gears only
EN_Beam	GBR	TBB	VL0010	UK only
EN_Beam	GBR	TBB	VL1012	UK only
EN_Beam	GBR	TBB	VL1218	UK only
EN_Beam	GBR	TBB	VL1824	UK only
EN_Beam	GBR	TBB	VL2440	UK only
EN_FDF	GBR	FDF	NA	no data
SC_FDF	GBR	FDF	NA	no data
UK_Otter<24	GBR	DTS	VL1012	SC_Otter<24 + EN_Otter<24
UK_Otter<24	GBR	DTS	VL1218	SC_Otter<24 + EN_Otter<24
UK_Otter<24	GBR	DTS	VL1824	SC_Otter<24 + EN_Otter<24
UK_Beam<10	GBR	DTS	VL0010	SC_U10_OTB + EN_U10
UK_Otter24-40	GBR	DTS	VL2440	EN_Otter24-40 + SC_Otter>=24
EN_Otter>=40	GBR	DTS	VL40XX	
SC_Static	GBR	DFN	VL0010	
SC_Static	GBR	DFN	VL1012	
SC_Static	GBR	DFN	VL1218	
SC_Static	GBR	DFN	VL2440	
SC_Static	GBR	FPO	VL0010	
SC_Static	GBR	FPO	VL1012	
SC_Static	GBR	FPO	VL1218	
SC_Static	GBR	FPO	VL2440	
SC_Static	GBR	HOK	VL0010	
SC_Static	GBR	HOK	VL1012	
SC_Static	GBR	HOK	VL2440	

Continued on next page

Table 1 – *Continued from previous page*

WGMIXFIXH	AER			Description
fleet code	country	gear	vessel length	
FR_Otter>=40	FRA	DTS	VL1012	
FR_Otter10-40	FRA	DTS	VL1218	
FR_Otter10-40	FRA	DTS	VL1824	
FR_Otter10-40	FRA	DTS	VL2440	
FR_Otter10-40	FRA	DTS	VL40XX	
FR_Nets	FRA	DFN	VL0010	
FR_Nets	FRA	DFN	VL1012	
FR_Nets	FRA	DFN	VL1218	
FR_Nets	FRA	DFN	VL1824	
FR_Nets	FRA	DFN	VL24XX	no fishing in North Sea
GE_Beam>=24	DEU	TBB	VL2440	
GE_Static	DEU	DFN	VL1218	
GE_Static	DEU	DFN	VL2440	
NL_Beam<24	NLD	TBB	VL1218	
NL_Beam<24	NLD	TBB	VL1824	
NL_Otter	NLD	DTS	VL0010	
NL_Otter	NLD	DTS	VL1824	
NL_Otter	NLD	DTS	VL2440	
NL_Static	NLD	PGP	VL1218	no fishing in North Sea
NO_Otter<40	NOR	DTS	VL2440	
NO_Otter>=40	NOR	DTS	VL40XX	
NO_Pelagic	NOR	PEL	NA	
NO_Static	NOR	DFN	NA	
NO_OTH	NOR	OTH	NA	
NL_Beam>=40	NLD	TBB	VL40XX	
NL_Beam24-40	NLD	TBB	VL2440	
GE_Otter24-40	DEU	DTS	VL40XX	
GE_Otter>=40	DEU	DTS	VL2440	
GE_Otter<24	DEU	DTS	VL1824	
GE_Otter<24	DEU	DTS	VL1218	
GE_Otter<24	DEU	DTS	VL1012	

The method used to compute economic costs for the North Sea demersal fishery was based on modelling economic variables by unit as a function of the fleet's components, which are shared between the two datasets, and use the North Sea information to scale the variables and estimate absolute economic indicators. The full analysis is presented in Annex 01.

Our approach was:

1. use the AER dataset to compute economic variables by unit: fixed costs by vessel, crew costs by revenue and variable costs by effort;
2. use the AER dataset to model the economic variables mention above as functions of the fleets' components: member state, gear and vessel length;

3. compute the economic variables by unit for the fleets defined in the WGMIXFISH dataset using the common components of the fleet definition;

4. compute the economic indicators for the North Sea: fixed costs, crew costs and variable costs, by scaling the economic variables by unit with the relevant information, capacity, revenue or effort.

For this analysis variable costs were split into variable costs depending on revenue, *e.g.* labour costs, and those depending on effort, *e.g.* energy costs. With regards to revenue the value of landings was computed using average prices estimated from the AER information and multiplied by the weight landed by species in the WGMIXFISH dataset. Furthermore, it was necessary to compute the revenue due to other species than those included in the WGMIXFISH dataset, since the fleets considered also landed other commercial species forming part of the revenue. Finally, all economic variables were adjusted for inflation to 2010 values. For details see Annex 01.

The major challenge of this analysis was to use information at distinct aggregation levels to compute all necessary indicators, the AER data is aggregated at the FAO region 27, while the WGMIXFISH dataset is aggregated to the North Sea. The rescaling mechanism adopted overcomes this problem but assumes that the costs per operational unit are constant for all area 27. This assumption is clearly sensitive to the relation between steaming and fishing each fleet segment has when fishing in the North Sea or outside the North Sea. In any case there was no information to inspect this assumption.

Several data problems were found during the exercise. The WGMIXFISH dataset information about prices is not coherent and some member states submitted data in different units for the same time series. With regards to the capacity information some member states did not provide information. As expected, the AER dataset is more consistent with regards to the economic information. However, there are several cases of incomplete information, *e.g.* providing fixed costs but not capacity. In both cases the expert's reports are valuable resources and both are available on STECF and ICES websites, respectively.

The definition of effort can be a major source of error when merging the datasets. Both the criteria used for allocation of fishing activity to segments/metiers and the unit of effort can be potentially problematic.

In the case of the allocation criteria there is a fundamental difference between the economic and the biological analysis. For economics the boat is the unit of analysis, and the fact that more fishing mortality may be executed by having more than one gear is not relevant. It simply reflects a different relationship between costs and income, when compared with a vessel using a single gear. However, for conservation purposes it's extremely important to know which gears a fleet can use and their selectivity. The dynamics associated with multi-gear fishing have a huge impact on the stocks' conservation and can not be ignored when forecasting. In this perspective, the AER criteria of allocating each vessel's effort to the dominant gear (used >50% of the time) may result in an underestimation of effort for multi-gear fleets, once that the effort of the non-dominant gears is not accounted. The WGMIXFISH data call does not state effort allocation criteria explicitly and seems to rely on the definition of metier.

With regards to the effort unit, neither data call states it explicitly, leaving the definition for the relevant regulations, and ultimately to the Members States' interpretation. One potential problem with the loose definitions of units for measuring fishing effort is the usage of "days-at-sea" and "days-fishing" interchangeably. If days-at-sea are recorded and supplied, then the steaming time of the vessel between the harbour and the fishing grounds is included. If days-fishing is supplied, then the steaming time is generally excluded from the data. For coastal fleets this shouldn't be too problematic but for fleets that go to faraway fishing grounds it may have some impact.

Potentially, there are discrepancies in the methods for effort allocation and the effort unit definition, which make it difficult to understand if both series are comparable. As a matter of fact, even within each data set the internal consistency of effort values between countries is not guaranteed.

Comparing CPUEs computed from each dataset for the same fleet reflect the problem of different effort definitions. Figure 1 shows an example for cod, where it is clear that differences between both datasets exist. The impact of this inconsistency was not further explored, but there is potential to change the relation between costs and revenues.

The results presented from the approach above have to be interpreted with care once there are still doubts about the data consistency. However, there are some improvements that can be done in future analysis:

- revise data
- get complete information from all countries and all variables;
- improve modelling
  - deal with high residuals through outliers analysis or alternative error models to deal with over-dispersion;
  - explore alternatives to GLM;
- explore the results at the fleet level to better identify data problems and improvements on modelling;
- explore methods to define how uncertainty on models can be included in the economic indicators;

4 Feedback

FLBEIA seems a well thought out framework for developing management strategy framework evaluations combining both economic and biological data.

Being developed within the FLR architecture, FLBEIA can rely on the full FLR machinery in terms of data structuring and parameter estimation for the fishery component.

However, as a stand-alone approach, FLBEIA combines functions embedded in the package and some specific scripts that need to be called and used in the right order to run the analysis.

Clearly it requires significant expertise on the R language and the FLBEIA framework in general. A new user will have to invest some time, even if already familiar with FLR, to apprehend the complexity of FLBEIA and feel confident with the results.

The examples prepared for the workshop run, which is an important achievement considering distinct platforms were used and each person had to make some tweaking of the code. The modular design worked moderately well, although some bugs prevented the group to go further

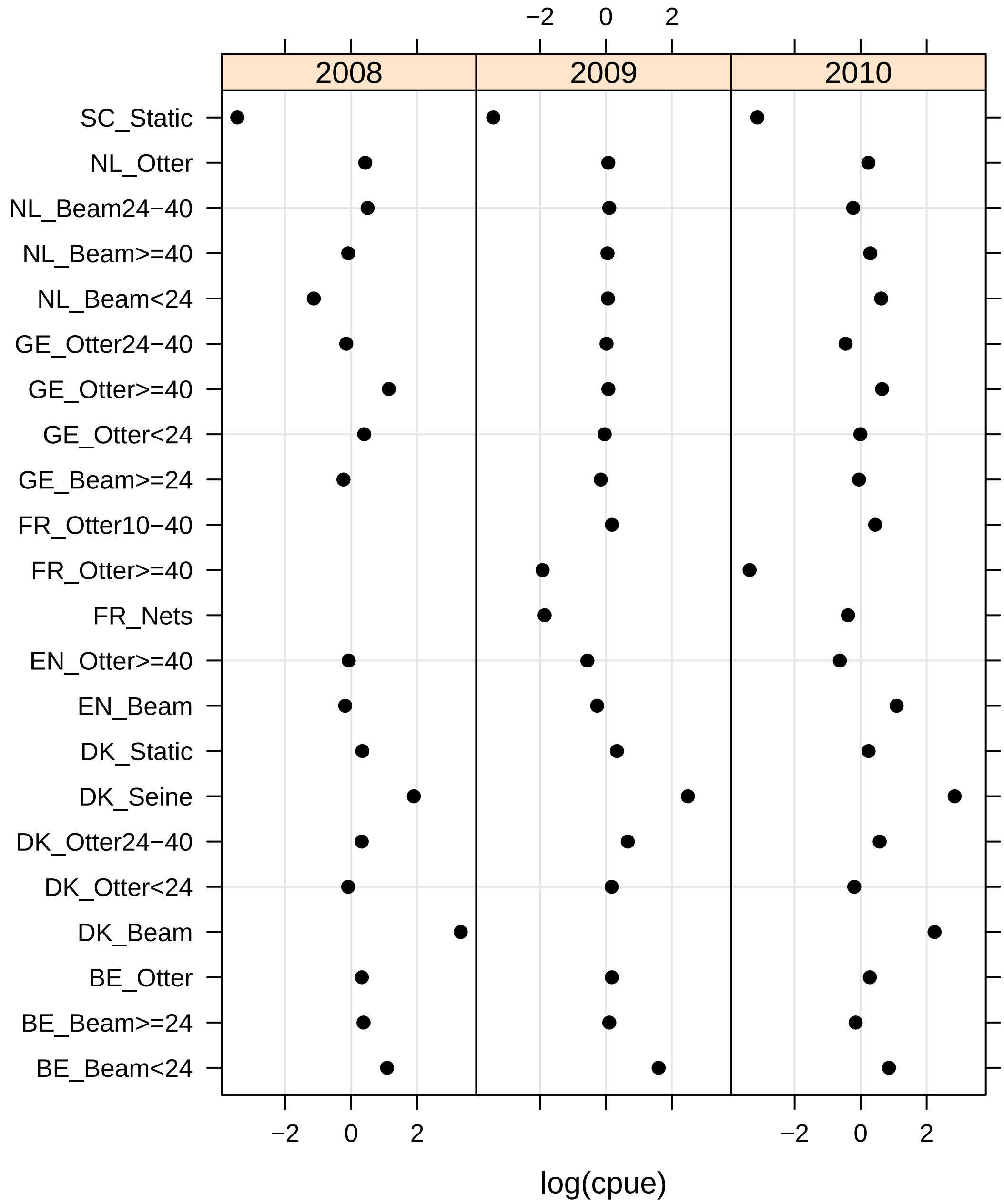


Figure 1: Log CPUE ratios. AER CPUE over WGMIXFISH CPUE

in testing. It appears that simple assumptions about the economic behavior of fishing fleets in multi-species fisheries can be modelled.

Overall FLBEIA seems very promising but there needs to be a fair amount of code streamlining and testing by multiple different users to assess flexibility of use under different situations.

- Design

  FLBEIA design in levels seems appropriate. However, the implementation is not complete and it should be revisited to simplify/clear the procedures to make changes of input functions or options. As it stands now it's confusing.

With regards to the user interface some debate is still required. Using files to run analysis is not the best approach (see below).

Memory and speed performance should be evaluated and improved when possible.

- FLR standard

  FLBEIA does not use the FLR objects appropriately. The code needs to be reviewed to more closely merge with FLR. FLR methods could be extended or modified if required, rather than implementing alternative versions.

  This situation makes the implementation of case studies cumbersome. A code review combined with the implementation of more flexible use of standard FLR objects would improve the usability for a wide group of people. For example, during the workshop the biological conditioning was reduced to ten lines of code by taking advantage of FLR functionality.

- Flexibility

  The flexibility of FLBEIA to allow freedom to the user to adapt, update or change some of the dynamics in the model following their own needs is still to be demonstrated. By design it seems promising but the group was unable to test it thoroughly. These features are not ready for production.

  Considering the combination of flexibility and transparency that are strengths of FLR it sounds promising and worthwhile to develop this package in a truly integrated and multidisciplinary way.

  Once more national labs try to use FLBEIA, it will become apparent if it indeed has sufficiently flexibility to accommodate the wide range of case-studies that are available in Europe.

- Documentation

  The documentation provided by FLBEIA is quite extensive when compared to other software packages.

  An extensive API documentation is required as it relates to the functions that can be provided at each level.

  In addition, providing examples on the FLR wiki would greatly facilitate the use of FLBEIA for the national labs in the EU.

- Code cleaning

  FLBEIA's code requires cleaning and naming standardization to make it possible for others to develop, check or contribute.

  Running examples showed some implementation problems which seem to be possible to overcome with a bit of work to modularize the code and organize the model building into distinct functions.

- Diagnostics

  Testing and contrasting for complex models such as MSEs is a general problem, which is reflected in FLBEIA's analysis. It's an open question that will require the involvement of the scientific community. Definitely it must be sorted out if FLBEIA is to be used in impact assessments.

- Conditioning

  It its current form it is not strait forward to tune a new case study.

  Conditioning is dependent on the state of the data, nevertheless this is something that has been made more user-friendly for non `FLR` users.

  As expected, conditioning requires some *ad hoc* coding for adapting the model to the data.

  Coding requires quite a lot of work specially for cleaning up.

  Data preparations of the different objects is currently a bit confusing.

- Long term optimization

  Ideally a long term management evaluation tool would provide optimal economic management advice. However, in such a complex environment it may be not be possible (nor necessary) to carry out such analysis. A discussion has to be made about the interest and relevance of optimizing the rent of multi-fleet mixed fisheries and in which scope it may happen.

- Analysis based on external files

  The mechanism applied to the `FLBEIA` examples makes review and adaptation of code more difficult, and limits the ability to apply certain mechanisms for High Performance Computing, like multicore. From the various experiences, a standard guideline for structuring files and folders could be developed.

  The architecture of the files is not optimal since there are many redundant objects and several read/write operations that can be streamlined to make it more efficient

- Other

  Avoid use of @ slot accessors.

4.1 Lessons learned for FLR

- Need to fully review FLFleet class and methods. Initial proposal is along these lines:
  - Possible improvements to class design, ensuring back compatibility
    * Class to move to DB (SQLite) implementation, and methods into SQL queries
    * Review needs for accessors and merging methods, draw a full map

5 Future work

The participants acknowledged the progress made during the workshop and showed interest in participating in a follow up.

5.1 FLBEIA

All participants considered `FLBEIA` a good framework for bioeconomic analysis to support impact assessments.

The participants showed interest in being involved in future developments and to contribute if possible/necessary.

To make it widely available and used it still requires some work, mainly tidying up examples and documentation, cleaning the code and integrating it better in `FLR`.

It is clear that more standard `FLR` objects should be used in `FLBEIA`, which will require some recoding of `FLBEIA` and `FLR`.

More documentation should be made available for `FLBEIA` on public accessible websites.

The user interface can be improved with some concerted effort involving `FLBEIA` core developers/users and `FLR` core developers and experienced R programmers. This would lead to the improvement of the economic classes and methods within `FLR` itself.

5.2 Link with STECF/Effort

The JRC effort database is considered a valuable resource as the data was requested specifically to be compatible with fleet definitions specified for recovery and long term management plans:

- the cod long term management plan [R(EC) No 1342/2008],
- the recovery plan for Southern hake and Norway lobster stocks in the Iberian peninsula [R(EC) No 2166/2005],
- the multi-annual plan for the North Sea plaice and sole stocks [R(EC) No 676/2007],
- the multi-annual plan of Western Channel sole stock [R(EC) No 509/2007],
- the multi-annual plan for the cod stocks in the Baltic Sea [R(EC) No 1098/2007],
- the multi-annual plan for the sustainable exploitation of the stock of sole in the Bay of Biscay [R(EC) No 388/2006],
- R(EC) No 2347/2002 establishing specific access requirements and associated conditions applicable to fishing for deep sea stocks, and
- R(EC) No 1954/2003 on the management of the fishing effort relating to certain Community fishing areas and resources - so called Western Waters regime.

The database contains effort statistics (kWdays, GTdays) and number of vessels by fleet and sub-fleet categories, and catch information (tonnes landed and, where data exists, discarded) for nearly all species caught by EU member states. To date it has not been considered possible to merge this data set with the AER economic data. The biggest difficulty is the different vessel length categories used.

For the Kattegat, Skagerrak, North Sea and the Western Waters the effort database uses three vessel length-over-all categories: less than 10m ('u10m'), between 10m and 15m ('o10t15m') and more than 15m ('o15m'). The first length category is consistent with the AER. The upper bound of the second category, 15m, falls part way between the bounds of the 12m to 18m category of the AER data ('VL1218'). The effort database split at 15m relates to the fact that only vessels greater than 15m were required to carry VMS. VMS is now required for vessels >= 12m. There is nothing in R(EC) No 1342/2008 requiring the 'o10t15m' vessel length category. For the Baltic region there is not a problem. The length categories less than 8m ('u8m') and between 8m and 10m ('o8t10m') can me merged. All other length categories are as for the AER.

Table 2 shows a possible link between gear definitions used in each dataset. Gear codes are mostly compatible.

Table 2: Gear definitions used in the AER and in the Effort Database

	AER		Effort Meeting		
Active/Passive	Description	Code	Code	Associated Gear Codes	Description
Active Gear	Beam Trawlers	TBB	BEAM	TBB	Beam Trawls
	Demersal trawlers	DTS	OTTER	OTB, OTT, PTB	Bottom otter trawls,
					multi-rig otter trawls or bottom pair trawls
	and/or demersal seiners		DEM_SEINE	SSC, SDN, SPR	Fly shooting seines,
					anchored seines or pair seines
	Pelagic Trawlers	TM	PEL_TRAWL	OTM, PTM	Midwater otter trawls,
					midwater pair trawls
	Purse Seiners	PS	PEL_SEINE	PS	Purse seines, fly shooting seines,
					anchored seines
	Dredges	DRB	DREDGE	DRB, HMD	Dredges
	Vessels using	MGO	No equivalent		
	other active gears				
	Vessels using	MGP	No equivalent		
	polyvalent active gears only				
Passive Gear	Vessles using hooks	HOK	LONGLINE	LHP, LHM, LTL, LLD, LLS	Drifting longlines,
					set longlines
	Drift and/or	DFN	GILL	GNS, GND	Driftnets,
					set gillnets (except trammel nets)
	fixed netters		TRAMMEL	GTR	Trammel nets
	Vessels using	FPO	POTS	FPO	Pots & traps
	pots and/or traps				
	Vessles using	PGO	No equivalent		
	other passive gears				
	Vessles using	PGP	No equivalent		
	polyvalent passive gears only				
Polyvalent Gears	Vessels using	PMP	No equivalent		
	active and passive gears				

One additional difficulty in matching the AER to the effort database is the different criteria used for the allocation of effort in the case of multi-gear vessels. The AER approach is to allocate effort deployed by each vessel to the dominant gear, defined by the gear used more than 50% of the time. While the effort database uses the criteria defined in the relevant regulation.

The effort database currently makes no distinction between Nephrops functional units. The WGMIXFISH showed effort and total landed weight data can be successfully supplied by specific Nephrops FU.

5.3 Link with ICES/WGMIXFISH

The ICES WGMIXFISH will continue meeting twice a year, and this is certainly a good framework for continuing the work, as it insures regular milestones, work planning from one time to the next, and embedding results in an operational advice context.

The work done to merge economic information from the AER to the WGMIXFISH dataset identified some problems with the data that WGMIXFISH will have to overcome if they want to pursue the objective of extending the `Fcube` analysis to integrate economic indicators.

The progress on getting economic indicators for `Fcube` should result in a true feedback loop so that it can serve as a operating model for Management Strategy Evaluation algorithms.

References

Anon., 2012. Report of the Working Group on Mixed Fisheries Advice for the North Sea (wgmixfish). ICES CM 2012/ACOM:22.

Garcia, D., Prellezo, R., Sanchez, S., Andres, M., Santurtun, M., 2012. FLBEIA: A toolbox to conduct bio-economic impact assessment of fisheries management strategies. In: ICES ASC, Bergen.

Salz, P., Buisman, E., Frost, H., Accadia, P., Prellezo, R., Soma, K., 2010. Study on the remuneration of spawning stock biomass. Tech. rep., Framian.

Salz, P., Buisman, E., Frost, H., Accadia, P., Prellezo, R., Soma, K., 2011. FISHRENT: Bio-economic simulation and optimisation model for fisheries. Tech. Rep. 2011-024, LEI.

STECF, 2012a. The annual economic report on the EU fishing fleet (STECF-12-10). JRC Scientific and Policy Reports. Publication Office of the European Union: EUR 25452 EN, JRC 73332.

STECF, 2012b. North Sea and Kattegat scoping for mixed fisheries (STECF-12-04). JRC Scientific and Policy Reports. Publication Office of the European Union: EUR 25314 EN, JRC 70966.

Ulrich, C., Reeves, S. A., Vermard, Y., Holmes, S. J., Vanhee, W., 2011. Reconciling single-species tacs in the north sea demersal fisheries using the fcube mixed-fisheries advice framework. ICES Journal of Marine Science: Journal du Conseil 68 (7), 1535–1547.

Annex #01
Building a bioeconomic dataset
Merging STECF economic indicators with ICES WGMIXFISH fisheries indicators under distinct Fcube scenario testing

January 15, 2013

Abstract

A methodology was developed to compute economic costs for the North Sea demersal fishery based on modelling economic indices as a function of the fleet's components and use the North Sea information to scale the indices and estimate crew costs, variable costs and fixed costs. The basis for this exercise were STECF's economic dataset published in the Annual Economic Report (AER) and the "biological" dataset with the results of the application of Fcube to the North Sea demersal fisheries, carried out by ICES WGMIXFISH. Revenue was computed by multiplying average prices estimated from the AER information by the weight landed by species in the North Sea. Furthermore, it was necessary to compute the revenue due to other species than those included in the WGMIXFISH dataset, once that the fleets considered also catch other commercial species from which a part of the revenue is made of. All economic variables were adjusted for inflation to 2010 values. Several data problems were found during the exercise. The WGMIXFISH dataset information about prices is not coherent and some member states submitted data in distinct units for the same time series. With regards to the capacity information, also some member states did not provide information. As expected, the AER dataset is more consistent with regards to the economic information. However, there are several cases of incomplete information, *e.g.* providing fixed costs but not capacity, which may bias the analysis of aggregated data. In both cases the expert's reports are valuable resources and both are available on STECF and ICES websites, respectively. The biggest problem however is the effort information, which in both cases does not seem to be the same, generating very different CPUE values for each dataset. The impact of this issue was not further explored, but clearly there is potential to change the relation between costs and revenues. In particular due to data problems the results were not sufficiently robust to allow the computation of fleet performance indicators. However, it is possible to evaluate relative differences for each scenario and add to the WGMIXFISH analysis a layer of rational based on economics.

Contents

1 Introduction

One of the biggest challenges to perform bioeconomic analysis in Europe is the mis-match between economic and stock assessment datasets. The different fleet definitions and spatial aggregation used for each group of variables, make it very hard to link the information from both sources.

During the Workshop on Bioeconomic Modelling (WKBEM) an exercise was carried out to explore the possibility of building a dataset containing both biological and economic information. Such dataset would allow the inclusion of economic dynamics in an operating model, a major step forward to integrated bioeconomic MSEs. On the other hand, it would expose shortfalls of the data and methodologies.

To carry out this exercise the group used two datasets:

- the STECF economic dataset published in the Annual Economic Report (REF) - this dataset was stored in a postgresql database;
- the ICES WGMIXFISH dataset with stock assessment results for the major demersal stocks in the North Sea and Fcube projections for distinct management scenarios (REF) - this dataset was stored in FLR objects.

The objective of this exercise was to compute economic indicators for the North Sea demersal fishery, using statistical modelling to estimate how economic indicators for FAO area 27 (from the AER) related with the fleet's components, which are shared between the two datasets, and apply these to the North Sea information (from WGMIXFISH) to compute economic indicators for the North Sea demersal fisheries.

As a secondary objective, the analysis performed by WGMIXFISH can be extended to include economic indicators. Such analysis is a complex scaling of costs and revenues and would not constitute an integrated bioeconomic analysis, but may help the scenario analysis done for Fcube results.

2 Data

In detail, the economic variables taken form the AER were:

- Income
  - value of landings (euros),
- Variable costs
  - energy costs (euros),
  - crew wage (euros),
  - unpaid labour (euros),
  - repair costs (euros),
  - other variable costs (euros)
- Fixed costs
  - depreciation costs (euros),
  - opportunity costs (euros),
  - other non-variable costs (euros)
- Fisheries
  - weight of landings (kg),
  - fishing effort (kwdays),
  - capacity (number of vessels),

while from the WGMIXFISH dataset were:

- Income
  - prices (euros/ton),
- Fisheries
  - weight of landings (kg),
  - fishing effort (kwdays),
  - capacity (number of vessels),

3 Methods

The methodology applied rescales economic indicators using a set of relationships with the components of the fleet definition, member state, gear and vessel length. These components are used by both datasets but aggregated and coded differently. Coding and aggregation are shown in Table 1.

Table 1: Link between the AER and the WGMIXFISH fleet definitions

WGMIXFIXH		AER		Description
fleet code	country	gear	vessel length	
BE_Beam<24	BEL	TBB	VL1824	
BE_Beam<24	BEL	TBB	VL1218	
BE_Beam>=24	BEL	TBB	VL2440	
BE_Otter	BEL	DTS	VL1824	
BE_Otter	BEL	DTS	VL2440	
DK_Beam	DNK	TBB	VL1218	
DK_Beam	DNK	TBB	VL1824	
DK_FDF	DNK	FDF	NA	Fully Documented Fishery
DK_OTH	DNK	OTH	NA	Other metier
DK_Otter<24	DNK	DTS	VL0010	
DK_Otter<24	DNK	DTS	VL1012	
DK_Otter<24	DNK	DTS	VL1218	
DK_Otter<24	DNK	DTS	VL1824	
DK_Otter24-40	DNK	DTS	VL2440	
DK_Pelagic	DNK	PEL	NA	No data for TM
DK_Seine	DNK	DTS	VL1012	
DK_Static	DNK	PGP	VL0010	polyvalent passive gears only
DK_Static	DNK	PGP	VL1012	polyvalent passive gears only
DK_Static	DNK	PGP	VL1218	polyvalent passive gears only
EN_Beam	GBR	TBB	VL0010	UK only
EN_Beam	GBR	TBB	VL1012	UK only
EN_Beam	GBR	TBB	VL1218	UK only
EN_Beam	GBR	TBB	VL1824	UK only
EN_Beam	GBR	TBB	VL2440	UK only
EN_FDF	GBR	FDF	NA	no data
SC_FDF	GBR	FDF	NA	no data
UK_Otter<24	GBR	DTS	VL1012	SC_Otter<24 + EN_Otter<24
UK_Otter<24	GBR	DTS	VL1218	SC_Otter<24 + EN_Otter<24
UK_Otter<24	GBR	DTS	VL1824	SC_Otter<24 + EN_Otter<24
UK_Beam<10	GBR	DTS	VL0010	SC_U10_OTB + EN_U10
UK_Otter24-40	GBR	DTS	VL2440	EN_Otter24-40 + SC_Otter>=24
EN_Otter>=40	GBR	DTS	VL40XX	
SC_Static	GBR	DFN	VL0010	
SC_Static	GBR	DFN	VL1012	
SC_Static	GBR	DFN	VL1218	

Continued on next page

Table 1 – *Continued from previous page*

WGMIXFIXH	AER			Description
fleet code	country	gear	vessel length	
SC_Static	GBR	DFN	VL2440	
SC_Static	GBR	FPO	VL0010	
SC_Static	GBR	FPO	VL1012	
SC_Static	GBR	FPO	VL1218	
SC_Static	GBR	FPO	VL2440	
SC_Static	GBR	HOK	VL0010	
SC_Static	GBR	HOK	VL1012	
SC_Static	GBR	HOK	VL2440	
FR_Otter>=40	FRA	DTS	VL1012	
FR_Otter10-40	FRA	DTS	VL1218	
FR_Otter10-40	FRA	DTS	VL1824	
FR_Otter10-40	FRA	DTS	VL2440	
FR_Otter10-40	FRA	DTS	VL40XX	
FR_Nets	FRA	DFN	VL0010	
FR_Nets	FRA	DFN	VL1012	
FR_Nets	FRA	DFN	VL1218	
FR_Nets	FRA	DFN	VL1824	
FR_Nets	FRA	DFN	VL24XX	no fishing in North Sea
GE_Beam>=24	DEU	TBB	VL2440	
GE_Static	DEU	DFN	VL1218	
GE_Static	DEU	DFN	VL2440	
NL_Beam<24	NLD	TBB	VL1218	
NL_Beam<24	NLD	TBB	VL1824	
NL_Otter	NLD	DTS	VL0010	
NL_Otter	NLD	DTS	VL1824	
NL_Otter	NLD	DTS	VL2440	
NL_Static	NLD	PGP	VL1218	no fishing in North Sea
NO_Otter<40	NOR	DTS	VL2440	
NO_Otter>=40	NOR	DTS	VL40XX	
NO_Pelagic	NOR	PEL	NA	
NO_Static	NOR	DFN	NA	
NO_OTH	NOR	OTH	NA	
NL_Beam>=40	NLD	TBB	VL40XX	
NL_Beam24-40	NLD	TBB	VL2440	
GE_Otter24-40	DEU	DTS	VL40XX	
GE_Otter>=40	DEU	DTS	VL2440	
GE_Otter<24	DEU	DTS	VL1824	
GE_Otter<24	DEU	DTS	VL1218	
GE_Otter<24	DEU	DTS	VL1012	

The method models economic variables by unit as a function of the fleet's components, which are shared between the two datasets, and use the North Sea information to scale the variables and estimate absolute economic indicators. The relationships are considered linear between the economic variables by unit and the fleet's components. A set of GLMs with log link functions and Gamma errors were fit, with the exception of crew share for which a logit link was used.

In summary, our approach focused on:

1. use the AER dataset to compute economic variables by unit: fixed costs by vessel, crew costs by revenue and variable costs by effort;
2. use the AER dataset to model the economic variables mention above as functions of the fleets' components: member state, gear and vessel length;

3. compute the economic variables by unit for the fleets defined in the WGMIXFISH dataset using the common components of the fleet definition;
4. compute the economic indicators for the North Sea: fixed costs, crew costs and variable costs, by scaling the economic variables by unit with the relevant information, capacity, revenue or effort.

For this analysis variable costs were split into variable costs depending on revenue, labour costs, and those depending on effort, energy and repair costs.

With regards to revenue a simple computation of value of landings was done using average prices estimated from the AER information and applied to the weight landed by species in the WGMIXFISH dataset. Furthermore, it was necessary to compute the revenue due to other species than those included in the WGMIXFISH dataset, once that the fleets considered also landed other commercial species from which a part of the revenue is made of.

Finally, all economic variables were adjusted for inflation to 2010 values.

```
#
# -------------------------------------------------------------------------------
# INIT
# -------------------------------------------------------------------------------
library(FLCore)

## Loading required package:  grid

## Loading required package:  lattice

## Loading required package:  MASS

## FLCore 2.5.0 development version

##
## Attaching package:  'FLCore'

## The following object(s) are masked from 'package:base':
##
## cbind, rbind

source("../analysis/funs.R")
yrs <- 2008:2010
sessionInfo()

## R version 2.15.1 (2012-06-22)
## Platform: x86_64-pc-linux-gnu (64-bit)
##
## locale:
##  [1] LC_CTYPE=en_US.UTF-8       LC_NUMERIC=C
##  [3] LC_TIME=en_US.UTF-8        LC_COLLATE=en_US.UTF-8
##  [5] LC_MONETARY=en_US.UTF-8    LC_MESSAGES=en_US.UTF-8
##  [7] LC_PAPER=C                 LC_NAME=C
##  [9] LC_ADDRESS=C               LC_TELEPHONE=C
## [11] LC_MEASUREMENT=en_US.UTF-8 LC_IDENTIFICATION=C
##
## attached base packages:
## [1] grid      stats     graphics  grDevices utils     datasets  methods
## [8] base
##
## other attached packages:
## [1] FLCore_2.5.0   MASS_7.3-22    lattice_0.20-6 knitr_0.8
##
## loaded via a namespace (and not attached):
## [1] digest_0.5.2   evaluate_0.4.2 formatR_0.6    plyr_1.7.1
## [5] stats4_2.15.1  stringr_0.6    tools_2.15.1
```

3.1 Read data

```
#
# -------------------------------------------------------------------------------
# WGMIXFISH
# -------------------------------------------------------------------------------
# fleet object
attach("../data/fleets/03_OneYearFcube v1_2_FcubeAllObjects.Rdata")
fltscn <- res.fleets
detach()
```

```
# stocks (only works in linux due to the usage of 'ls')
stks <- system("ls ../data/stocks/", inter = TRUE)
stks <- split(stks, stks)

for (i in stks) {
    load(paste("../data/stocks/", i, sep = ""))
    stks[[i]] <- stock
}

names(stks) <- unlist(lapply(strsplit(names(stks), "\\."), "[", 1))
stks <- FLStocks(stks)

#
# ------------------------------------------------------------------------------
# economic
# ------------------------------------------------------------------------------
eco.orig <- read.csv("../data/economic/WGMIXFISH_data.csv", stringsAsFactors = FALSE)
eco <- eco.orig[, c("country_code", "fishing_tech", "vessel_length", "variable_code",
    "species_code", "year", "value", "sub_reg", "wgmix_code")]
# NS divisions
NSdiv <- c("27.3.A", "27.7.D", unique(eco.orig$sub_reg)[grep("27.4", unique(eco.orig$sub_reg))])
# !NOTE: will remove VL24XX not sure about VL40XX
eco <- subset(eco, year %in% yrs & vessel_length != "VL24XX" & country_code !=
    "NOR")
wg2eco <- read.csv("../data/economic/WGMIXFISH_segments.csv", stringsAsFactors = FALSE)
inflation <- read.csv("../data/economic/WGMIXFISH_ratio.csv", stringsAsFactors = FALSE)
```

3.2 Pre-process data

3.2.1 Correction by inflation

```
infIndex <- subset(inflation[, -4], year < 2011)
# correct up to 2010
infIndex[infIndex$year == 2010, "inflation"] <- 0
# compute the multiplicative index
infIndex <- infIndex[order(infIndex$year), ]
infIndex <- lapply(split(infIndex, infIndex$country), function(x) {
    x[, "inflation"] <- cumprod(x[, "inflation"]/100 + 1)
    x
})
infIndex <- do.call("rbind", infIndex)
# merge and correct the relevant variables
ecoFix <- merge(eco, infIndex, by.x = c("country_code", "year"), by.y = c("country",
    "year"), all.x = TRUE)
vars2fix <- c("totenercost", "totvarcost", "totdepcost", "totnovarcost", "OPR",
    "totrepcost", "totcrewwage", "totunpaidlab", "totvallandg")
df0 <- subset(ecoFix, variable_code %in% vars2fix)
df0 <- transform(df0, value = value * inflation)
ecoFix <- rbind(df0, subset(ecoFix, !(variable_code %in% vars2fix)))
```

3.2.2 Average prices

Prices by species and year were computed from the AER information and allocated to the WGMIX-FISH landings information, so that revenue from landings could be estimated. For years without price information the average prices for years with information were used. The information from the AER was aggregated at the sub-region level (Areas 27.4a,b,c + 27.3a 27.7d were used), Member State, fleet segment, fishing gear, vessel length, species and year.

Average fish price by species was computed by $AvP = vL.wL^{-1}$, while for years without information a weighted average between 2008 and 2010 was used, $\bar{AvP} = \sum_{t=2008}^{2010}(vL)_t(\sum_{t=2008}^{2010}(wL)_t)^{-1}$, where AvP is *average price*, vL is *value of landings* and wL is *volume of landings*.

```
nms <- names(fltscn[[1]])
fltscn <- lapply(fltscn, function(x) {
    cat("\n")
    for (i in nms) {
        cat(i, " ")
        flt <- x[[i]]
        metiers(flt) <- lapply(metiers(flt), function(y) {
            flc <- catches(y)
            # stk <- grep('NEP', names(flc)) if(length(stk>0)){ flc[stk] <-
            # lapply(flc[stk], function(z){
            flc <- lapply(flc, function(z) {
                cat(".")
                stk <- z@name
                fl <- flt@name
                if (fl %in% c("SC_Otter<24", "EN_Otter<24"))
                  fl <- "UK_Otter<24"
                if (fl %in% c("SC_U10_OTB", "EN_U10"))
                  fl <- "UK_Beam<10"
                if (fl %in% c("EN_Otter24-40", "SC_Otter>=24"))
                  fl <- "UK_Otter24-40"
                cc <- subset(wg2eco, wgmix_code == fl)
                gr <- cc$gear_code[1]
                ms <- cc$country_code[1]
                if (!(ms == "NOR" | fl %in% c("NL_Static", "FR_Nets", "OTH_OTH",
                  "unalloc"))) {
                  if (!is.na(pmatch("NEP", stk)))
                    stk <- "NEP"
                  if (gr %in% c("FDF", "OTH", "PEL"))
                    gr <- "DTS"
                  # value of landings
                  val <- subset(ecoFix, variable_code == "totvallandg" & country_code ==
                    ms & fishing_tech == gr & species_code == stk)[, c("vessel_length",
                    "year", "value")]
                  # weight of landings
                  wgt <- subset(ecoFix, variable_code == "totwghtlandg" & country_code ==
                    cc$country_code[1] & fishing_tech == gr & species_code ==
                    stk)[, c("vessel_length", "year", "value")]
                  # compute prices
                  val <- transform(val, id = paste(vessel_length, year, paste = ""))
                  wgt <- transform(wgt, id = paste(vessel_length, year, paste = ""))
                  id <- unique(val$id)
                  df0 <- data.frame(id = id, pr = NA)
                  for (i in id) df0[df0$id == i, "pr"] <- sum(subset(val, id ==
                    i)$value)/sum(subset(wgt, id == i)$value)
                  pr <- tapply(df0$pr, unlist(lapply(strsplit(as.character(df0$id),
                    " "), "[", 2)), mean, na.rm = T)
                  # prices in euros per tonne
                  price(z)[] <- mean(df0$pr, na.rm = T) * 1000
                  price(z)[, names(pr)] <- pr * 1000
                }
```

```
                z
            })
            # }
            catches(y) <- flc
            y
        })
        x[[i]] <- flt
    }
    x
})
```

Visualize prices for one scenario (should be the same for all).

```
x <- fltscn[[1]]
pr <- lapply(x, function(y) {
    pr <- lapply(metiers(y), function(z) {
        pr <- do.call("rbind", price(z))
        data.frame(metier = name(z), expand.grid(stk = rownames(pr), year = z@range["minyear"]:z@range[
            price = c(pr))
    })
    pr <- do.call("rbind", pr)
    pr$flt <- name(y)
    pr
})
pr <- do.call("rbind", pr)
```

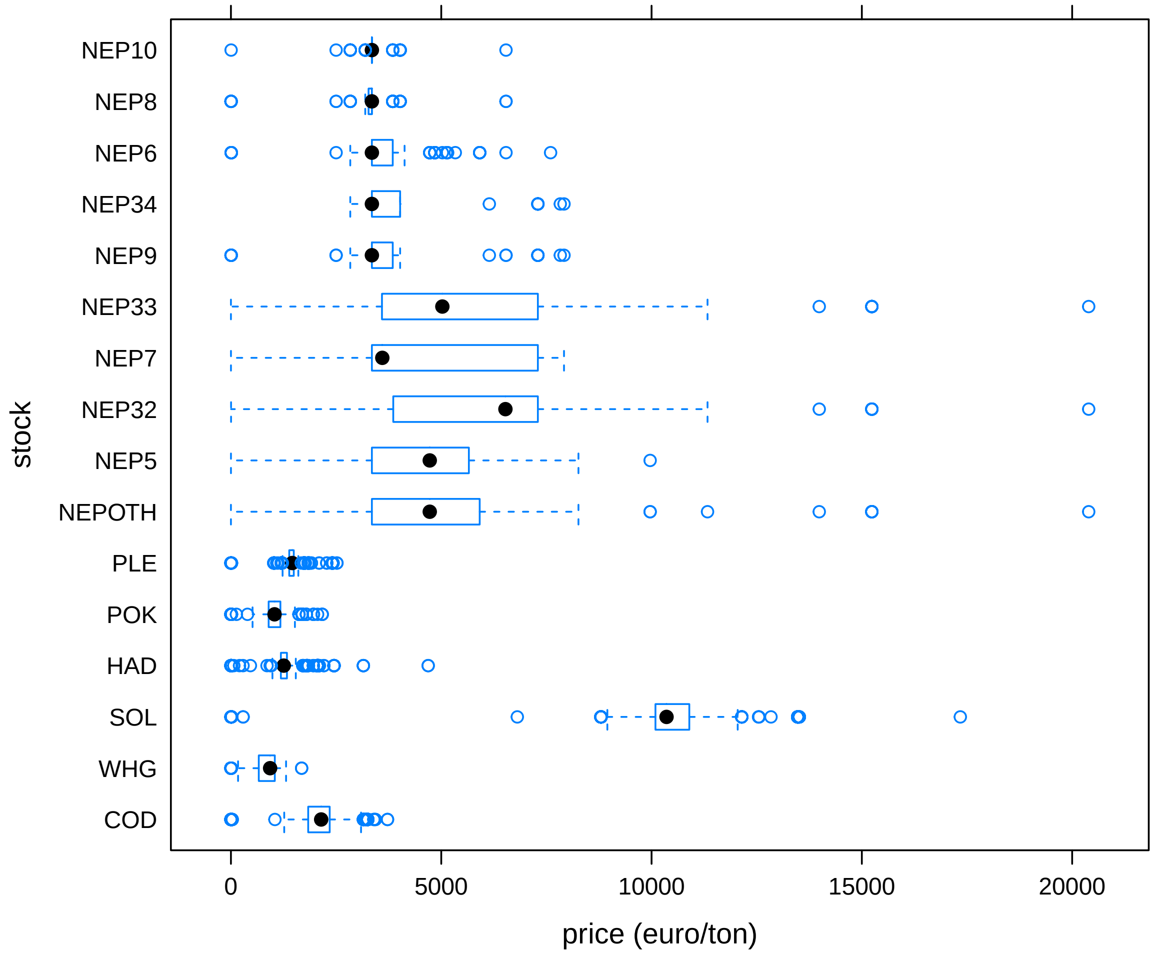


Figure 1: Prices by species

4 Stocks

The stocks include in the WGMIXFISH dataset are presented below. With the exception of some Nephrops stocks all of these have analytical assessments, estimates of biomass and fishing mortality.

```
names(stks)

## [1] "COD"    "HAD"    "NEP10"  "NEP32"  "NEP33"  "NEP34"  "NEP5"
## [8] "NEP6"   "NEP7"   "NEP8"   "NEP9"   "NEPOTH" "PLE"    "POK"
## [15] "SOL"    "WHG"
```

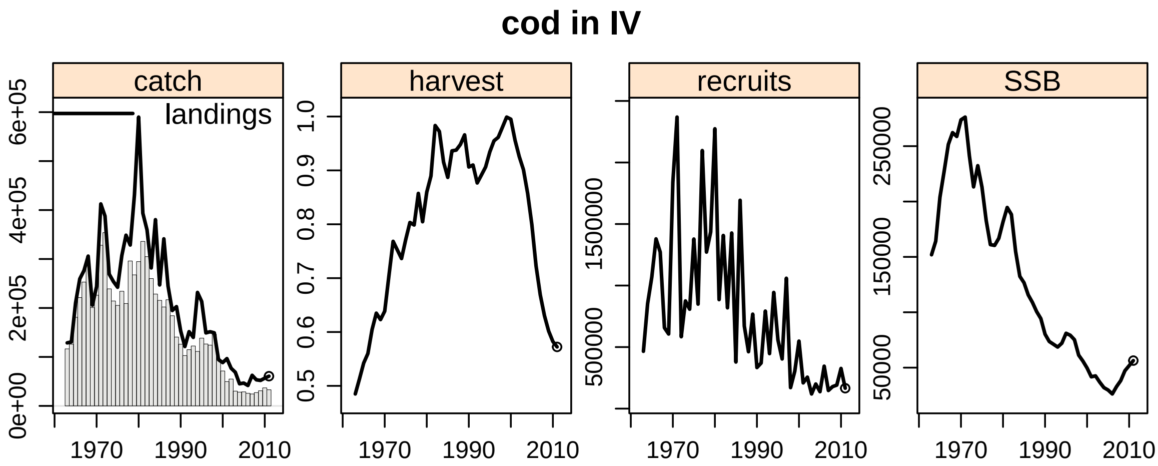


Figure 2: Stock summary

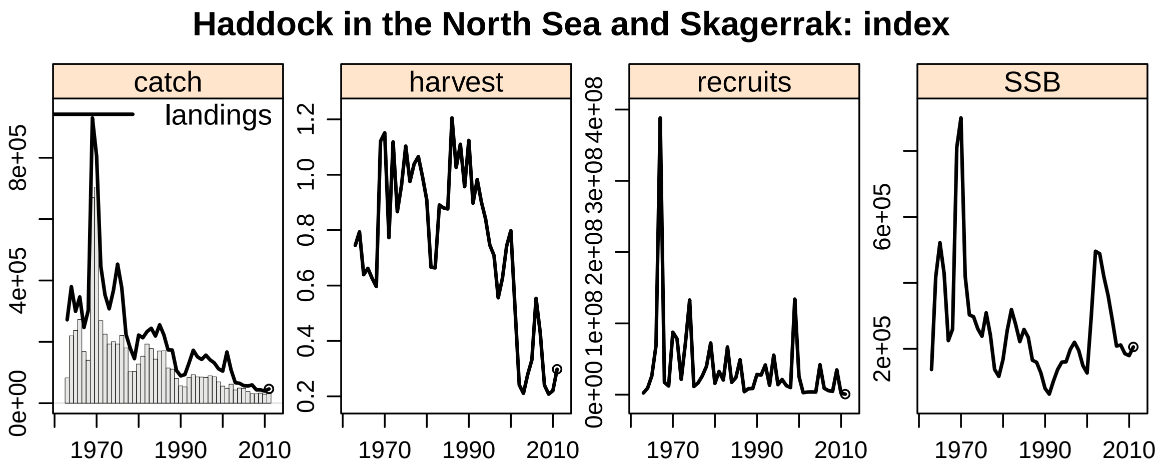


Figure 3: Stock summary

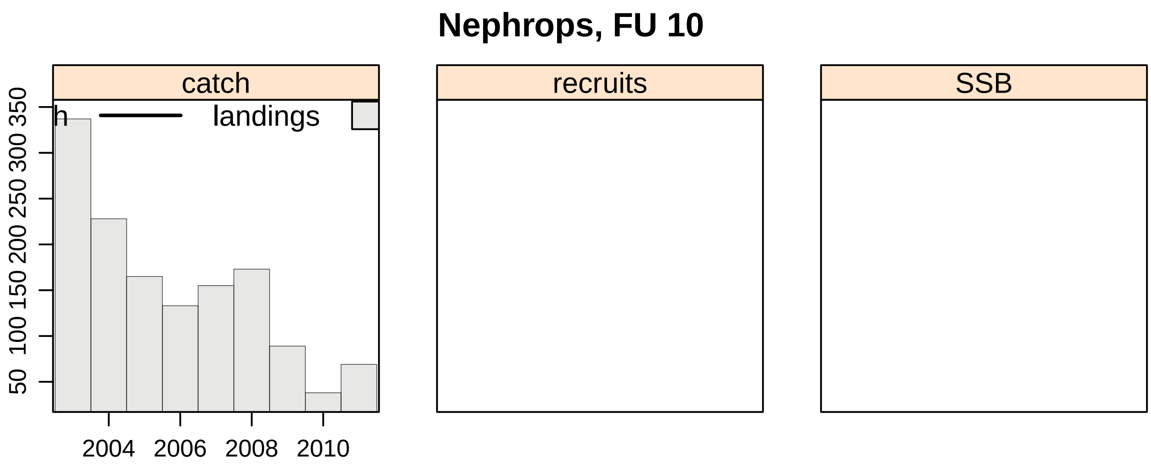


Figure 4: Stock summary

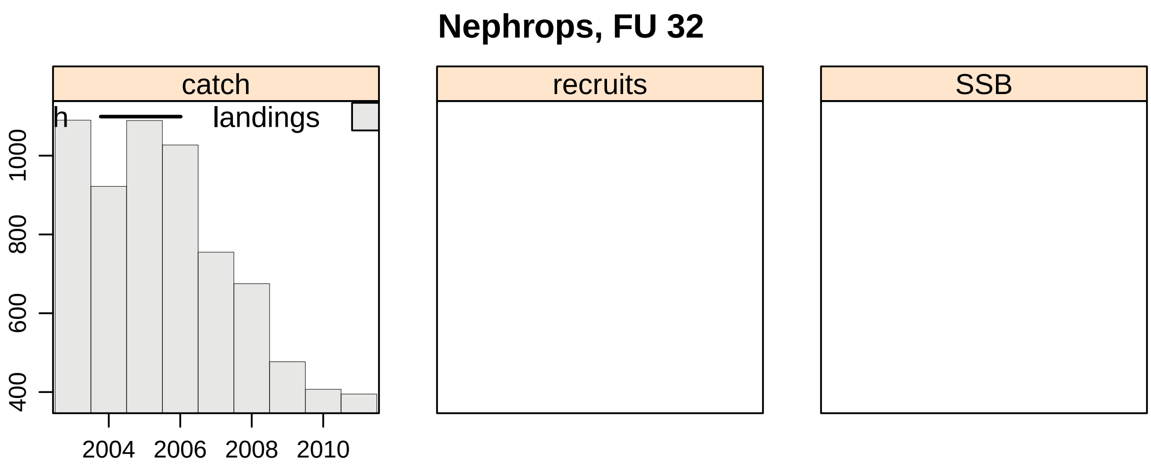


Figure 5: Stock summary

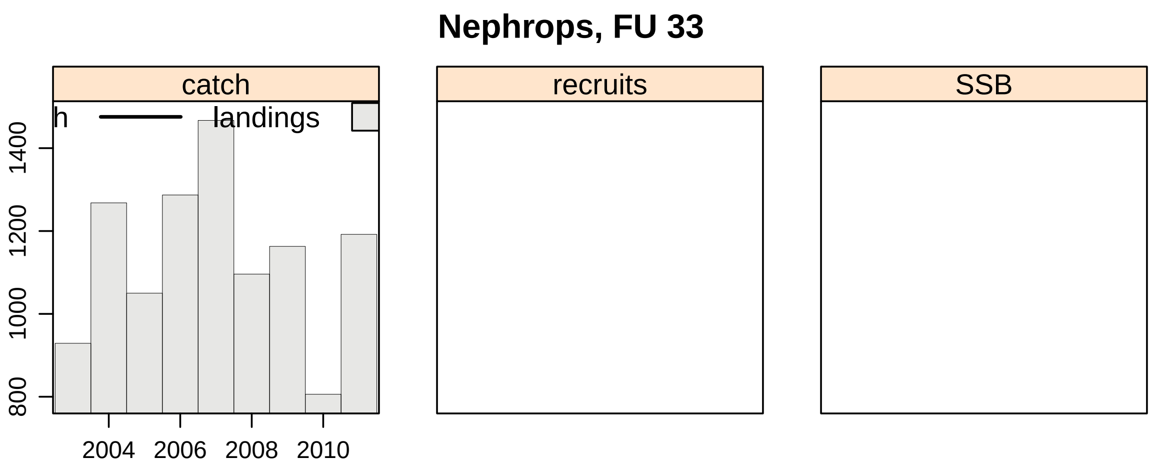


Figure 6: Stock summary

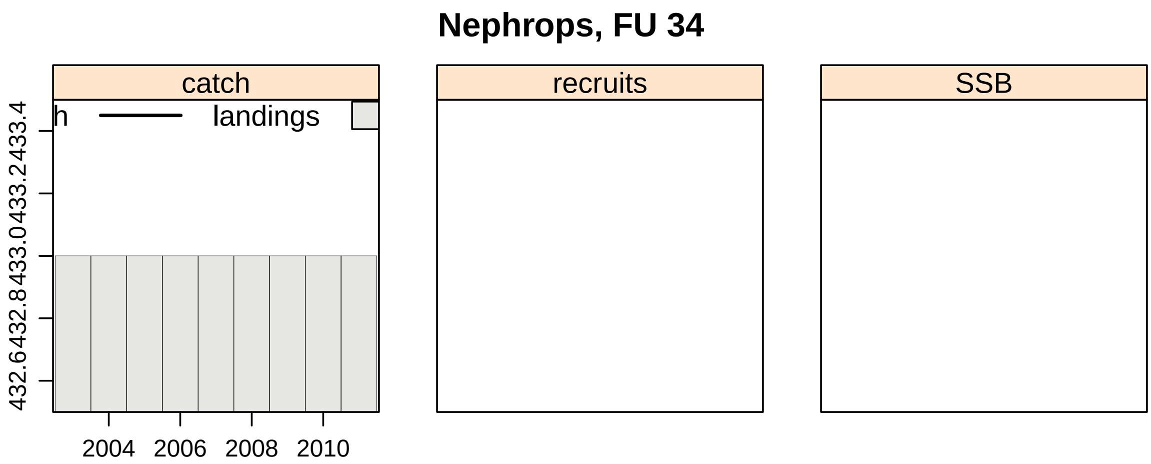


Figure 7: Stock summary

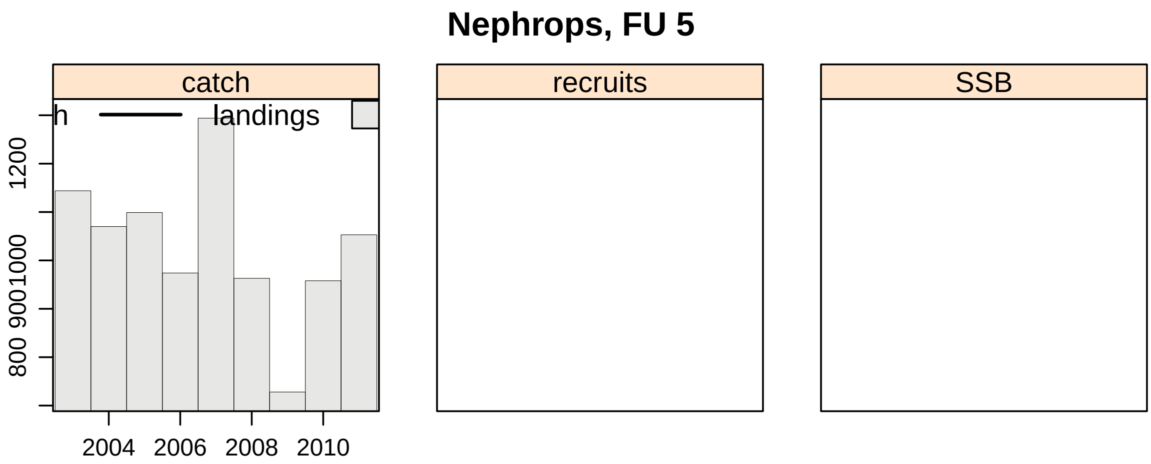


Figure 8: Stock summary

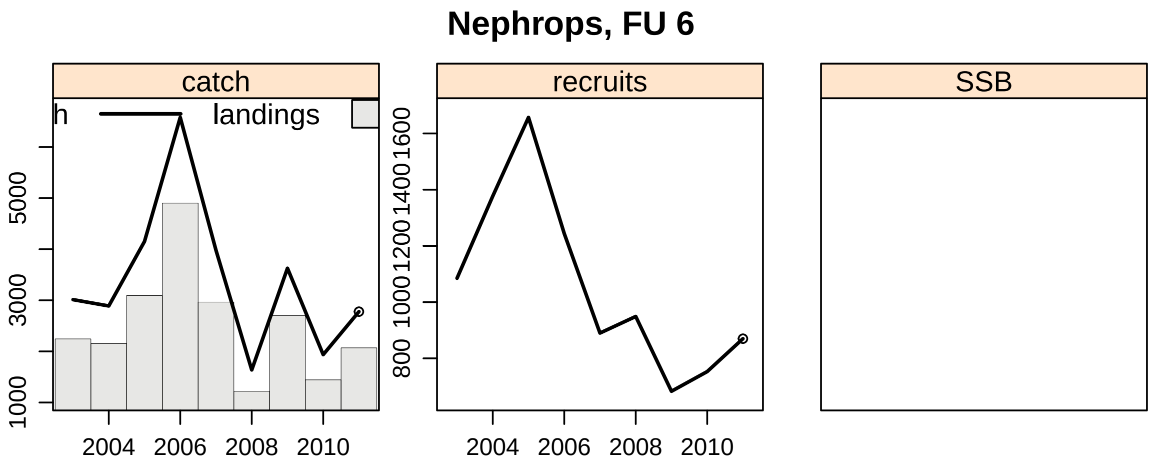


Figure 9: Stock summary

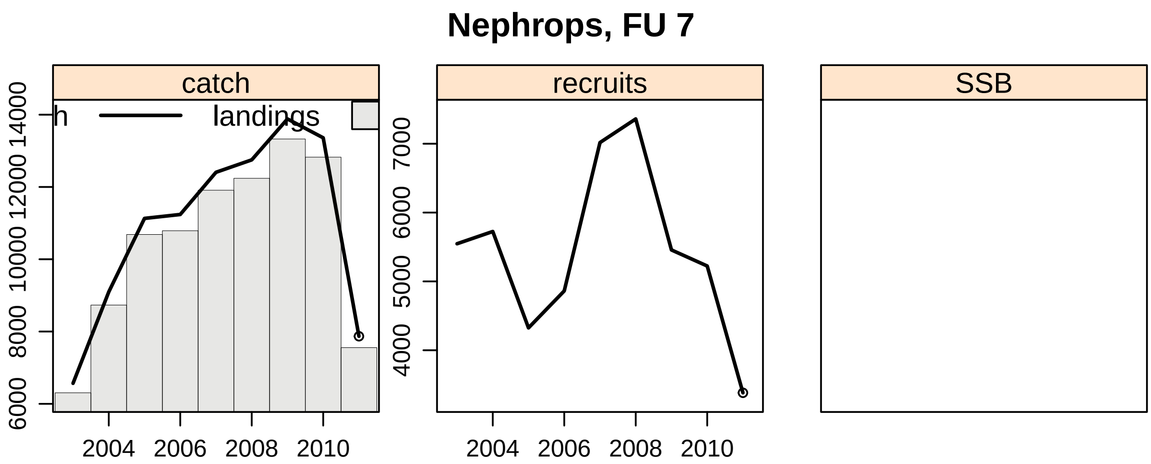


Figure 10: Stock summary

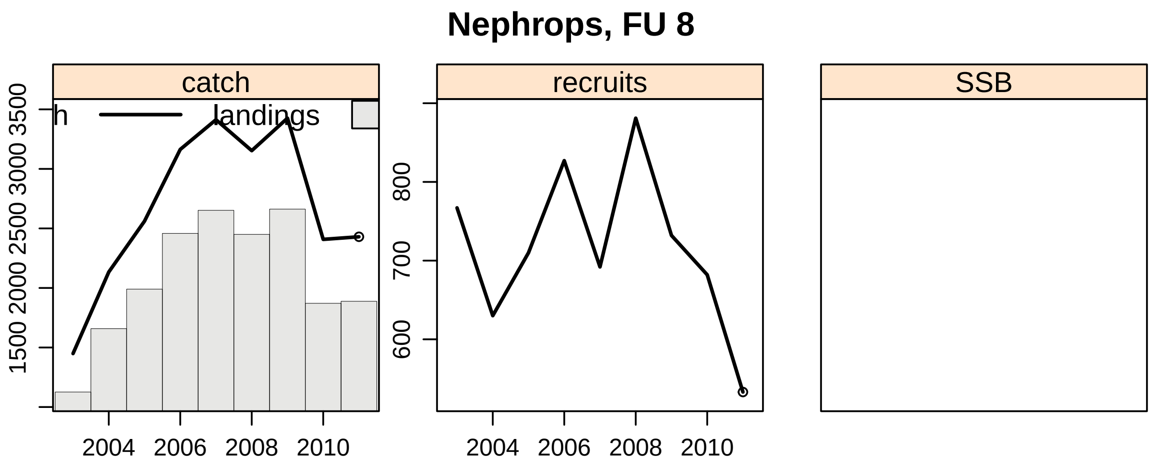


Figure 11: Stock summary

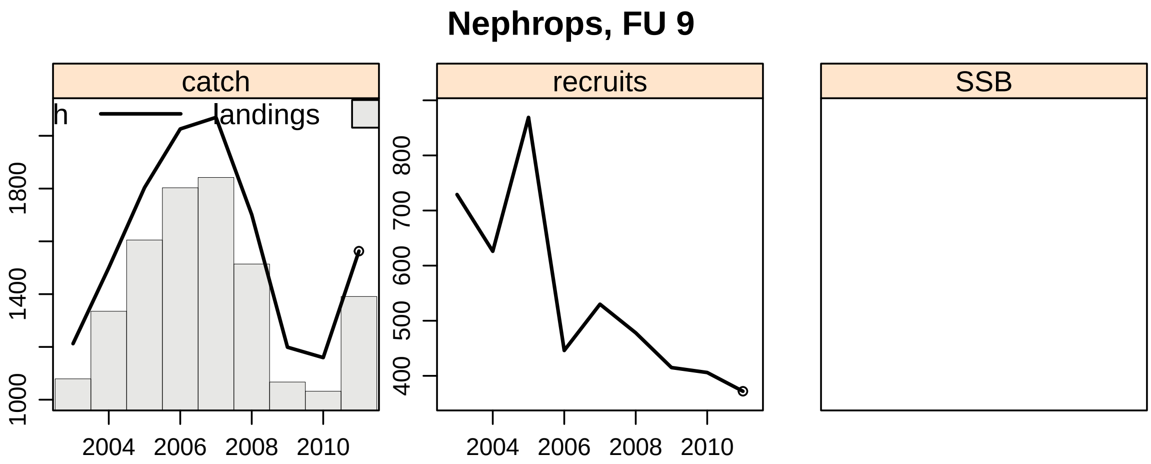


Figure 12: Stock summary

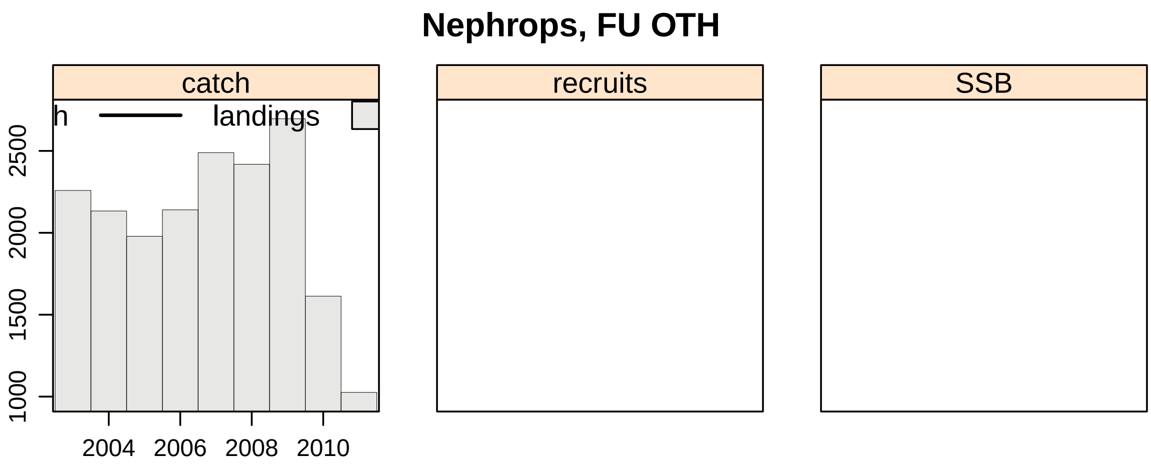


Figure 13: Stock summary

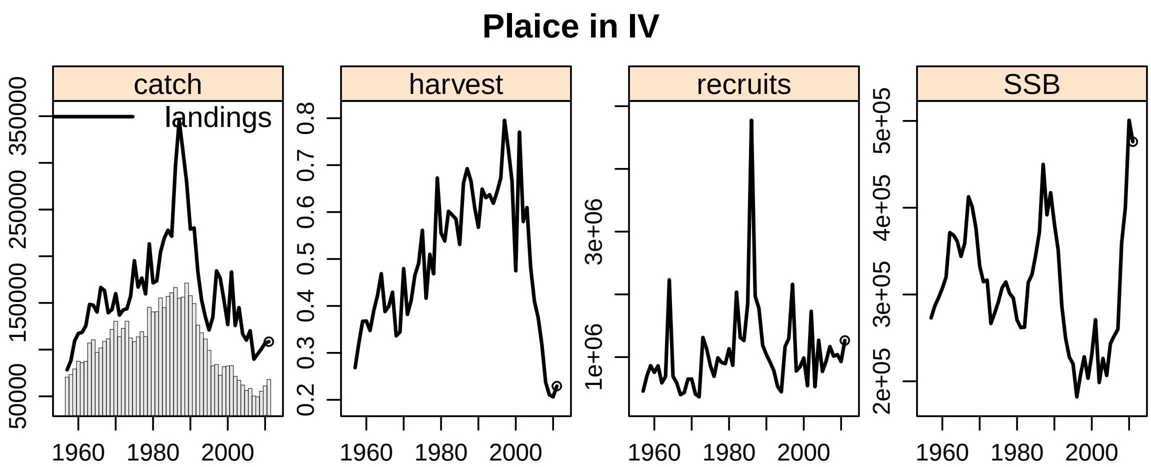


Figure 14: Stock summary

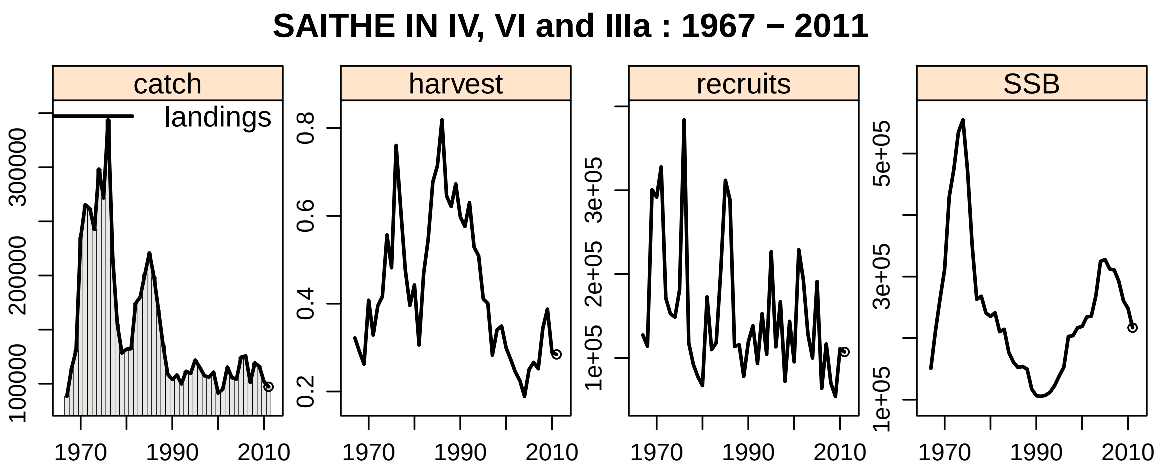


Figure 15: Stock summary

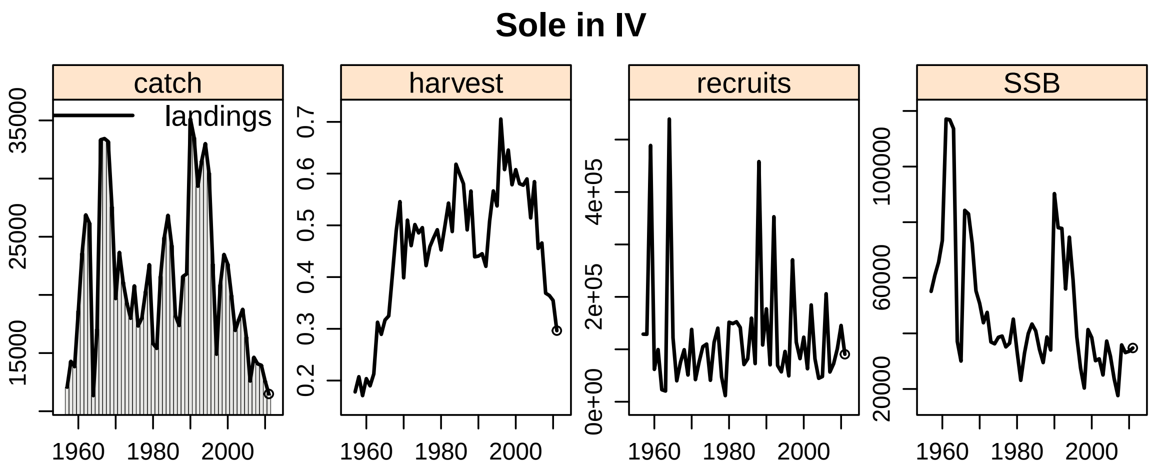


Figure 16: Stock summary

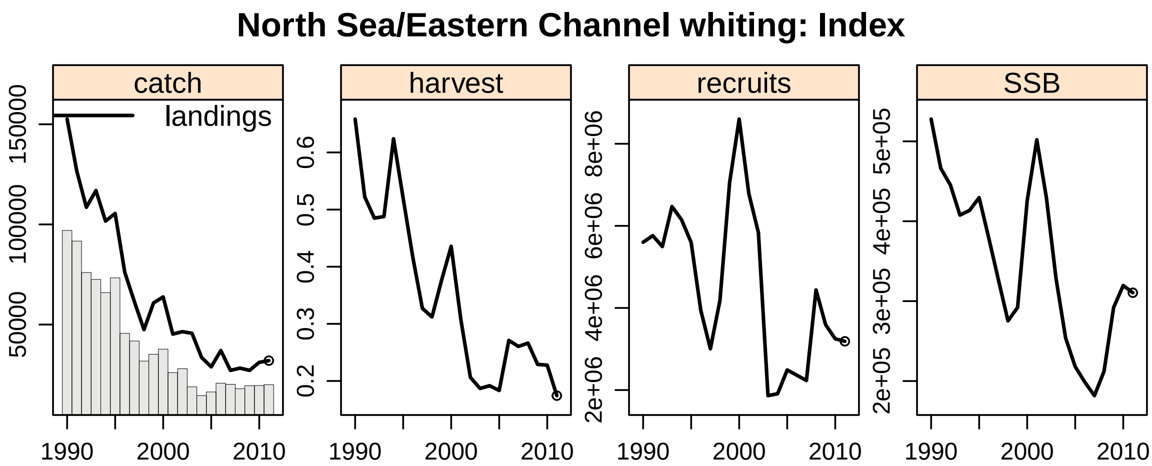


Figure 17: Stock summary

5 Fleets

The fleets include in the WGMIXFISH dataset are presented below. This information was provided as FLFleet objects, which are very complex and difficult to parse. The structure of the economic data within the FLFleet class is the following:

1. fleet level
    - effort
    - fcost
    - capacity
    - crewshare

    (a) metier level
        - effshare
        - vcost

        i. catch level
            - price

```
# using the projection in status quo, the historical data is the same
flts <- names(fltscn[["sq_E"]])
flts

##  [1] "BE_Beam<24"    "BE_Beam>=24"   "BE_Otter"      "DK_Beam"
##  [5] "DK_FDF"        "DK_OTH"        "DK_Otter<24"   "DK_Otter24-40"
##  [9] "DK_Pelagic"    "DK_Seine"      "DK_Static"     "EN_Beam"
## [13] "EN_FDF"        "EN_Otter<24"   "EN_Otter>=40"  "EN_Otter24-40"
## [17] "EN_U10"        "FR_Nets"       "FR_Otter>=40"  "FR_Otter10-40"
## [21] "GE_Beam>=24"   "GE_Otter<24"   "GE_Otter>=40"  "GE_Otter24-40"
## [25] "GE_Static"     "NL_Beam<24"    "NL_Beam>=40"   "NL_Beam24-40"
## [29] "NL_Otter"      "NL_Static"     "NO_Otter<40"   "NO_Otter>=40"
## [33] "NO_Pelagic"    "NO_Static"     "SC_FDF"        "SC_Otter<24"
## [37] "SC_Otter>=24"  "SC_Static"     "SC_U10_OTB"    "OTH_OTH"
## [41] "unalloc"
```

```
for (i in flts) {
    message("-----------------------------------------------------------------")
    summary(fltscn[["sq_E"]][[i]])
}

## ----------------------------------------------------------------

## An object of class "FLFleet"
##
## Name: BE_Beam<24
## Description:
## Range:  min max minyear maxyear
##  NA NA 2003 2012
## Quant: quant
##
## effort        : [ 1 10 1 1 1 1 ], units =  000 kWdays
## fcost         : [ 1 10 1 1 1 1 ], units =  number of vessels
## capacity      : [ 1 10 1 1 1 1 ], units =  number of vessels
## crewshare     : [ 1 10 1 1 1 1 ], units =  NA
```

```
##
## Metiers:
##   BT2.4 :
##   COD : [ 1 10 1 1 1 1 ]
##   WHG : [ 1 10 1 1 1 1 ]
##   SOL : [ 1 10 1 1 1 1 ]
##   HAD : [ 1 10 1 1 1 1 ]
##   POK : [ 1 10 1 1 1 1 ]
##   PLE : [ 1 10 1 1 1 1 ]
##   NEPOTH : [ 1 10 1 1 1 1 ]
##   NEP5 : [ 1 10 1 1 1 1 ]
##   OTH :
##   COD : [ 1 10 1 1 1 1 ]
##   WHG : [ 1 10 1 1 1 1 ]
##   PLE : [ 1 10 1 1 1 1 ]
##   SOL : [ 1 10 1 1 1 1 ]
##   HAD : [ 1 10 1 1 1 1 ]

## ----------------------------------------------------------------

## An object of class "FLFleet"
##
## Name: BE_Beam>=24
## Description:
## Range:  min max minyear maxyear
##  NA NA 2003 2012
## Quant: quant
##
## effort        : [ 1 10 1 1 1 1 ], units =  000 kWdays
## fcost         : [ 1 10 1 1 1 1 ], units =  number of vessels
## capacity      : [ 1 10 1 1 1 1 ], units =  number of vessels
## crewshare     : [ 1 10 1 1 1 1 ], units =  NA
##
## Metiers:
##   BT1.4 :
##   SOL : [ 1 10 1 1 1 1 ]
##   WHG : [ 1 10 1 1 1 1 ]
##   COD : [ 1 10 1 1 1 1 ]
##   PLE : [ 1 10 1 1 1 1 ]
##   POK : [ 1 10 1 1 1 1 ]
##   HAD : [ 1 10 1 1 1 1 ]
##   NEPOTH : [ 1 10 1 1 1 1 ]
##   NEP5 : [ 1 10 1 1 1 1 ]
##   BT2.4 :
##   WHG : [ 1 10 1 1 1 1 ]
##   PLE : [ 1 10 1 1 1 1 ]
##   COD : [ 1 10 1 1 1 1 ]
##   POK : [ 1 10 1 1 1 1 ]
##   HAD : [ 1 10 1 1 1 1 ]
##   SOL : [ 1 10 1 1 1 1 ]
##   NEPOTH : [ 1 10 1 1 1 1 ]
##   NEP5 : [ 1 10 1 1 1 1 ]
##   OTH :
##   COD : [ 1 10 1 1 1 1 ]
##   WHG : [ 1 10 1 1 1 1 ]
##   SOL : [ 1 10 1 1 1 1 ]
##   PLE : [ 1 10 1 1 1 1 ]
##   NEPOTH : [ 1 10 1 1 1 1 ]
```

```
## ------------------------------------------------------------------

## An object of class "FLFleet"
##
## Name: BE_Otter
## Description:
## Range:  min max minyear maxyear
##  NA NA 2003 2012
## Quant: quant
##
## effort        : [ 1 10 1 1 1 1 ], units =  000 kWdays
## fcost         : [ 1 10 1 1 1 1 ], units =  number of vessels
## capacity      : [ 1 10 1 1 1 1 ], units =  number of vessels
## crewshare     : [ 1 10 1 1 1 1 ], units =  NA
##
## Metiers:
##   OTH :
##   COD : [ 1 10 1 1 1 1 ]
##   WHG : [ 1 10 1 1 1 1 ]
##   POK : [ 1 10 1 1 1 1 ]
##   HAD : [ 1 10 1 1 1 1 ]
##   SOL : [ 1 10 1 1 1 1 ]
##   PLE : [ 1 10 1 1 1 1 ]
##   NEPOTH : [ 1 10 1 1 1 1 ]
##   TR2.4 :
##   PLE : [ 1 10 1 1 1 1 ]
##   COD : [ 1 10 1 1 1 1 ]
##   SOL : [ 1 10 1 1 1 1 ]
##   POK : [ 1 10 1 1 1 1 ]
##   HAD : [ 1 10 1 1 1 1 ]
##   WHG : [ 1 10 1 1 1 1 ]
##   NEPOTH : [ 1 10 1 1 1 1 ]
##   NEP5 : [ 1 10 1 1 1 1 ]

## ------------------------------------------------------------------

## An object of class "FLFleet"
##
## Name: DK_Beam
## Description:
## Range:  min max minyear maxyear
##  NA NA 2003 2012
## Quant: quant
##
## effort        : [ 1 10 1 1 1 1 ], units =  000 kWdays
## fcost         : [ 1 10 1 1 1 1 ], units =  number of vessels
## capacity      : [ 1 10 1 1 1 1 ], units =  number of vessels
## crewshare     : [ 1 10 1 1 1 1 ], units =  NA
##
## Metiers:
##   BT1.4 :
##   COD : [ 1 10 1 1 1 1 ]
##   HAD : [ 1 10 1 1 1 1 ]
##   PLE : [ 1 10 1 1 1 1 ]
##   POK : [ 1 10 1 1 1 1 ]
##   SOL : [ 1 10 1 1 1 1 ]
##   WHG : [ 1 10 1 1 1 1 ]
##   NEP32 : [ 1 10 1 1 1 1 ]
```

```
##   OTH :
##   HAD : [ 1 10 1 1 1 1 ]
##   POK : [ 1 10 1 1 1 1 ]
##   COD : [ 1 10 1 1 1 1 ]

## ----------------------------------------------------------------

## An object of class "FLFleet"
##
## Name: DK_FDF
## Description:
## Range:  min max minyear maxyear
##  NA NA 2003 2012
## Quant: quant
##
## effort        : [ 1 10 1 1 1 1 ], units =  000 kWdays
## fcost         : [ 1 10 1 1 1 1 ], units =  number of vessels
## capacity      : [ 1 10 1 1 1 1 ], units =  number of vessels
## crewshare     : [ 1 10 1 1 1 1 ], units =  NA
##
## Metiers:
##   OTH :
##   PLE : [ 1 10 1 1 1 1 ]
##   WHG : [ 1 10 1 1 1 1 ]
##   SOL : [ 1 10 1 1 1 1 ]
##   COD : [ 1 10 1 1 1 1 ]
##   HAD : [ 1 10 1 1 1 1 ]
##   POK : [ 1 10 1 1 1 1 ]
##   NEP32 : [ 1 10 1 1 1 1 ]
##   TR1.3AN :
##   COD : [ 1 10 1 1 1 1 ]
##   HAD : [ 1 10 1 1 1 1 ]
##   POK : [ 1 10 1 1 1 1 ]
##   TR1.4 :
##   COD : [ 1 10 1 1 1 1 ]
##   PLE : [ 1 10 1 1 1 1 ]
##   POK : [ 1 10 1 1 1 1 ]
##   HAD : [ 1 10 1 1 1 1 ]
##   SOL : [ 1 10 1 1 1 1 ]
##   WHG : [ 1 10 1 1 1 1 ]
##   NEP32 : [ 1 10 1 1 1 1 ]
##   NEP7 : [ 1 10 1 1 1 1 ]

## ----------------------------------------------------------------

## An object of class "FLFleet"
##
## Name: DK_OTH
## Description:
## Range:  min max minyear maxyear
##  NA NA 2003 2012
## Quant: quant
##
## effort        : [ 1 10 1 1 1 1 ], units =  000 kWdays
## fcost         : [ 1 10 1 1 1 1 ], units =  number of vessels
## capacity      : [ 1 10 1 1 1 1 ], units =  number of vessels
## crewshare     : [ 1 10 1 1 1 1 ], units =  NA
##
```

```
## Metiers:
##   demhc.3AN :
##   COD : [ 1 10 1 1 1 1 ]
##   HAD : [ 1 10 1 1 1 1 ]
##   POK : [ 1 10 1 1 1 1 ]
##   OTH :
##   POK : [ 1 10 1 1 1 1 ]
##   COD : [ 1 10 1 1 1 1 ]
##   HAD : [ 1 10 1 1 1 1 ]
##   PLE : [ 1 10 1 1 1 1 ]
##   SOL : [ 1 10 1 1 1 1 ]
##   WHG : [ 1 10 1 1 1 1 ]
##   NEP32 : [ 1 10 1 1 1 1 ]
##   NEP33 : [ 1 10 1 1 1 1 ]

## ----------------------------------------------------------------

## An object of class "FLFleet"
##
## Name: DK_Otter<24
## Description:
## Range:  min max minyear maxyear
##  NA NA 2003 2012
## Quant: quant
##
## effort        : [ 1 10 1 1 1 1 ], units =  000 kWdays
## fcost         : [ 1 10 1 1 1 1 ], units =  number of vessels
## capacity      : [ 1 10 1 1 1 1 ], units =  number of vessels
## crewshare     : [ 1 10 1 1 1 1 ], units =  NA
##
## Metiers:
##   OTH :
##   SOL : [ 1 10 1 1 1 1 ]
##   WHG : [ 1 10 1 1 1 1 ]
##   HAD : [ 1 10 1 1 1 1 ]
##   COD : [ 1 10 1 1 1 1 ]
##   POK : [ 1 10 1 1 1 1 ]
##   PLE : [ 1 10 1 1 1 1 ]
##   NEP32 : [ 1 10 1 1 1 1 ]
##   NEP33 : [ 1 10 1 1 1 1 ]
##   NEP7 : [ 1 10 1 1 1 1 ]
##   NEPOTH : [ 1 10 1 1 1 1 ]
##   TR1.4 :
##   COD : [ 1 10 1 1 1 1 ]
##   HAD : [ 1 10 1 1 1 1 ]
##   SOL : [ 1 10 1 1 1 1 ]
##   WHG : [ 1 10 1 1 1 1 ]
##   PLE : [ 1 10 1 1 1 1 ]
##   POK : [ 1 10 1 1 1 1 ]
##   NEP7 : [ 1 10 1 1 1 1 ]
##   NEP32 : [ 1 10 1 1 1 1 ]
##   NEPOTH : [ 1 10 1 1 1 1 ]
##   NEP33 : [ 1 10 1 1 1 1 ]
##   NEP5 : [ 1 10 1 1 1 1 ]
##   TR2.3AN :
##   COD : [ 1 10 1 1 1 1 ]
##   HAD : [ 1 10 1 1 1 1 ]
##   POK : [ 1 10 1 1 1 1 ]
```

```
##   TR2.4 :
##   WHG : [ 1 10 1 1 1 1 ]
##   SOL : [ 1 10 1 1 1 1 ]
##   PLE : [ 1 10 1 1 1 1 ]
##   HAD : [ 1 10 1 1 1 1 ]
##   COD : [ 1 10 1 1 1 1 ]
##   POK : [ 1 10 1 1 1 1 ]
##   NEP7 : [ 1 10 1 1 1 1 ]
##   NEP32 : [ 1 10 1 1 1 1 ]
##   NEP33 : [ 1 10 1 1 1 1 ]
##   NEPOTH : [ 1 10 1 1 1 1 ]
##   NEP5 : [ 1 10 1 1 1 1 ]

## ----------------------------------------------------------------

## An object of class "FLFleet"
##
## Name: DK_Otter24-40
## Description:
## Range:  min max minyear maxyear
##  NA NA 2003 2012
## Quant: quant
##
## effort        : [ 1 10 1 1 1 1 ], units =  000 kWdays
## fcost         : [ 1 10 1 1 1 1 ], units =  number of vessels
## capacity      : [ 1 10 1 1 1 1 ], units =  number of vessels
## crewshare     : [ 1 10 1 1 1 1 ], units =  NA
##
## Metiers:
##   OTH :
##   COD : [ 1 10 1 1 1 1 ]
##   POK : [ 1 10 1 1 1 1 ]
##   HAD : [ 1 10 1 1 1 1 ]
##   WHG : [ 1 10 1 1 1 1 ]
##   PLE : [ 1 10 1 1 1 1 ]
##   SOL : [ 1 10 1 1 1 1 ]
##   NEP32 : [ 1 10 1 1 1 1 ]
##   NEP7 : [ 1 10 1 1 1 1 ]
##   NEPOTH : [ 1 10 1 1 1 1 ]
##   NEP33 : [ 1 10 1 1 1 1 ]
##   NEP5 : [ 1 10 1 1 1 1 ]
##   TR1.4 :
##   WHG : [ 1 10 1 1 1 1 ]
##   SOL : [ 1 10 1 1 1 1 ]
##   COD : [ 1 10 1 1 1 1 ]
##   POK : [ 1 10 1 1 1 1 ]
##   PLE : [ 1 10 1 1 1 1 ]
##   HAD : [ 1 10 1 1 1 1 ]
##   NEP7 : [ 1 10 1 1 1 1 ]
##   NEPOTH : [ 1 10 1 1 1 1 ]
##   NEP33 : [ 1 10 1 1 1 1 ]
##   NEP32 : [ 1 10 1 1 1 1 ]
##   NEP5 : [ 1 10 1 1 1 1 ]
##   TR2.4 :
##   HAD : [ 1 10 1 1 1 1 ]
##   COD : [ 1 10 1 1 1 1 ]
##   SOL : [ 1 10 1 1 1 1 ]
##   PLE : [ 1 10 1 1 1 1 ]
```

```
##   POK : [ 1 10 1 1 1 1 ]
##   WHG : [ 1 10 1 1 1 1 ]
##   NEPOTH : [ 1 10 1 1 1 1 ]
##   NEP5 : [ 1 10 1 1 1 1 ]
##   NEP7 : [ 1 10 1 1 1 1 ]
##   NEP33 : [ 1 10 1 1 1 1 ]
##   NEP32 : [ 1 10 1 1 1 1 ]
##   NEP9 : [ 1 10 1 1 1 1 ]
##   NEP34 : [ 1 10 1 1 1 1 ]

## ----------------------------------------------------------------

## An object of class "FLFleet"
##
## Name: DK_Pelagic
## Description:
## Range:  min max minyear maxyear
##  NA NA 2003 2012
## Quant: quant
##
## effort        : [ 1 10 1 1 1 1 ], units =  000 kWdays
## fcost         : [ 1 10 1 1 1 1 ], units =  number of vessels
## capacity      : [ 1 10 1 1 1 1 ], units =  number of vessels
## crewshare     : [ 1 10 1 1 1 1 ], units =  NA
##
## Metiers:
##   OTH :
##   POK : [ 1 10 1 1 1 1 ]
##   HAD : [ 1 10 1 1 1 1 ]
##   COD : [ 1 10 1 1 1 1 ]
##   pelagic.4 :
##   SOL : [ 1 10 1 1 1 1 ]
##   COD : [ 1 10 1 1 1 1 ]
##   HAD : [ 1 10 1 1 1 1 ]
##   WHG : [ 1 10 1 1 1 1 ]
##   PLE : [ 1 10 1 1 1 1 ]
##   POK : [ 1 10 1 1 1 1 ]
##   NEP7 : [ 1 10 1 1 1 1 ]
##   NEPOTH : [ 1 10 1 1 1 1 ]
##   NEP32 : [ 1 10 1 1 1 1 ]
##   NEP33 : [ 1 10 1 1 1 1 ]

## ----------------------------------------------------------------

## An object of class "FLFleet"
##
## Name: DK_Seine
## Description:
## Range:  min max minyear maxyear
##  NA NA 2003 2012
## Quant: quant
##
## effort        : [ 1 10 1 1 1 1 ], units =  000 kWdays
## fcost         : [ 1 10 1 1 1 1 ], units =  number of vessels
## capacity      : [ 1 10 1 1 1 1 ], units =  number of vessels
## crewshare     : [ 1 10 1 1 1 1 ], units =  NA
##
## Metiers:
```

```
##   TR1.3AN :
##   HAD : [ 1 10 1 1 1 1 ]
##   POK : [ 1 10 1 1 1 1 ]
##   COD : [ 1 10 1 1 1 1 ]
##   TR1.4 :
##   COD : [ 1 10 1 1 1 1 ]
##   SOL : [ 1 10 1 1 1 1 ]
##   HAD : [ 1 10 1 1 1 1 ]
##   WHG : [ 1 10 1 1 1 1 ]
##   PLE : [ 1 10 1 1 1 1 ]
##   POK : [ 1 10 1 1 1 1 ]
##   NEP32 : [ 1 10 1 1 1 1 ]
##   NEPOTH : [ 1 10 1 1 1 1 ]
##   NEP7 : [ 1 10 1 1 1 1 ]
##   NEP33 : [ 1 10 1 1 1 1 ]

## ----------------------------------------------------------------

## An object of class "FLFleet"
##
## Name: DK_Static
## Description:
## Range:  min max minyear maxyear
##  NA NA 2003 2012
## Quant: quant
##
## effort        : [ 1 10 1 1 1 1 ], units =  000 kWdays
## fcost         : [ 1 10 1 1 1 1 ], units =  number of vessels
## capacity      : [ 1 10 1 1 1 1 ], units =  number of vessels
## crewshare     : [ 1 10 1 1 1 1 ], units =  NA
##
## Metiers:
##   GN1.3AN :
##   COD : [ 1 10 1 1 1 1 ]
##   POK : [ 1 10 1 1 1 1 ]
##   HAD : [ 1 10 1 1 1 1 ]
##   GN1.4 :
##   HAD : [ 1 10 1 1 1 1 ]
##   PLE : [ 1 10 1 1 1 1 ]
##   SOL : [ 1 10 1 1 1 1 ]
##   POK : [ 1 10 1 1 1 1 ]
##   WHG : [ 1 10 1 1 1 1 ]
##   COD : [ 1 10 1 1 1 1 ]
##   NEPOTH : [ 1 10 1 1 1 1 ]
##   NEP5 : [ 1 10 1 1 1 1 ]
##   NEP33 : [ 1 10 1 1 1 1 ]
##   NEP32 : [ 1 10 1 1 1 1 ]
##   OTH :
##   HAD : [ 1 10 1 1 1 1 ]
##   COD : [ 1 10 1 1 1 1 ]
##   POK : [ 1 10 1 1 1 1 ]
##   SOL : [ 1 10 1 1 1 1 ]
##   PLE : [ 1 10 1 1 1 1 ]
##   WHG : [ 1 10 1 1 1 1 ]
##   NEP33 : [ 1 10 1 1 1 1 ]
##   NEPOTH : [ 1 10 1 1 1 1 ]

## ----------------------------------------------------------------
```

```
## An object of class "FLFleet"
##
## Name: EN_Beam
## Description:
## Range:  min max minyear maxyear
##  NA NA 2003 2012
## Quant: quant
##
## effort        : [ 1 10 1 1 1 1 ], units =  000 kWdays
## fcost         : [ 1 10 1 1 1 1 ], units =  number of vessels
## capacity      : [ 1 10 1 1 1 1 ], units =  number of vessels
## crewshare     : [ 1 10 1 1 1 1 ], units =  NA
##
## Metiers:
##   BT2.4 :
##   COD : [ 1 10 1 1 1 1 ]
##   HAD : [ 1 10 1 1 1 1 ]
##   SOL : [ 1 10 1 1 1 1 ]
##   WHG : [ 1 10 1 1 1 1 ]
##   PLE : [ 1 10 1 1 1 1 ]
##   POK : [ 1 10 1 1 1 1 ]
##   NEP33 : [ 1 10 1 1 1 1 ]
##   NEP5 : [ 1 10 1 1 1 1 ]
##   NEP6 : [ 1 10 1 1 1 1 ]
##   NEPOTH : [ 1 10 1 1 1 1 ]
##   OTH :
##   SOL : [ 1 10 1 1 1 1 ]
##   HAD : [ 1 10 1 1 1 1 ]
##   WHG : [ 1 10 1 1 1 1 ]
##   COD : [ 1 10 1 1 1 1 ]
##   PLE : [ 1 10 1 1 1 1 ]
##   POK : [ 1 10 1 1 1 1 ]
##   NEPOTH : [ 1 10 1 1 1 1 ]
##   NEP33 : [ 1 10 1 1 1 1 ]
##   NEP32 : [ 1 10 1 1 1 1 ]

## ----------------------------------------------------------------

## An object of class "FLFleet"
##
## Name: EN_FDF
## Description:
## Range:  min max minyear maxyear
##  NA NA 2003 2012
## Quant: quant
##
## effort        : [ 1 10 1 1 1 1 ], units =  000 kWdays
## fcost         : [ 1 10 1 1 1 1 ], units =  number of vessels
## capacity      : [ 1 10 1 1 1 1 ], units =  number of vessels
## crewshare     : [ 1 10 1 1 1 1 ], units =  NA
##
## Metiers:
##   OTH :
##   PLE : [ 1 10 1 1 1 1 ]
##   COD : [ 1 10 1 1 1 1 ]
##   POK : [ 1 10 1 1 1 1 ]
##   HAD : [ 1 10 1 1 1 1 ]
##   SOL : [ 1 10 1 1 1 1 ]
```

```
##   WHG : [ 1 10 1 1 1 1 ]
##   TR1.4 :
##   PLE : [ 1 10 1 1 1 1 ]
##   HAD : [ 1 10 1 1 1 1 ]
##   WHG : [ 1 10 1 1 1 1 ]
##   COD : [ 1 10 1 1 1 1 ]
##   POK : [ 1 10 1 1 1 1 ]
##   SOL : [ 1 10 1 1 1 1 ]
##   NEP5 : [ 1 10 1 1 1 1 ]
##   NEP6 : [ 1 10 1 1 1 1 ]
##   NEP7 : [ 1 10 1 1 1 1 ]
##   NEPOTH : [ 1 10 1 1 1 1 ]

## ----------------------------------------------------------------

## An object of class "FLFleet"
##
## Name: EN_Otter<24
## Description:
## Range:  min max minyear maxyear
##  NA NA 2003 2012
## Quant: quant
##
## effort        : [ 1 10 1 1 1 1 ], units =  000 kWdays
## fcost         : [ 1 10 1 1 1 1 ], units =  number of vessels
## capacity      : [ 1 10 1 1 1 1 ], units =  number of vessels
## crewshare     : [ 1 10 1 1 1 1 ], units =  NA
##
## Metiers:
##   OTH :
##   COD : [ 1 10 1 1 1 1 ]
##   WHG : [ 1 10 1 1 1 1 ]
##   TR1.4 :
##   HAD : [ 1 10 1 1 1 1 ]
##   COD : [ 1 10 1 1 1 1 ]
##   SOL : [ 1 10 1 1 1 1 ]
##   WHG : [ 1 10 1 1 1 1 ]
##   POK : [ 1 10 1 1 1 1 ]
##   PLE : [ 1 10 1 1 1 1 ]
##   NEP32 : [ 1 10 1 1 1 1 ]
##   NEPOTH : [ 1 10 1 1 1 1 ]
##   NEP5 : [ 1 10 1 1 1 1 ]
##   NEP9 : [ 1 10 1 1 1 1 ]
##   NEP7 : [ 1 10 1 1 1 1 ]
##   NEP6 : [ 1 10 1 1 1 1 ]
##   NEP33 : [ 1 10 1 1 1 1 ]
##   NEP8 : [ 1 10 1 1 1 1 ]
##   TR2.4 :
##   PLE : [ 1 10 1 1 1 1 ]
##   POK : [ 1 10 1 1 1 1 ]
##   SOL : [ 1 10 1 1 1 1 ]
##   WHG : [ 1 10 1 1 1 1 ]
##   COD : [ 1 10 1 1 1 1 ]
##   HAD : [ 1 10 1 1 1 1 ]
##   NEP5 : [ 1 10 1 1 1 1 ]
##   NEP9 : [ 1 10 1 1 1 1 ]
##   NEP8 : [ 1 10 1 1 1 1 ]
##   NEP10 : [ 1 10 1 1 1 1 ]
```

```
##   NEP6 : [ 1 10 1 1 1 1 ]
##   NEP7 : [ 1 10 1 1 1 1 ]
##   NEPOTH : [ 1 10 1 1 1 1 ]
##   NEP33 : [ 1 10 1 1 1 1 ]

## ----------------------------------------------------------------

## An object of class "FLFleet"
##
## Name: EN_Otter>=40
## Description:
## Range:  min max minyear maxyear
##  NA NA 2003 2012
## Quant: quant
##
## effort        : [ 1 10 1 1 1 1 ], units =  000 kWdays
## fcost         : [ 1 10 1 1 1 1 ], units =  number of vessels
## capacity      : [ 1 10 1 1 1 1 ], units =  number of vessels
## crewshare     : [ 1 10 1 1 1 1 ], units =  NA
##
## Metiers:
##   OTH :
##   SOL : [ 1 10 1 1 1 1 ]
##   WHG : [ 1 10 1 1 1 1 ]
##   HAD : [ 1 10 1 1 1 1 ]
##   PLE : [ 1 10 1 1 1 1 ]
##   COD : [ 1 10 1 1 1 1 ]
##   POK : [ 1 10 1 1 1 1 ]
##   NEPOTH : [ 1 10 1 1 1 1 ]
##   NEP33 : [ 1 10 1 1 1 1 ]
##   NEP5 : [ 1 10 1 1 1 1 ]
##   TR1.4 :
##   PLE : [ 1 10 1 1 1 1 ]
##   POK : [ 1 10 1 1 1 1 ]
##   HAD : [ 1 10 1 1 1 1 ]
##   SOL : [ 1 10 1 1 1 1 ]
##   COD : [ 1 10 1 1 1 1 ]
##   WHG : [ 1 10 1 1 1 1 ]
##   NEPOTH : [ 1 10 1 1 1 1 ]
##   NEP33 : [ 1 10 1 1 1 1 ]
##   NEP5 : [ 1 10 1 1 1 1 ]
##   NEP32 : [ 1 10 1 1 1 1 ]

## ----------------------------------------------------------------

## An object of class "FLFleet"
##
## Name: EN_Otter24-40
## Description:
## Range:  min max minyear maxyear
##  NA NA 2003 2012
## Quant: quant
##
## effort        : [ 1 10 1 1 1 1 ], units =  000 kWdays
## fcost         : [ 1 10 1 1 1 1 ], units =  number of vessels
## capacity      : [ 1 10 1 1 1 1 ], units =  number of vessels
## crewshare     : [ 1 10 1 1 1 1 ], units =  NA
##
```

```
## Metiers:
##   TR1.4 :
##   WHG : [ 1 10 1 1 1 1 ]
##   PLE : [ 1 10 1 1 1 1 ]
##   POK : [ 1 10 1 1 1 1 ]
##   SOL : [ 1 10 1 1 1 1 ]
##   COD : [ 1 10 1 1 1 1 ]
##   HAD : [ 1 10 1 1 1 1 ]
##   NEP33 : [ 1 10 1 1 1 1 ]
##   NEP5 : [ 1 10 1 1 1 1 ]
##   NEPOTH : [ 1 10 1 1 1 1 ]
##   NEP7 : [ 1 10 1 1 1 1 ]
##   NEP6 : [ 1 10 1 1 1 1 ]
##   NEP10 : [ 1 10 1 1 1 1 ]
##   TR2.4 :
##   SOL : [ 1 10 1 1 1 1 ]
##   COD : [ 1 10 1 1 1 1 ]
##   HAD : [ 1 10 1 1 1 1 ]
##   PLE : [ 1 10 1 1 1 1 ]
##   POK : [ 1 10 1 1 1 1 ]
##   WHG : [ 1 10 1 1 1 1 ]
##   NEP5 : [ 1 10 1 1 1 1 ]
##   NEP33 : [ 1 10 1 1 1 1 ]
##   NEPOTH : [ 1 10 1 1 1 1 ]
##   NEP9 : [ 1 10 1 1 1 1 ]
##   NEP7 : [ 1 10 1 1 1 1 ]
##   NEP6 : [ 1 10 1 1 1 1 ]
##   OTH :
##   COD : [ 1 10 1 1 1 1 ]
##   WHG : [ 1 10 1 1 1 1 ]

## ----------------------------------------------------------------

## An object of class "FLFleet"
##
## Name: EN_U10
## Description:
## Range:  min max minyear maxyear
##  NA NA 2003 2012
## Quant: quant
##
## effort        : [ 1 10 1 1 1 1 ], units =  000 kWdays
## fcost         : [ 1 10 1 1 1 1 ], units =  number of vessels
## capacity      : [ 1 10 1 1 1 1 ], units =  number of vessels
## crewshare     : [ 1 10 1 1 1 1 ], units =  NA
##
## Metiers:
##   GN1.4 :
##   HAD : [ 1 10 1 1 1 1 ]
##   PLE : [ 1 10 1 1 1 1 ]
##   POK : [ 1 10 1 1 1 1 ]
##   SOL : [ 1 10 1 1 1 1 ]
##   WHG : [ 1 10 1 1 1 1 ]
##   COD : [ 1 10 1 1 1 1 ]
##   NEP6 : [ 1 10 1 1 1 1 ]
##   OTH :
##   COD : [ 1 10 1 1 1 1 ]
##   PLE : [ 1 10 1 1 1 1 ]
```

```
##   HAD : [ 1 10 1 1 1 1 ]
##   POK : [ 1 10 1 1 1 1 ]
##   SOL : [ 1 10 1 1 1 1 ]
##   WHG : [ 1 10 1 1 1 1 ]
##   NEP6 : [ 1 10 1 1 1 1 ]
##   NEP8 : [ 1 10 1 1 1 1 ]
##   NEPOTH : [ 1 10 1 1 1 1 ]
##   TR2.4 :
##   COD : [ 1 10 1 1 1 1 ]
##   HAD : [ 1 10 1 1 1 1 ]
##   PLE : [ 1 10 1 1 1 1 ]
##   POK : [ 1 10 1 1 1 1 ]
##   SOL : [ 1 10 1 1 1 1 ]
##   WHG : [ 1 10 1 1 1 1 ]
##   NEPOTH : [ 1 10 1 1 1 1 ]
##   NEP6 : [ 1 10 1 1 1 1 ]
##   NEP8 : [ 1 10 1 1 1 1 ]
##   NEP9 : [ 1 10 1 1 1 1 ]
##   NEP7 : [ 1 10 1 1 1 1 ]
##   demhc.4 :
##   PLE : [ 1 10 1 1 1 1 ]
##   POK : [ 1 10 1 1 1 1 ]
##   WHG : [ 1 10 1 1 1 1 ]
##   SOL : [ 1 10 1 1 1 1 ]
##   HAD : [ 1 10 1 1 1 1 ]
##   COD : [ 1 10 1 1 1 1 ]
##   NEP6 : [ 1 10 1 1 1 1 ]
##   NEP8 : [ 1 10 1 1 1 1 ]

## ----------------------------------------------------------------

## An object of class "FLFleet"
##
## Name: FR_Nets
## Description:
## Range:  min max minyear maxyear
##  NA NA 2003 2012
## Quant: quant
##
## effort        : [ 1 10 1 1 1 1 ], units =  000 kWdays
## fcost         : [ 1 10 1 1 1 1 ], units =  number of vessels
## capacity      : [ 1 10 1 1 1 1 ], units =  number of vessels
## crewshare     : [ 1 10 1 1 1 1 ], units =  NA
##
## Metiers:
##   GT1.4 :
##   COD : [ 1 10 1 1 1 1 ]
##   PLE : [ 1 10 1 1 1 1 ]
##   WHG : [ 1 10 1 1 1 1 ]
##   SOL : [ 1 10 1 1 1 1 ]
##   POK : [ 1 10 1 1 1 1 ]
##   HAD : [ 1 10 1 1 1 1 ]
##   OTH :
##   COD : [ 1 10 1 1 1 1 ]
##   WHG : [ 1 10 1 1 1 1 ]

## ----------------------------------------------------------------
```

```
## An object of class "FLFleet"
##
## Name: FR_Otter>=40
## Description:
## Range:  min max minyear maxyear
##  NA NA 2003 2012
## Quant: quant
##
## effort        : [ 1 10 1 1 1 1 ], units =  000 kWdays
## fcost         : [ 1 10 1 1 1 1 ], units =  number of vessels
## capacity      : [ 1 10 1 1 1 1 ], units =  number of vessels
## crewshare     : [ 1 10 1 1 1 1 ], units =  NA
##
## Metiers:
##   OTH :
##   WHG : [ 1 10 1 1 1 1 ]
##   COD : [ 1 10 1 1 1 1 ]
##   TR1.4 :
##   PLE : [ 1 10 1 1 1 1 ]
##   WHG : [ 1 10 1 1 1 1 ]
##   HAD : [ 1 10 1 1 1 1 ]
##   POK : [ 1 10 1 1 1 1 ]
##   COD : [ 1 10 1 1 1 1 ]
##   SOL : [ 1 10 1 1 1 1 ]

## ----------------------------------------------------------------

## An object of class "FLFleet"
##
## Name: FR_Otter10-40
## Description:
## Range:  min max minyear maxyear
##  NA NA 2003 2012
## Quant: quant
##
## effort        : [ 1 10 1 1 1 1 ], units =  000 kWdays
## fcost         : [ 1 10 1 1 1 1 ], units =  number of vessels
## capacity      : [ 1 10 1 1 1 1 ], units =  number of vessels
## crewshare     : [ 1 10 1 1 1 1 ], units =  NA
##
## Metiers:
##   TR2.4 :
##   COD : [ 1 10 1 1 1 1 ]
##   PLE : [ 1 10 1 1 1 1 ]
##   HAD : [ 1 10 1 1 1 1 ]
##   WHG : [ 1 10 1 1 1 1 ]
##   SOL : [ 1 10 1 1 1 1 ]
##   POK : [ 1 10 1 1 1 1 ]
##   TR2.7D :
##   COD : [ 1 10 1 1 1 1 ]
##   WHG : [ 1 10 1 1 1 1 ]

## ----------------------------------------------------------------

## An object of class "FLFleet"
##
## Name: GE_Beam>=24
## Description:
```

```
## Range:  min max minyear maxyear
##  NA NA 2003 2012
## Quant: quant
##
## effort        : [ 1 10 1 1 1 1 ], units =  000 kWdays
## fcost         : [ 1 10 1 1 1 1 ], units =  number of vessels
## capacity      : [ 1 10 1 1 1 1 ], units =  number of vessels
## crewshare     : [ 1 10 1 1 1 1 ], units =  NA
##
## Metiers:
##   BT2.4 :
##   COD : [ 1 10 1 1 1 1 ]
##   HAD : [ 1 10 1 1 1 1 ]
##   PLE : [ 1 10 1 1 1 1 ]
##   POK : [ 1 10 1 1 1 1 ]
##   SOL : [ 1 10 1 1 1 1 ]
##   WHG : [ 1 10 1 1 1 1 ]
##   NEP33 : [ 1 10 1 1 1 1 ]
##   NEP5 : [ 1 10 1 1 1 1 ]
##   NEPOTH : [ 1 10 1 1 1 1 ]

## ----------------------------------------------------------------

## An object of class "FLFleet"
##
## Name: GE_Otter<24
## Description:
## Range:  min max minyear maxyear
##  NA NA 2003 2012
## Quant: quant
##
## effort        : [ 1 10 1 1 1 1 ], units =  000 kWdays
## fcost         : [ 1 10 1 1 1 1 ], units =  number of vessels
## capacity      : [ 1 10 1 1 1 1 ], units =  number of vessels
## crewshare     : [ 1 10 1 1 1 1 ], units =  NA
##
## Metiers:
##   OTH :
##   PLE : [ 1 10 1 1 1 1 ]
##   SOL : [ 1 10 1 1 1 1 ]
##   COD : [ 1 10 1 1 1 1 ]
##   HAD : [ 1 10 1 1 1 1 ]
##   POK : [ 1 10 1 1 1 1 ]
##   WHG : [ 1 10 1 1 1 1 ]
##   NEP33 : [ 1 10 1 1 1 1 ]
##   NEPOTH : [ 1 10 1 1 1 1 ]
##   NEP5 : [ 1 10 1 1 1 1 ]
##   TR2.4 :
##   COD : [ 1 10 1 1 1 1 ]
##   HAD : [ 1 10 1 1 1 1 ]
##   SOL : [ 1 10 1 1 1 1 ]
##   PLE : [ 1 10 1 1 1 1 ]
##   POK : [ 1 10 1 1 1 1 ]
##   WHG : [ 1 10 1 1 1 1 ]
##   NEP5 : [ 1 10 1 1 1 1 ]
##   NEPOTH : [ 1 10 1 1 1 1 ]
##   NEP33 : [ 1 10 1 1 1 1 ]

## ----------------------------------------------------------------
```

```
## An object of class "FLFleet"
##
## Name: GE_Otter>=40
## Description:
## Range:  min max minyear maxyear
##  NA NA 2003 2012
## Quant: quant
##
## effort        : [ 1 10 1 1 1 1 ], units =  000 kWdays
## fcost         : [ 1 10 1 1 1 1 ], units =  number of vessels
## capacity      : [ 1 10 1 1 1 1 ], units =  number of vessels
## crewshare     : [ 1 10 1 1 1 1 ], units =  NA
##
## Metiers:
##   OTH :
##   POK : [ 1 10 1 1 1 1 ]
##   COD : [ 1 10 1 1 1 1 ]
##   HAD : [ 1 10 1 1 1 1 ]
##   TR1.4 :
##   HAD : [ 1 10 1 1 1 1 ]
##   COD : [ 1 10 1 1 1 1 ]
##   POK : [ 1 10 1 1 1 1 ]
##   PLE : [ 1 10 1 1 1 1 ]
##   WHG : [ 1 10 1 1 1 1 ]

## ----------------------------------------------------------------

## An object of class "FLFleet"
##
## Name: GE_Otter24-40
## Description:
## Range:  min max minyear maxyear
##  NA NA 2003 2012
## Quant: quant
##
## effort        : [ 1 10 1 1 1 1 ], units =  000 kWdays
## fcost         : [ 1 10 1 1 1 1 ], units =  number of vessels
## capacity      : [ 1 10 1 1 1 1 ], units =  number of vessels
## crewshare     : [ 1 10 1 1 1 1 ], units =  NA
##
## Metiers:
##   OTH :
##   COD : [ 1 10 1 1 1 1 ]
##   HAD : [ 1 10 1 1 1 1 ]
##   POK : [ 1 10 1 1 1 1 ]
##   TR1.4 :
##   PLE : [ 1 10 1 1 1 1 ]
##   POK : [ 1 10 1 1 1 1 ]
##   COD : [ 1 10 1 1 1 1 ]
##   HAD : [ 1 10 1 1 1 1 ]
##   SOL : [ 1 10 1 1 1 1 ]
##   WHG : [ 1 10 1 1 1 1 ]
##   NEPOTH : [ 1 10 1 1 1 1 ]
##   NEP33 : [ 1 10 1 1 1 1 ]
##   NEP5 : [ 1 10 1 1 1 1 ]
##   NEP32 : [ 1 10 1 1 1 1 ]
##   TR2.4 :
##   COD : [ 1 10 1 1 1 1 ]
```

```
##   PLE : [ 1 10 1 1 1 1 ]
##   HAD : [ 1 10 1 1 1 1 ]
##   POK : [ 1 10 1 1 1 1 ]
##   SOL : [ 1 10 1 1 1 1 ]
##   WHG : [ 1 10 1 1 1 1 ]
##   NEPOTH : [ 1 10 1 1 1 1 ]
##   NEP33 : [ 1 10 1 1 1 1 ]
##   NEP5 : [ 1 10 1 1 1 1 ]

## ----------------------------------------------------------------

## An object of class "FLFleet"
##
## Name: GE_Static
## Description:
## Range:  min max minyear maxyear
##  NA NA 2003 2012
## Quant: quant
##
## effort        : [ 1 10 1 1 1 1 ], units =  000 kWdays
## fcost         : [ 1 10 1 1 1 1 ], units =  number of vessels
## capacity      : [ 1 10 1 1 1 1 ], units =  number of vessels
## crewshare     : [ 1 10 1 1 1 1 ], units =  NA
##
## Metiers:
##   GN1.4 :
##   COD : [ 1 10 1 1 1 1 ]
##   HAD : [ 1 10 1 1 1 1 ]
##   POK : [ 1 10 1 1 1 1 ]
##   SOL : [ 1 10 1 1 1 1 ]
##   PLE : [ 1 10 1 1 1 1 ]
##   WHG : [ 1 10 1 1 1 1 ]
##   NEPOTH : [ 1 10 1 1 1 1 ]
##   NEP33 : [ 1 10 1 1 1 1 ]
##   NEP32 : [ 1 10 1 1 1 1 ]

## ----------------------------------------------------------------

## An object of class "FLFleet"
##
## Name: NL_Beam<24
## Description:
## Range:  min max minyear maxyear
##  NA NA 2003 2012
## Quant: quant
##
## effort        : [ 1 10 1 1 1 1 ], units =  000 kWdays
## fcost         : [ 1 10 1 1 1 1 ], units =  number of vessels
## capacity      : [ 1 10 1 1 1 1 ], units =  number of vessels
## crewshare     : [ 1 10 1 1 1 1 ], units =  NA
##
## Metiers:
##   BT2.4 :
##   COD : [ 1 10 1 1 1 1 ]
##   HAD : [ 1 10 1 1 1 1 ]
##   PLE : [ 1 10 1 1 1 1 ]
##   SOL : [ 1 10 1 1 1 1 ]
##   WHG : [ 1 10 1 1 1 1 ]
```

```
##   NEP33 : [ 1 10 1 1 1 1 ]
##   NEPOTH : [ 1 10 1 1 1 1 ]
##   NEP5 : [ 1 10 1 1 1 1 ]
##   NEP32 : [ 1 10 1 1 1 1 ]
##   OTH :
##   COD : [ 1 10 1 1 1 1 ]
##   PLE : [ 1 10 1 1 1 1 ]
##   SOL : [ 1 10 1 1 1 1 ]
##   WHG : [ 1 10 1 1 1 1 ]
##   HAD : [ 1 10 1 1 1 1 ]
##   NEPOTH : [ 1 10 1 1 1 1 ]
##   NEP33 : [ 1 10 1 1 1 1 ]

## ----------------------------------------------------------------

## An object of class "FLFleet"
##
## Name: NL_Beam>=40
## Description:
## Range:  min max minyear maxyear
##  NA NA 2003 2012
## Quant: quant
##
## effort        : [ 1 10 1 1 1 1 ], units =  000 kWdays
## fcost         : [ 1 10 1 1 1 1 ], units =  number of vessels
## capacity      : [ 1 10 1 1 1 1 ], units =  number of vessels
## crewshare     : [ 1 10 1 1 1 1 ], units =  NA
##
## Metiers:
##   BT2.4 :
##   POK : [ 1 10 1 1 1 1 ]
##   WHG : [ 1 10 1 1 1 1 ]
##   PLE : [ 1 10 1 1 1 1 ]
##   COD : [ 1 10 1 1 1 1 ]
##   HAD : [ 1 10 1 1 1 1 ]
##   SOL : [ 1 10 1 1 1 1 ]
##   NEPOTH : [ 1 10 1 1 1 1 ]
##   NEP33 : [ 1 10 1 1 1 1 ]
##   NEP5 : [ 1 10 1 1 1 1 ]
##   NEP32 : [ 1 10 1 1 1 1 ]
##   NEP6 : [ 1 10 1 1 1 1 ]
##   OTH :
##   POK : [ 1 10 1 1 1 1 ]
##   PLE : [ 1 10 1 1 1 1 ]
##   HAD : [ 1 10 1 1 1 1 ]
##   COD : [ 1 10 1 1 1 1 ]
##   SOL : [ 1 10 1 1 1 1 ]
##   WHG : [ 1 10 1 1 1 1 ]
##   NEPOTH : [ 1 10 1 1 1 1 ]
##   NEP5 : [ 1 10 1 1 1 1 ]
##   NEP33 : [ 1 10 1 1 1 1 ]

## ----------------------------------------------------------------

## An object of class "FLFleet"
##
## Name: NL_Beam24-40
## Description:
```

```
## Range:  min max minyear maxyear
##  NA NA 2003 2012
## Quant: quant
##
## effort        : [ 1 10 1 1 1 1 ], units =  000 kWdays
## fcost         : [ 1 10 1 1 1 1 ], units =  number of vessels
## capacity      : [ 1 10 1 1 1 1 ], units =  number of vessels
## crewshare     : [ 1 10 1 1 1 1 ], units =  NA
##
## Metiers:
##   BT2.4 :
##   PLE : [ 1 10 1 1 1 1 ]
##   SOL : [ 1 10 1 1 1 1 ]
##   WHG : [ 1 10 1 1 1 1 ]
##   COD : [ 1 10 1 1 1 1 ]
##   HAD : [ 1 10 1 1 1 1 ]
##   NEPOTH : [ 1 10 1 1 1 1 ]
##   NEP33 : [ 1 10 1 1 1 1 ]
##   NEP5 : [ 1 10 1 1 1 1 ]
##   NEP32 : [ 1 10 1 1 1 1 ]
##   OTH :
##   PLE : [ 1 10 1 1 1 1 ]
##   SOL : [ 1 10 1 1 1 1 ]
##   WHG : [ 1 10 1 1 1 1 ]
##   COD : [ 1 10 1 1 1 1 ]
##   HAD : [ 1 10 1 1 1 1 ]
##   POK : [ 1 10 1 1 1 1 ]
##   NEP5 : [ 1 10 1 1 1 1 ]
##   NEPOTH : [ 1 10 1 1 1 1 ]
##   NEP33 : [ 1 10 1 1 1 1 ]

## ----------------------------------------------------------------

## An object of class "FLFleet"
##
## Name: NL_Otter
## Description:
## Range:  min max minyear maxyear
##  NA NA 2003 2012
## Quant: quant
##
## effort        : [ 1 10 1 1 1 1 ], units =  000 kWdays
## fcost         : [ 1 10 1 1 1 1 ], units =  number of vessels
## capacity      : [ 1 10 1 1 1 1 ], units =  number of vessels
## crewshare     : [ 1 10 1 1 1 1 ], units =  NA
##
## Metiers:
##   OTH :
##   SOL : [ 1 10 1 1 1 1 ]
##   COD : [ 1 10 1 1 1 1 ]
##   WHG : [ 1 10 1 1 1 1 ]
##   HAD : [ 1 10 1 1 1 1 ]
##   POK : [ 1 10 1 1 1 1 ]
##   PLE : [ 1 10 1 1 1 1 ]
##   NEP5 : [ 1 10 1 1 1 1 ]
##   NEPOTH : [ 1 10 1 1 1 1 ]
##   NEP33 : [ 1 10 1 1 1 1 ]
##   TR1.4 :
```

```
##   POK : [ 1 10 1 1 1 1 ]
##   PLE : [ 1 10 1 1 1 1 ]
##   COD : [ 1 10 1 1 1 1 ]
##   HAD : [ 1 10 1 1 1 1 ]
##   SOL : [ 1 10 1 1 1 1 ]
##   WHG : [ 1 10 1 1 1 1 ]
##   NEPOTH : [ 1 10 1 1 1 1 ]
##   NEP33 : [ 1 10 1 1 1 1 ]
##   NEP5 : [ 1 10 1 1 1 1 ]
##   TR2.4 :
##   WHG : [ 1 10 1 1 1 1 ]
##   COD : [ 1 10 1 1 1 1 ]
##   SOL : [ 1 10 1 1 1 1 ]
##   HAD : [ 1 10 1 1 1 1 ]
##   POK : [ 1 10 1 1 1 1 ]
##   PLE : [ 1 10 1 1 1 1 ]
##   NEP33 : [ 1 10 1 1 1 1 ]
##   NEPOTH : [ 1 10 1 1 1 1 ]
##   NEP5 : [ 1 10 1 1 1 1 ]
##   NEP6 : [ 1 10 1 1 1 1 ]
##   TR2.7D :
##   WHG : [ 1 10 1 1 1 1 ]
##   COD : [ 1 10 1 1 1 1 ]

## ----------------------------------------------------------------

## An object of class "FLFleet"
##
## Name: NL_Static
## Description:
## Range:  min max minyear maxyear
##  NA NA 2003 2012
## Quant: quant
##
## effort        : [ 1 10 1 1 1 1 ], units =  000 kWdays
## fcost         : [ 1 10 1 1 1 1 ], units =  number of vessels
## capacity      : [ 1 10 1 1 1 1 ], units =  number of vessels
## crewshare     : [ 1 10 1 1 1 1 ], units =  NA
##
## Metiers:
##   GN1.4 :
##   COD : [ 1 10 1 1 1 1 ]
##   PLE : [ 1 10 1 1 1 1 ]
##   POK : [ 1 10 1 1 1 1 ]
##   SOL : [ 1 10 1 1 1 1 ]
##   WHG : [ 1 10 1 1 1 1 ]
##   HAD : [ 1 10 1 1 1 1 ]
##   NEPOTH : [ 1 10 1 1 1 1 ]
##   OTH :
##   SOL : [ 1 10 1 1 1 1 ]
##   PLE : [ 1 10 1 1 1 1 ]
##   COD : [ 1 10 1 1 1 1 ]
##   WHG : [ 1 10 1 1 1 1 ]

## ----------------------------------------------------------------

## An object of class "FLFleet"
##
```

```
## Name: NO_Otter<40
## Description:
## Range:  min max minyear maxyear
##  NA NA 2003 2012
## Quant: quant
##
## effort        : [ 1 10 1 1 1 1 ], units =  000 kWdays
## fcost         : [ 1 10 1 1 1 1 ], units =  number of vessels
## capacity      : [ 1 10 1 1 1 1 ], units =  number of vessels
## crewshare     : [ 1 10 1 1 1 1 ], units =  NA
##
## Metiers:
##   OTH :
##   COD : [ 1 10 1 1 1 1 ]
##   HAD : [ 1 10 1 1 1 1 ]
##   POK : [ 1 10 1 1 1 1 ]
##   otter.4 :
##   POK : [ 1 10 1 1 1 1 ]
##   WHG : [ 1 10 1 1 1 1 ]
##   PLE : [ 1 10 1 1 1 1 ]
##   SOL : [ 1 10 1 1 1 1 ]
##   HAD : [ 1 10 1 1 1 1 ]
##   COD : [ 1 10 1 1 1 1 ]

## ----------------------------------------------------------------

## An object of class "FLFleet"
##
## Name: NO_Otter>=40
## Description:
## Range:  min max minyear maxyear
##  NA NA 2003 2012
## Quant: quant
##
## effort        : [ 1 10 1 1 1 1 ], units =  000 kWdays
## fcost         : [ 1 10 1 1 1 1 ], units =  number of vessels
## capacity      : [ 1 10 1 1 1 1 ], units =  number of vessels
## crewshare     : [ 1 10 1 1 1 1 ], units =  NA
##
## Metiers:
##   otter.4 :
##   PLE : [ 1 10 1 1 1 1 ]
##   POK : [ 1 10 1 1 1 1 ]
##   HAD : [ 1 10 1 1 1 1 ]
##   COD : [ 1 10 1 1 1 1 ]
##   WHG : [ 1 10 1 1 1 1 ]

## ----------------------------------------------------------------

## An object of class "FLFleet"
##
## Name: NO_Pelagic
## Description:
## Range:  min max minyear maxyear
##  NA NA 2003 2012
## Quant: quant
##
## effort        : [ 1 10 1 1 1 1 ], units =  000 kWdays
```

```
## fcost         : [ 1 10 1 1 1 1 ], units =  number of vessels
## capacity      : [ 1 10 1 1 1 1 ], units =  number of vessels
## crewshare     : [ 1 10 1 1 1 1 ], units =  NA
##
## Metiers:
##   pelagic.4 :
##   POK : [ 1 10 1 1 1 1 ]
##   HAD : [ 1 10 1 1 1 1 ]
##   COD : [ 1 10 1 1 1 1 ]

## ----------------------------------------------------------------

## An object of class "FLFleet"
##
## Name: NO_Static
## Description:
## Range:  min max minyear maxyear
##  NA NA 2003 2012
## Quant: quant
##
## effort        : [ 1 10 1 1 1 1 ], units =  000 kWdays
## fcost         : [ 1 10 1 1 1 1 ], units =  number of vessels
## capacity      : [ 1 10 1 1 1 1 ], units =  number of vessels
## crewshare     : [ 1 10 1 1 1 1 ], units =  NA
##
## Metiers:
##   GN1.4 :
##   COD : [ 1 10 1 1 1 1 ]
##   HAD : [ 1 10 1 1 1 1 ]
##   PLE : [ 1 10 1 1 1 1 ]
##   POK : [ 1 10 1 1 1 1 ]
##   WHG : [ 1 10 1 1 1 1 ]
##   LL1.4 :
##   COD : [ 1 10 1 1 1 1 ]
##   HAD : [ 1 10 1 1 1 1 ]
##   POK : [ 1 10 1 1 1 1 ]
##   WHG : [ 1 10 1 1 1 1 ]

## ----------------------------------------------------------------

## An object of class "FLFleet"
##
## Name: SC_FDF
## Description:
## Range:  min max minyear maxyear
##  NA NA 2003 2012
## Quant: quant
##
## effort        : [ 1 10 1 1 1 1 ], units =  000 kWdays
## fcost         : [ 1 10 1 1 1 1 ], units =  number of vessels
## capacity      : [ 1 10 1 1 1 1 ], units =  number of vessels
## crewshare     : [ 1 10 1 1 1 1 ], units =  NA
##
## Metiers:
##   TR1.4 :
##   COD : [ 1 10 1 1 1 1 ]
##   HAD : [ 1 10 1 1 1 1 ]
##   PLE : [ 1 10 1 1 1 1 ]
```

```
##   POK : [ 1 10 1 1 1 1 ]
##   WHG : [ 1 10 1 1 1 1 ]
##   NEP10 : [ 1 10 1 1 1 1 ]
##   NEP7 : [ 1 10 1 1 1 1 ]
##   NEPOTH : [ 1 10 1 1 1 1 ]

## ----------------------------------------------------------------

## An object of class "FLFleet"
##
## Name: SC_Otter<24
## Description:
## Range:  min max minyear maxyear
##  NA NA 2003 2012
## Quant: quant
##
## effort        : [ 1 10 1 1 1 1 ], units =  000 kWdays
## fcost         : [ 1 10 1 1 1 1 ], units =  number of vessels
## capacity      : [ 1 10 1 1 1 1 ], units =  number of vessels
## crewshare     : [ 1 10 1 1 1 1 ], units =  NA
##
## Metiers:
##   TR1.4 :
##   WHG : [ 1 10 1 1 1 1 ]
##   COD : [ 1 10 1 1 1 1 ]
##   SOL : [ 1 10 1 1 1 1 ]
##   PLE : [ 1 10 1 1 1 1 ]
##   POK : [ 1 10 1 1 1 1 ]
##   HAD : [ 1 10 1 1 1 1 ]
##   NEP32 : [ 1 10 1 1 1 1 ]
##   NEP6 : [ 1 10 1 1 1 1 ]
##   NEP9 : [ 1 10 1 1 1 1 ]
##   NEPOTH : [ 1 10 1 1 1 1 ]
##   NEP5 : [ 1 10 1 1 1 1 ]
##   NEP10 : [ 1 10 1 1 1 1 ]
##   NEP7 : [ 1 10 1 1 1 1 ]
##   NEP8 : [ 1 10 1 1 1 1 ]
##   NEP34 : [ 1 10 1 1 1 1 ]
##   TR2.4 :
##   PLE : [ 1 10 1 1 1 1 ]
##   COD : [ 1 10 1 1 1 1 ]
##   SOL : [ 1 10 1 1 1 1 ]
##   POK : [ 1 10 1 1 1 1 ]
##   HAD : [ 1 10 1 1 1 1 ]
##   WHG : [ 1 10 1 1 1 1 ]
##   NEP9 : [ 1 10 1 1 1 1 ]
##   NEPOTH : [ 1 10 1 1 1 1 ]
##   NEP10 : [ 1 10 1 1 1 1 ]
##   NEP8 : [ 1 10 1 1 1 1 ]
##   NEP7 : [ 1 10 1 1 1 1 ]
##   NEP6 : [ 1 10 1 1 1 1 ]
##   NEP5 : [ 1 10 1 1 1 1 ]
##   NEP32 : [ 1 10 1 1 1 1 ]
##   NEP33 : [ 1 10 1 1 1 1 ]
##   NEP34 : [ 1 10 1 1 1 1 ]

## ----------------------------------------------------------------
```

```
## An object of class "FLFleet"
##
## Name: SC_Otter>=24
## Description:
## Range:  min max minyear maxyear
##  NA NA 2003 2012
## Quant: quant
##
## effort        : [ 1 10 1 1 1 1 ], units =  000 kWdays
## fcost         : [ 1 10 1 1 1 1 ], units =  number of vessels
## capacity      : [ 1 10 1 1 1 1 ], units =  number of vessels
## crewshare     : [ 1 10 1 1 1 1 ], units =  NA
##
## Metiers:
##   OTH :
##   COD : [ 1 10 1 1 1 1 ]
##   WHG : [ 1 10 1 1 1 1 ]
##   TR1.4 :
##   PLE : [ 1 10 1 1 1 1 ]
##   POK : [ 1 10 1 1 1 1 ]
##   COD : [ 1 10 1 1 1 1 ]
##   SOL : [ 1 10 1 1 1 1 ]
##   HAD : [ 1 10 1 1 1 1 ]
##   WHG : [ 1 10 1 1 1 1 ]
##   NEP7 : [ 1 10 1 1 1 1 ]
##   NEP32 : [ 1 10 1 1 1 1 ]
##   NEPOTH : [ 1 10 1 1 1 1 ]
##   NEP33 : [ 1 10 1 1 1 1 ]
##   NEP9 : [ 1 10 1 1 1 1 ]
##   NEP10 : [ 1 10 1 1 1 1 ]
##   NEP6 : [ 1 10 1 1 1 1 ]
##   NEP5 : [ 1 10 1 1 1 1 ]
##   NEP34 : [ 1 10 1 1 1 1 ]
##   TR2.4 :
##   SOL : [ 1 10 1 1 1 1 ]
##   POK : [ 1 10 1 1 1 1 ]
##   PLE : [ 1 10 1 1 1 1 ]
##   COD : [ 1 10 1 1 1 1 ]
##   HAD : [ 1 10 1 1 1 1 ]
##   WHG : [ 1 10 1 1 1 1 ]
##   NEPOTH : [ 1 10 1 1 1 1 ]
##   NEP5 : [ 1 10 1 1 1 1 ]
##   NEP10 : [ 1 10 1 1 1 1 ]
##   NEP7 : [ 1 10 1 1 1 1 ]
##   NEP9 : [ 1 10 1 1 1 1 ]
##   NEP33 : [ 1 10 1 1 1 1 ]
##   NEP6 : [ 1 10 1 1 1 1 ]
##   NEP32 : [ 1 10 1 1 1 1 ]
##   NEP34 : [ 1 10 1 1 1 1 ]

## ----------------------------------------------------------------

## An object of class "FLFleet"
##
## Name: SC_Static
## Description:
## Range:  min max minyear maxyear
##  NA NA 2003 2012
```

```
## Quant: quant
##
## effort        : [ 1 10 1 1 1 1 ], units =  000 kWdays
## fcost         : [ 1 10 1 1 1 1 ], units =  number of vessels
## capacity      : [ 1 10 1 1 1 1 ], units =  number of vessels
## crewshare     : [ 1 10 1 1 1 1 ], units =  NA
##
## Metiers:
##   OTH :
##   WHG : [ 1 10 1 1 1 1 ]
##   HAD : [ 1 10 1 1 1 1 ]
##   PLE : [ 1 10 1 1 1 1 ]
##   COD : [ 1 10 1 1 1 1 ]
##   POK : [ 1 10 1 1 1 1 ]
##   SOL : [ 1 10 1 1 1 1 ]
##   NEP9 : [ 1 10 1 1 1 1 ]
##   NEPOTH : [ 1 10 1 1 1 1 ]
##   NEP8 : [ 1 10 1 1 1 1 ]
##   NEP7 : [ 1 10 1 1 1 1 ]
##   pots.4 :
##   HAD : [ 1 10 1 1 1 1 ]
##   WHG : [ 1 10 1 1 1 1 ]
##   COD : [ 1 10 1 1 1 1 ]
##   POK : [ 1 10 1 1 1 1 ]
##   PLE : [ 1 10 1 1 1 1 ]
##   SOL : [ 1 10 1 1 1 1 ]
##   NEP9 : [ 1 10 1 1 1 1 ]
##   NEPOTH : [ 1 10 1 1 1 1 ]
##   NEP7 : [ 1 10 1 1 1 1 ]
##   NEP8 : [ 1 10 1 1 1 1 ]
##   NEP10 : [ 1 10 1 1 1 1 ]
##   NEP6 : [ 1 10 1 1 1 1 ]

## ----------------------------------------------------------------

## An object of class "FLFleet"
##
## Name: SC_U10_OTB
## Description:
## Range:  min max minyear maxyear
##  NA NA 2003 2012
## Quant: quant
##
## effort        : [ 1 10 1 1 1 1 ], units =  000 kWdays
## fcost         : [ 1 10 1 1 1 1 ], units =  number of vessels
## capacity      : [ 1 10 1 1 1 1 ], units =  number of vessels
## crewshare     : [ 1 10 1 1 1 1 ], units =  NA
##
## Metiers:
##   TR1.4 :
##   PLE : [ 1 10 1 1 1 1 ]
##   COD : [ 1 10 1 1 1 1 ]
##   SOL : [ 1 10 1 1 1 1 ]
##   WHG : [ 1 10 1 1 1 1 ]
##   HAD : [ 1 10 1 1 1 1 ]
##   POK : [ 1 10 1 1 1 1 ]
##   NEP8 : [ 1 10 1 1 1 1 ]
##   NEP6 : [ 1 10 1 1 1 1 ]
```

```
##   NEP9 : [ 1 10 1 1 1 1 ]
##   NEPOTH : [ 1 10 1 1 1 1 ]
##   NEP10 : [ 1 10 1 1 1 1 ]
##   TR2.4 :
##   PLE : [ 1 10 1 1 1 1 ]
##   COD : [ 1 10 1 1 1 1 ]
##   HAD : [ 1 10 1 1 1 1 ]
##   WHG : [ 1 10 1 1 1 1 ]
##   SOL : [ 1 10 1 1 1 1 ]
##   POK : [ 1 10 1 1 1 1 ]
##   NEP8 : [ 1 10 1 1 1 1 ]
##   NEP6 : [ 1 10 1 1 1 1 ]
##   NEP7 : [ 1 10 1 1 1 1 ]
##   NEPOTH : [ 1 10 1 1 1 1 ]
##   NEP9 : [ 1 10 1 1 1 1 ]
##   NEP10 : [ 1 10 1 1 1 1 ]

## ----------------------------------------------------------------

## An object of class "FLFleet"
##
## Name: OTH_OTH
## Description:
## Range:  min max minyear maxyear
##  NA NA 2003 2012
## Quant: quant
##
## effort        : [ 1 10 1 1 1 1 ], units =  NA
## fcost         : [ 1 10 1 1 1 1 ], units =  NA
## capacity      : [ 1 10 1 1 1 1 ], units =  NA
## crewshare     : [ 1 10 1 1 1 1 ], units =  NA
##
## Metiers:
##   OTH :
##   COD : [ 1 10 1 1 1 1 ]
##   HAD : [ 1 10 1 1 1 1 ]
##   PLE : [ 1 10 1 1 1 1 ]
##   POK : [ 1 10 1 1 1 1 ]
##   SOL : [ 1 10 1 1 1 1 ]
##   WHG : [ 1 10 1 1 1 1 ]
##   NEP33 : [ 1 10 1 1 1 1 ]
##   NEP6 : [ 1 10 1 1 1 1 ]
##   NEP32 : [ 1 10 1 1 1 1 ]
##   NEP9 : [ 1 10 1 1 1 1 ]
##   NEP7 : [ 1 10 1 1 1 1 ]
##   NEP8 : [ 1 10 1 1 1 1 ]
##   NEP5 : [ 1 10 1 1 1 1 ]
##   NEPOTH : [ 1 10 1 1 1 1 ]
##   NEP10 : [ 1 10 1 1 1 1 ]

## ----------------------------------------------------------------

## An object of class "FLFleet"
##
## Name: unalloc
## Description:
## Range:  min max minyear maxyear
##  NA NA 2003 2012
```

```
## Quant: quant
##
## effort        : [ 1 10 1 1 1 1 ], units =  NA
## fcost         : [ 1 10 1 1 1 1 ], units =  NA
## capacity      : [ 1 10 1 1 1 1 ], units =  NA
## crewshare     : [ 1 10 1 1 1 1 ], units =  NA
##
## Metiers:
##   unalloc :
##   COD : [ 1 10 1 1 1 1 ]
```

6 AER Economic Indicators by Year

This section presents the economic indicators computed for area 27 based on the information of the AER, fixed costs ("fixCost"), variable costs depending on effort ("effCost"), crew costs ("crewCost"), revenue from the North Sea ("nsval") and revenue from area 27 ("value"). These will be used for comparison with the same indicators computed for the North Sea after merging the two datasets. Due to the distinct space scales used, the comparison will have to be carried out in relative terms, *e.g.* the percentage of revenues allocated to costs.

```
eco4tests <- transform(eco.orig, id = paste(country_code, fishing_tech, vessel_length),
    ns = sub_reg %in% NSdiv)

lst <- lapply(split(eco4tests, eco4tests$id), function(x) {
    mat <- tapply(x$value, list(var = x$variable_code, y = x$year, ns = x$ns),
        sum, na.rm = T)
    data.frame(expand.grid(dimnames(mat)), value = c(mat), flt = unique(x$id))
})
eco4tests <- do.call("rbind", lst)

nsval <- with(subset(eco4tests, var == "totvallandg" & ns == TRUE), tapply(value,
    list(flt, y), sum, na.rm = T))
nsval <- apply(nsval, 2, sum, na.rm = T)/1e+06

fixCost <- with(subset(eco4tests, var %in% c("totdepcost", "totnovarcost", "OPR")),
    tapply(value, list(flt, y), sum, na.rm = T))
fixCost <- apply(fixCost, 2, sum, na.rm = T)/1e+06

nves <- with(subset(eco4tests, var == "totves"), tapply(value, list(flt, y),
    sum, na.rm = T))
nves <- apply(nves, 2, sum, na.rm = T)

effCost <- with(subset(eco4tests, var %in% c("totenercost", "totrepcost")),
    tapply(value, list(flt, y), sum, na.rm = T))
effCost <- apply(effCost, 2, sum, na.rm = T)/1e+06

crewCost <- with(subset(eco4tests, var %in% c("totcrewwage", "totunpaidlab")),
    tapply(value, list(flt, y), sum, na.rm = T))
crewCost <- apply(crewCost, 2, sum, na.rm = T)/1e+06

val <- with(subset(eco4tests, var == "totvallandg"), tapply(value, list(flt,
    y), sum, na.rm = T))
val <- apply(val, 2, sum, na.rm = T)/1e+06

nms <- list(year = 2008:2012, indicator = c("nsval", "value", "fixCost", "effCost",
    "crewCost", "totCost"), type = c("absolute", "rel2value"))
```

```r
eco.aer <- array(c(nsval, val, fixCost, effCost, crewCost, fixCost + effCost +
    crewCost), dimnames = nms, dim = unlist(lapply(nms, length)))
eco.aer[, , 2] <- sweep(eco.aer[, , 2], 1, eco.aer[, "value", 1], "/")
```

```
## , , type = absolute
##
##       indicator
## year   nsval value fixCost effCost crewCost totCost
##   2008 770.2  1136   426.5   578.5    529.7    1535
##   2009 759.0  1433   313.6   457.0    502.2    1273
##   2010 828.1  1544   361.5   492.4    498.9    1353
##
## , , type = rel2value
##
##       indicator
## year    nsval value fixCost effCost crewCost totCost
##   2008 0.6782     1  0.3756  0.5094   0.4665  1.3515
##   2009 0.5298     1  0.2189  0.3190   0.3505  0.8884
##   2010 0.5363     1  0.2341  0.3189   0.3231  0.8761
```

7 Computing economic variables by unit based on the AER information

At the first step the economic indicators were standardized by unit and estimated by fleet segment and year.

Part of variable costs is more dependent on fleet effort (e.g. energy costs), while labour costs are more dependent on value of landings. For this exercise variable costs been distinguished to effort and income related.

Additionally, to have the full revenue on the North Sea it was necessary to model the extra income coming from species not included in the WGMIXFISH dataset.

The indices used in this exercise are: costs of effort by effort unit (euro/kwday), fixed costs by vessel (euro/vessel) and crew share[1] (%).

7.1 Other revenue

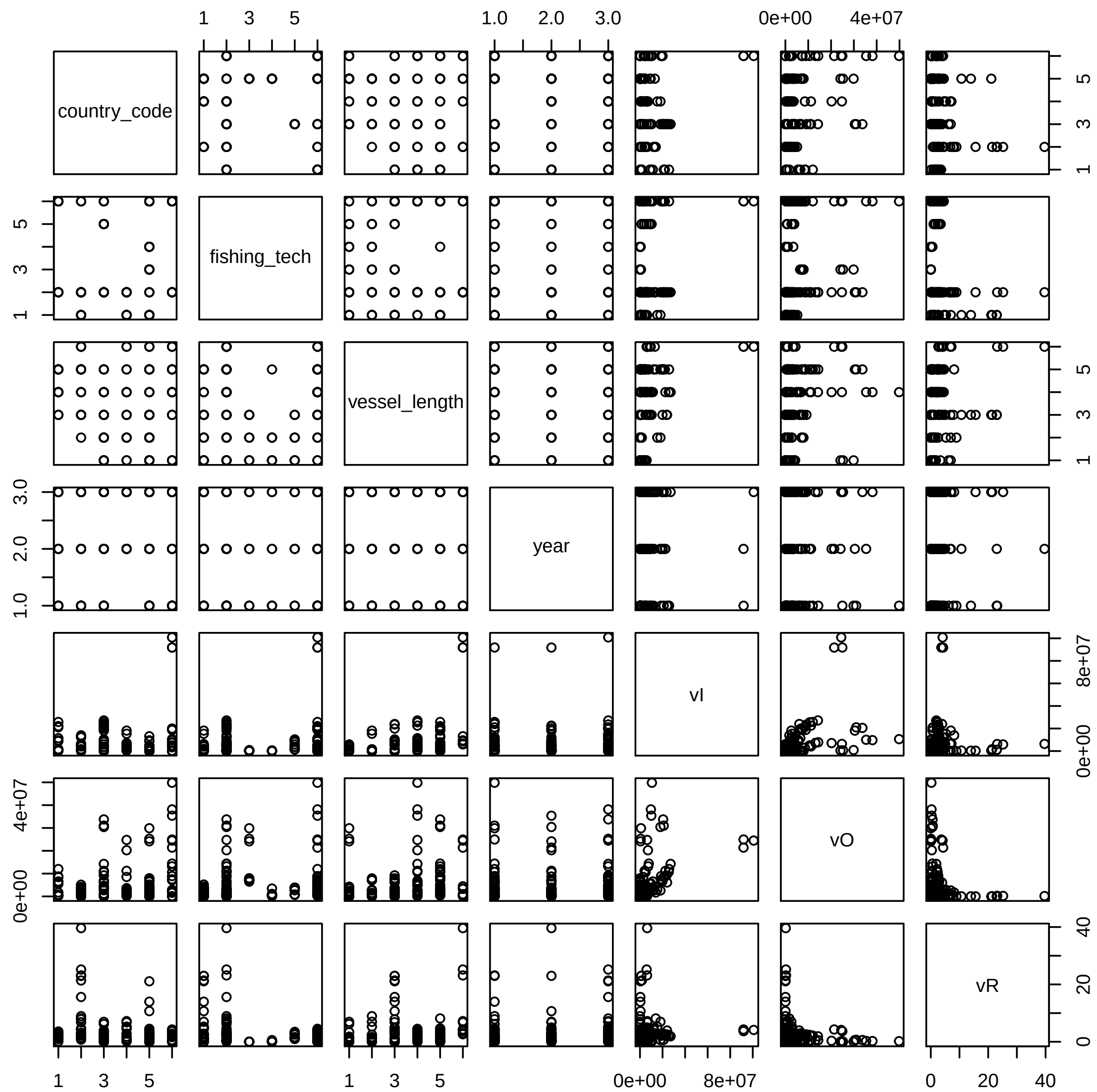
To estimate the full revenue for each fleet, the ratio between value of landings of species considered in the WG dataset (vI) and not considered in the WG dataset (vO) was modelled. This procedure allows scaling partial income to total income from the North Sea.

```r
# subset
df0 <- subset(ecoFix, variable_code == "totvallandg" & sub_reg %in% NSdiv)
# id species in fleet
df0$wgspp <- FALSE
nms <- lapply(fltscn[[1]], function(x) {
    nms <- catchNames(x)
    nms[nchar(nms) > 3] <- substring(nms[nchar(nms) > 3], 1, 3)
    unique(nms)
})
for (i in names(nms)) df0[df0$wgmix_code == i & df0$species_code %in% nms[[i]],
    "wgspp"] <- TRUE
```

[1]could be referred to as crew costs by unit of income (euro/euro)

```
# compute income of other species
df1 <- subset(df0, !wgspp)
vO <- tapply(df1$value, df1[, c("country_code", "fishing_tech", "vessel_length",
    "year")], sum, na.rm = T)

# compute income of WG species
df1 <- subset(df0, wgspp)
vI <- tapply(df1$value, df1[, c("country_code", "fishing_tech", "vessel_length",
    "year")], sum, na.rm = T)

# check all levels of factors match
all.equal(dimnames(vI), dimnames(vO))

## [1] TRUE


# compute variable costs by unit effort
vR <- vI/vO
```

```
# build data.frame for glm and rename factors to make it easier ...
vR.df <- data.frame(expand.grid(dimnames(vR)), vI = c(vI), vO = c(vO), vR = c(vR))
vR.df <- subset(vR.df, !is.na(vR) & vR > 0)
pairs(vR.df)
```




```
names(vR.df)[1:4] <- c("ms", "gr", "loa", "y")
vR.df <- transform(vR.df, metier = paste(ms, gr, loa, sep = ":"))
```

```
# summaries
table(vR.df$loa)

##
## VL0010 VL1012 VL1218 VL1824 VL2440 VL40XX
##     22     23     34     27     33     11

tapply(vR.df$vR, vR.df$loa, mean, na.rm = T)

## VL0010 VL1012 VL1218 VL1824 VL2440 VL40XX
##  1.367  1.572  5.199  1.784  1.928 11.122
```

```r
bwplot(vR ~ loa, data = vR.df)
```

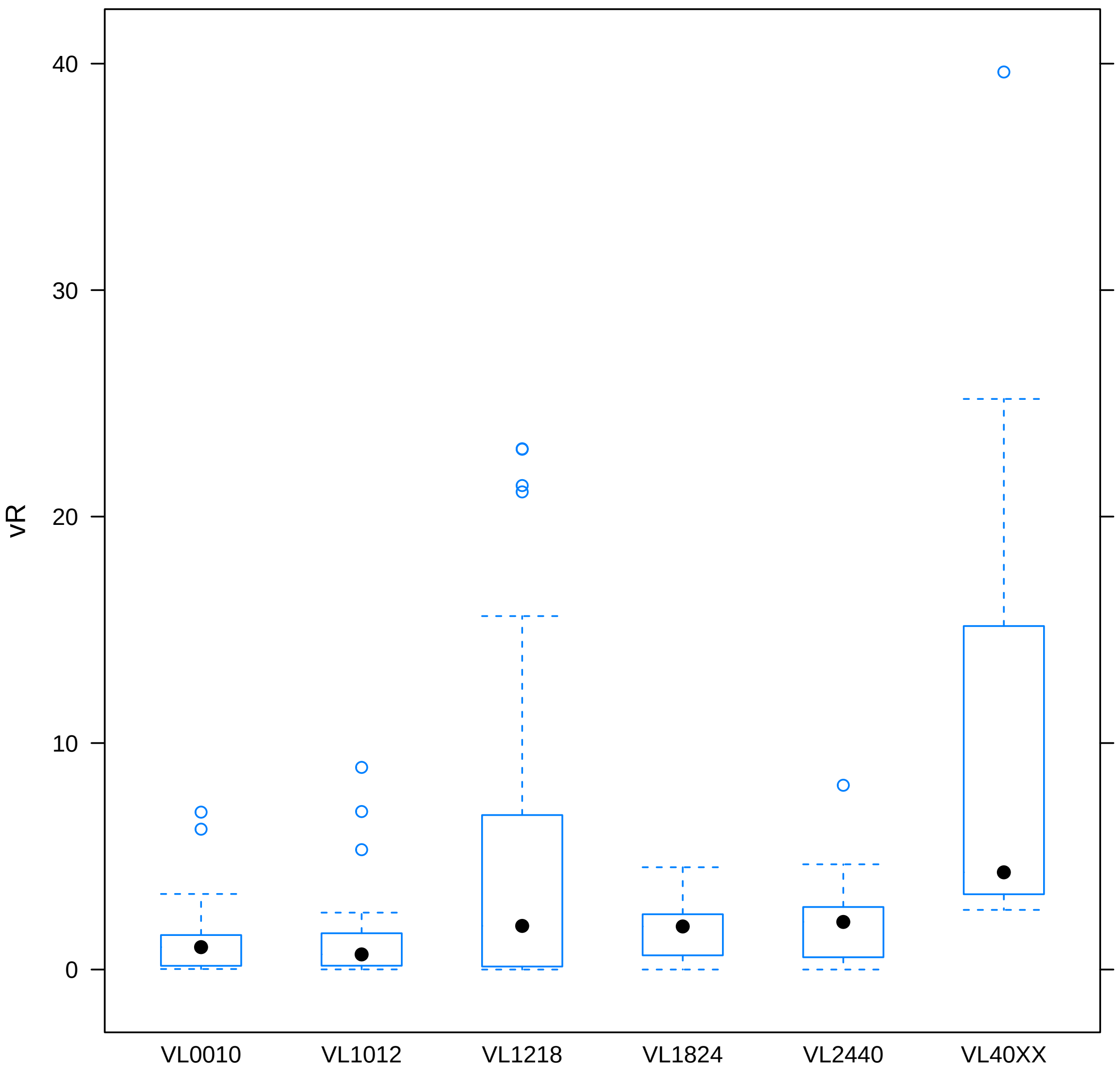


Figure 18: by fleet

```r
table(vR.df$y)

##
## 2008 2009 2010
##   46   52   52

tapply(vR.df$vR, vR.df$y, mean, na.rm = T)

##  2008  2009  2010
## 2.978 3.221 3.320
```

```r
bwplot(vR ~ y, data = vR.df)
```

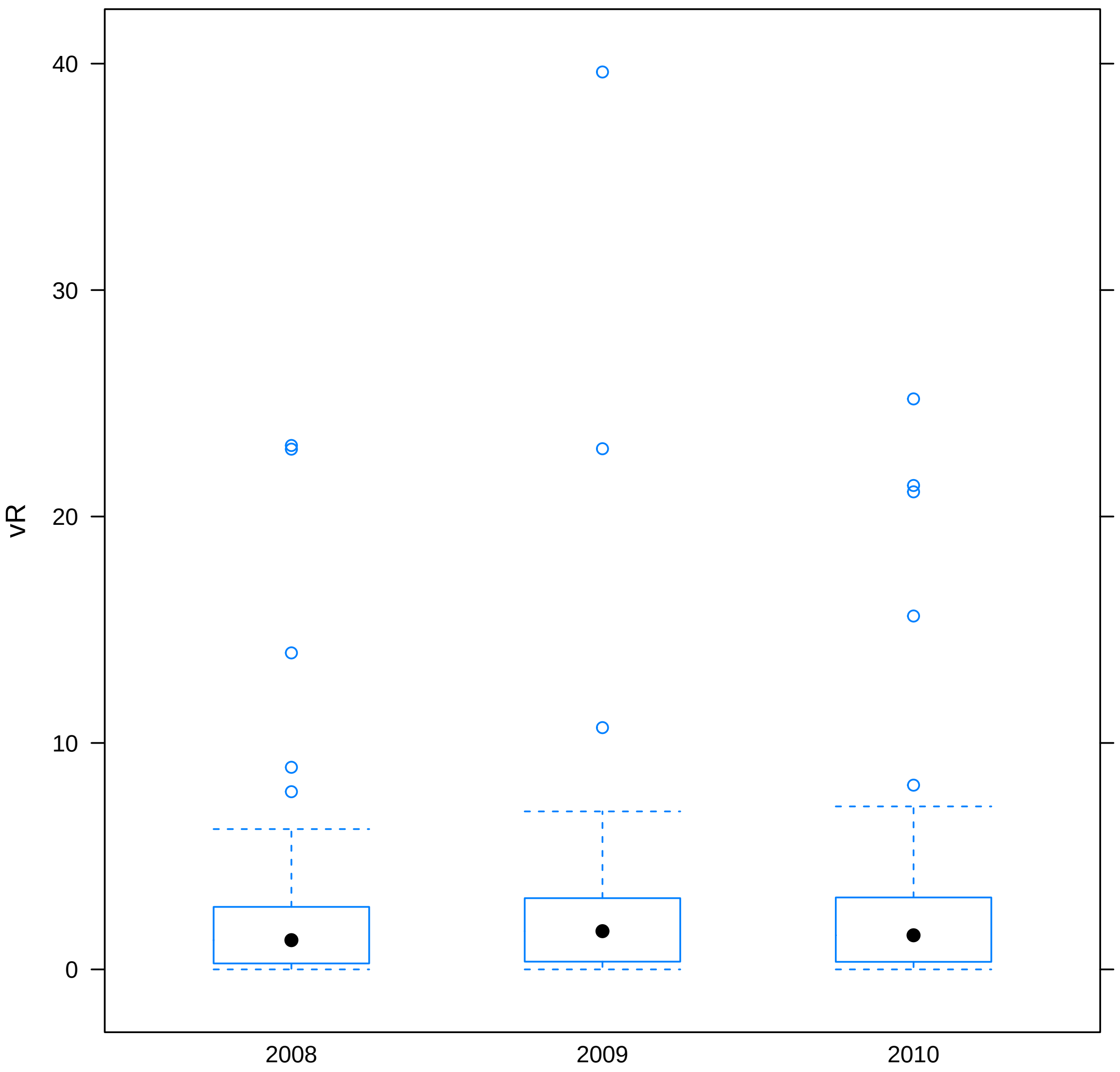


Figure 19: by year

```r
table(vR.df$ms)

##
## BEL DEU DNK FRA GBR NLD
##  15  22  29  18  45  21

tapply(vR.df$vR, vR.df$ms, mean, na.rm = T)

##    BEL    DEU    DNK    FRA    GBR    NLD
##  1.995 10.391  1.892  2.740  1.873  1.434
```

```
bwplot(vR ~ ms, data = vR.df)
```

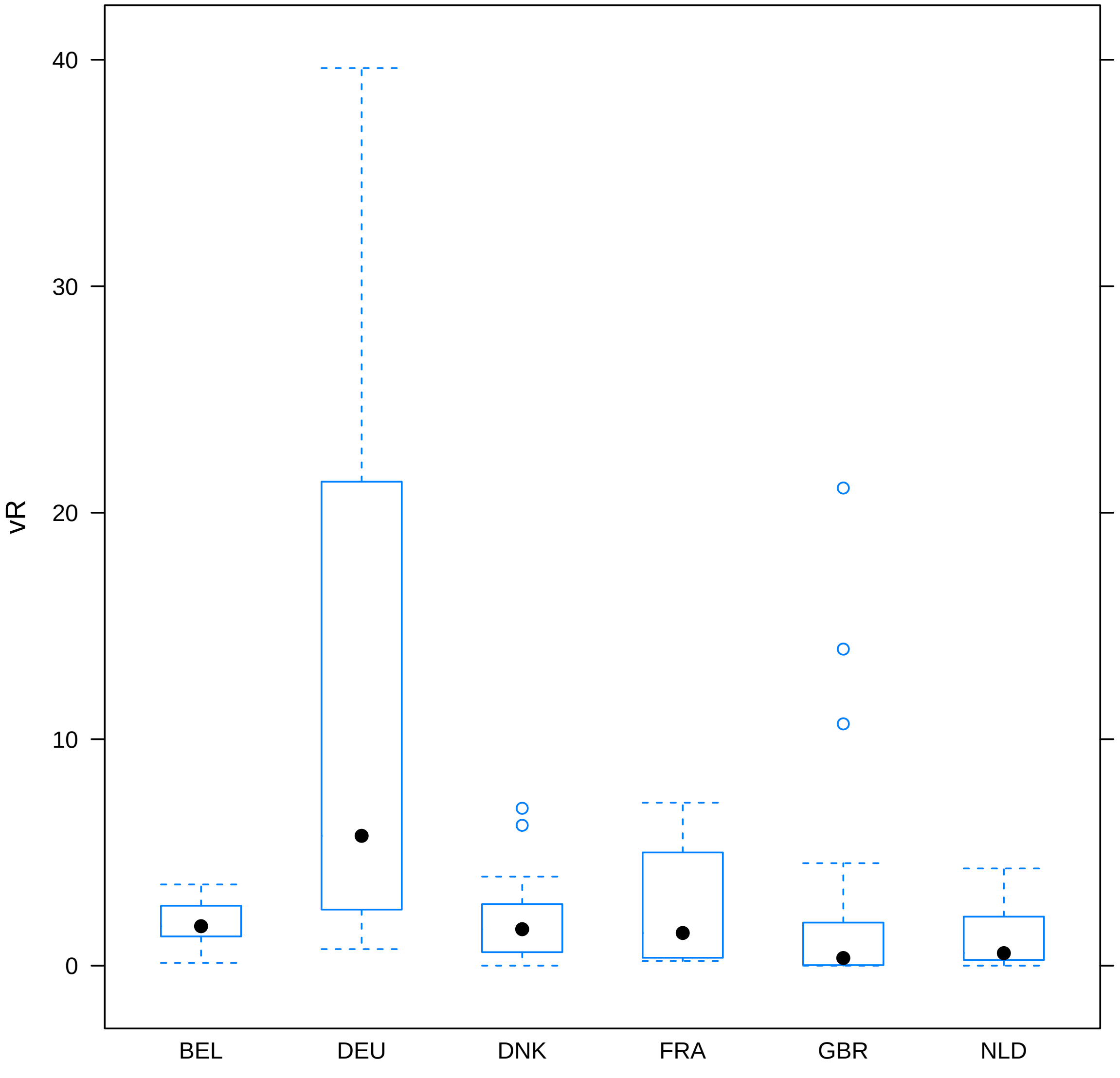


Figure 20: by member state

```
table(vR.df$gr)

##
## DFN DTS FPO HOK PGP TBB
##  26  56   9   7   9  43

tapply(vR.df$vR, vR.df$gr, mean, na.rm = T)

##     DFN     DTS     FPO     HOK     PGP     TBB
## 6.08561 4.22343 0.01851 0.19774 2.02857 1.45470
```

```
bwplot(vR ~ gr, data = vR.df)
```

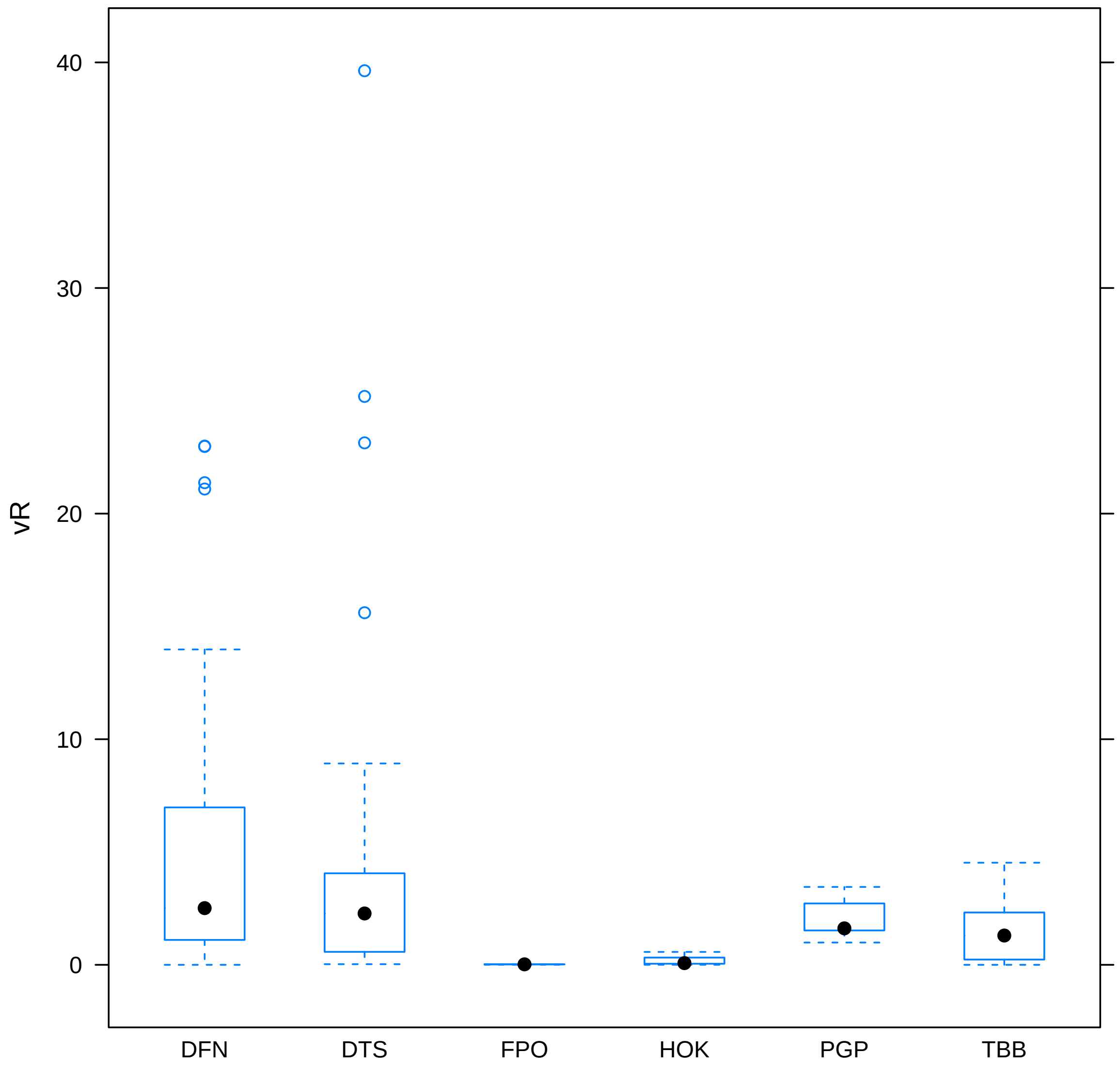


Figure 21: by gear

7.1.1 GLM

```
# GLM for metier components ! NOTE: shall observations 22,111 need to be
# removed because had leverage 1 ??
vR.glm <- glm(vR ~ (loa + gr + ms + y)^2, family = Gamma("log"), data = vR.df,
    maxit = 200)
anova(vR.glm, test = "F")

## Analysis of Deviance Table
##
## Model: Gamma, link: log
##
```

```
## Response: vR
##
## Terms added sequentially (first to last)
##
##
##        Df Deviance Resid. Df Resid. Dev     F  Pr(>F)
## NULL                      149        451
## loa     5     72.9       144        378 30.51 6.2e-16 ***
## gr      5    109.0       139        269 45.58 < 2e-16 ***
## ms      5     29.2       134        240 12.23 2.1e-08 ***
## y       2      0.3       132        239  0.27    0.76
## loa:gr 15     84.7       117        155 11.82 2.2e-13 ***
## loa:ms 17     45.3       100        109  5.57 1.7e-07 ***
## loa:y  10      1.4        90        108  0.29    0.98
## gr:ms   5     44.2        85         64 18.50 1.9e-11 ***
## gr:y   10      1.6        75         62  0.33    0.97
## ms:y    9      4.8        66         57  1.12    0.36
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
# year is not significative
vR.glm <- glm(vR ~ (loa + gr + ms)^2, family = Gamma("log"), data = vR.df, maxit = 500)
anova(vR.glm, test = "F")
```

```
## Analysis of Deviance Table
##
## Model: Gamma, link: log
##
## Response: vR
##
## Terms added sequentially (first to last)
##
##
##        Df Deviance Resid. Df Resid. Dev    F  Pr(>F)
## NULL                      149        451
## loa     5     72.9       144        378 38.2 < 2e-16 ***
## gr      5    109.0       139        269 57.1 < 2e-16 ***
## ms      5     29.2       134        240 15.3 4.4e-11 ***
## loa:gr 15     84.9       119        155 14.8 < 2e-16 ***
## loa:ms 17     45.4       102        109  7.0 1.1e-10 ***
## gr:ms   5     42.4        97         67 22.2 8.9e-15 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
par(mfrow = c(2, 2))
plot(vR.glm)
```

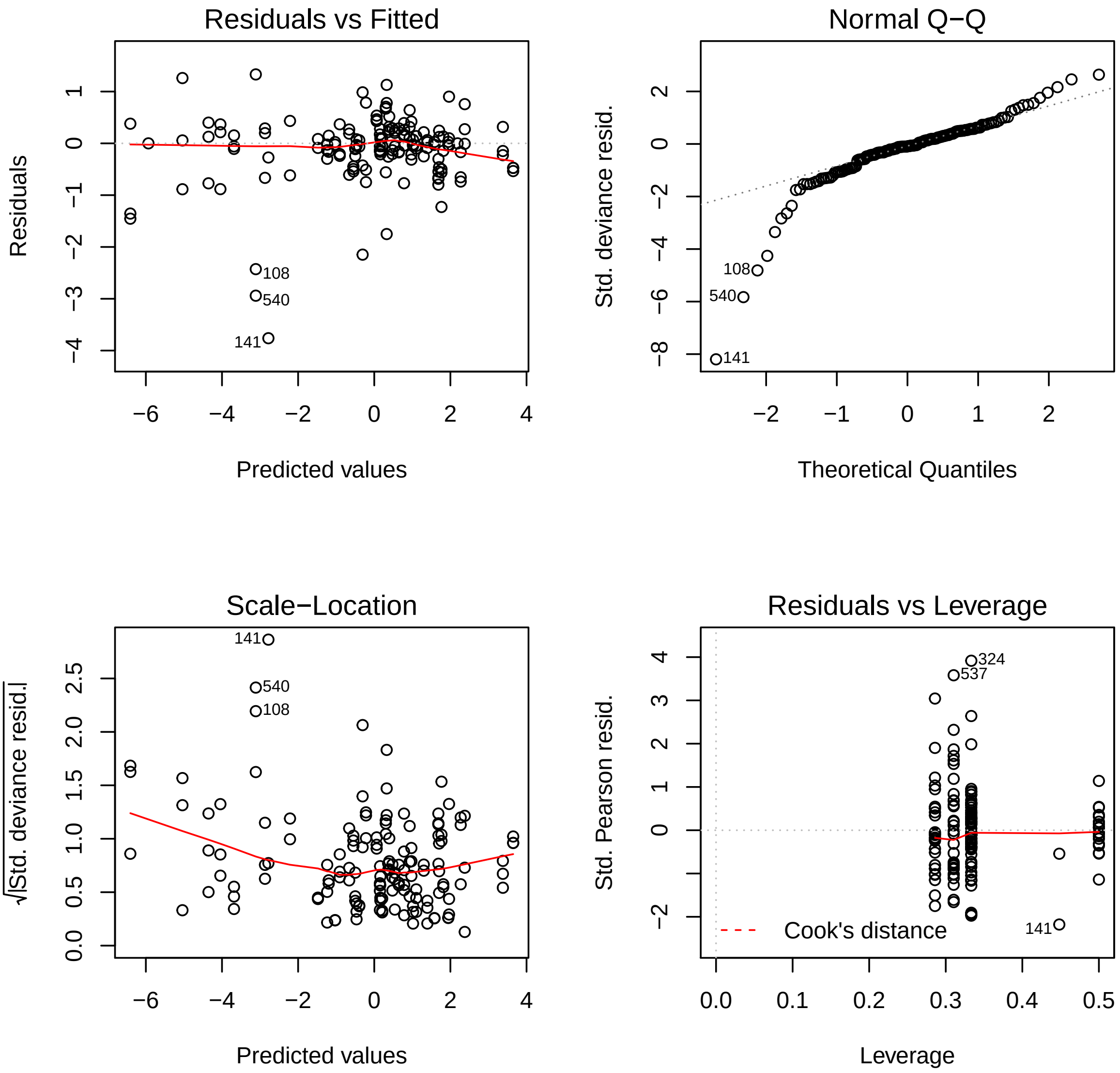


Figure 22: GLM diagnostics

```
xyplot(residuals(vR.glm) ~ predict(vR.glm) | vR.df$gr, type = c("smooth", "p"),
    xlab = "", ylab = "")
```

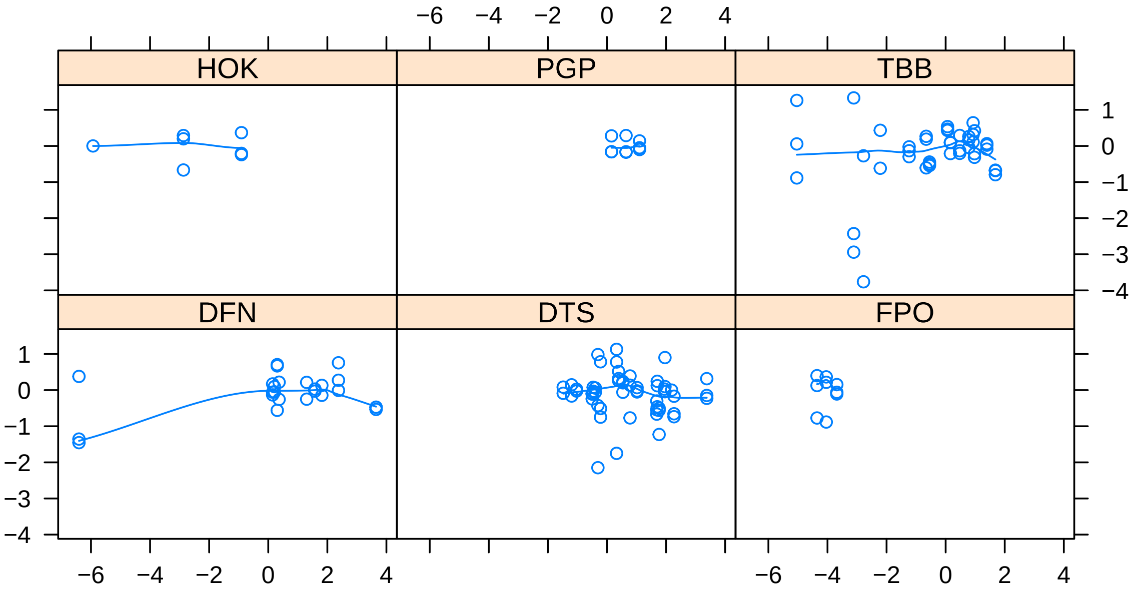


Figure 23: GLM residuals VS predicted by MS

```
xyplot(residuals(vR.glm) ~ predict(vR.glm) | vR.df$gr, type = c("smooth", "p"),
    xlab = "", ylab = "")
```

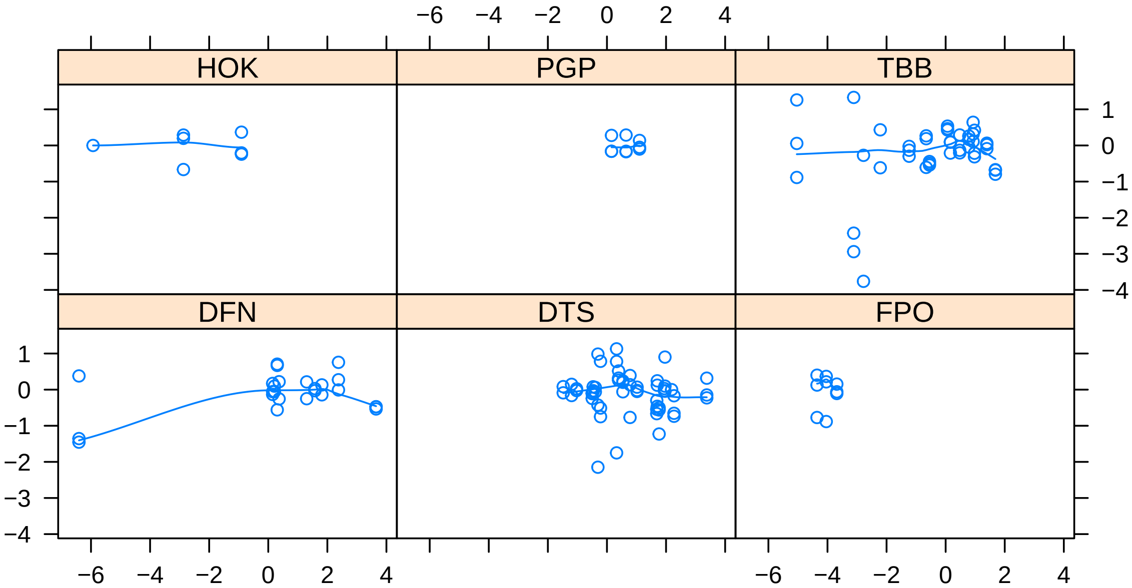


Figure 24: GLM residuals VS predicted by gear

```
xyplot(residuals(vR.glm) ~ predict(vR.glm) | vR.df$loa, type = c("smooth", "p"),
    xlab = "", ylab = "")
```

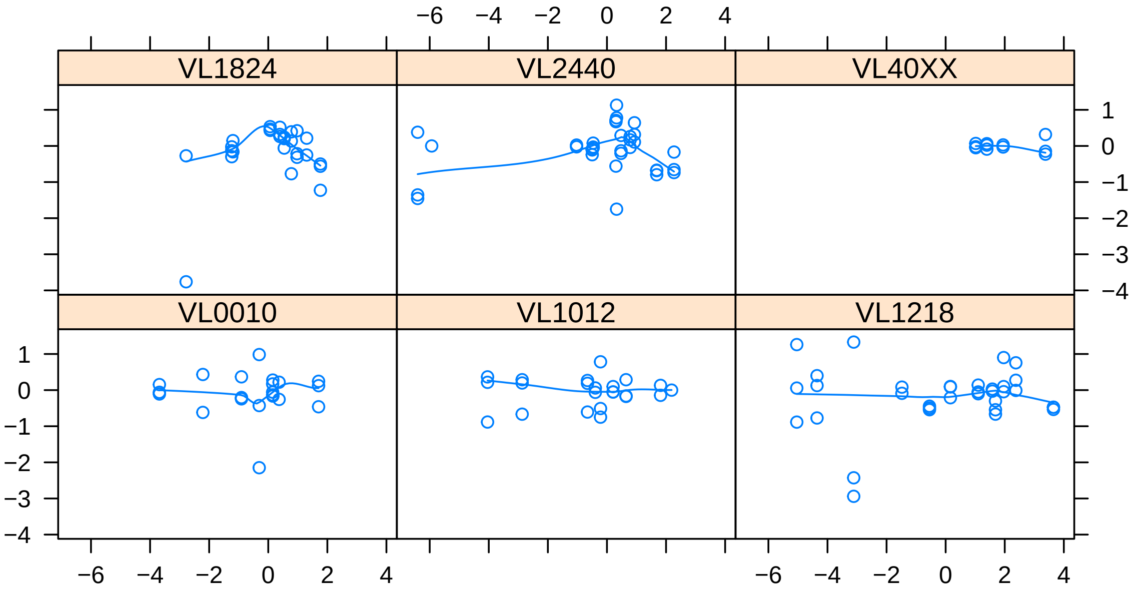


Figure 25: GLM residuals VS predicted by vessel length category

7.1.2 Predictions

```
vRnew.df <- do.call("rbind", strsplit(unique(with(wg2eco, paste(country_code,
    gear_code, vessel_length_code, sep = ":"))), ":"))
vRnew.df <- data.frame(vRnew.df)
names(vRnew.df) <- c("ms", "gr", "loa")
vRnew.df <- vRnew.df[vRnew.df$loa != "NA" & vRnew.df$loa != "VL24XX" & vRnew.df$ms !=
    "NOR", ]
vRnew.df <- transform(vRnew.df, metier = paste(ms, gr, loa, sep = ":"))
vRnew.df$vRpred <- predict(vR.glm, newdata = vRnew.df, type = "response")
```

```
dotplot(reorder(metier, vRpred) ~ vRpred, type = c("p", "h"), data = vRnew.df,
    xlab = "ratio")
```

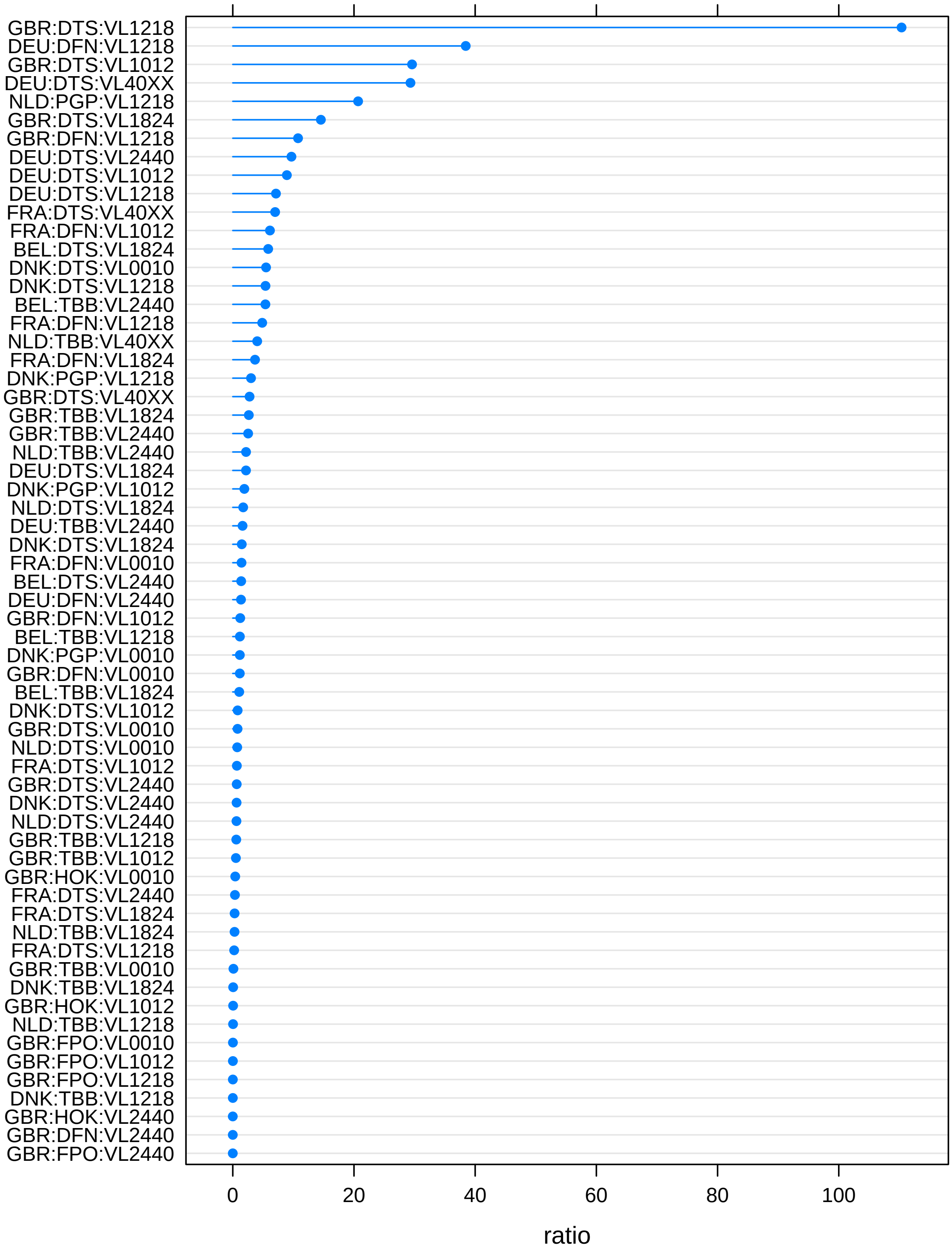


Figure 26: Estimates of value of landings ratio for all metiers

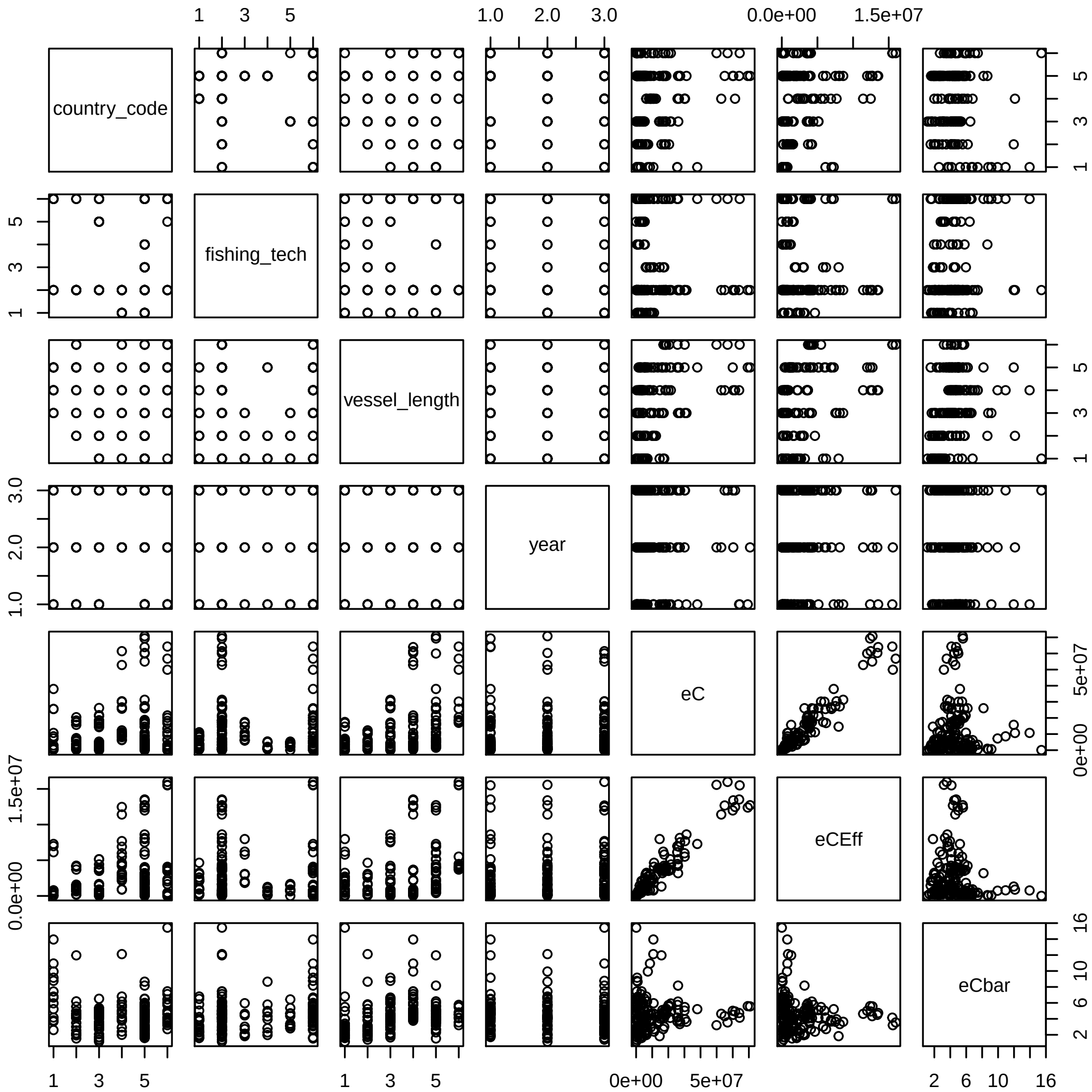
7.2 Variable costs by effort

The information from the AER was aggregated at the region level (Area 27), Member State, fleet segment, fishing gear, vessel length and year.

Effort costs by unit of effort were computed by year as $eC = (rC+nC+vC).eff^{-1}$, while for years without information a weighted average between 2008 and 2010 was used, $\bar{eC} = \sum_{t=2008}^{2010}(rC+nC+vC)_t(\sum_{t=2008}^{2010}(eff)_t)^{-1}$, where eC is *effort costs*, rC is *repair and maintenance costs*, nC is *energy costs*, vC is *other variable costs* and eff is *fishing effort* in kwday.

```
# subset
df0 <- subset(ecoFix, variable_code %in% c("totenercost", "totvarcost", "totrepcost",
    "totkwfishdays"))
df0 <- transform(df0, id = paste(country_code, fishing_tech, vessel_length,
    year, sep = ":"))
# remove cases that don't have energy or effort
errvec <- unique(subset(df0, variable_code %in% c("totenercost", "totkwfishdays") &
    value <= 0)$id)
df0 <- subset(df0, !(id %in% errvec))
# remove cases that don't have totvar and repair at the same time
errvec <- unique(subset(df0, (variable_code == "totvarcost" & value <= 0) &
    (variable_code == "totrepcost" & value <= 0))$id)
df0 <- subset(df0, !(id %in% errvec))

# compute costs
df1 <- subset(df0, variable_code != "totkwfishdays")
eC <- tapply(df1$value, df1[, c("country_code", "fishing_tech", "vessel_length",
    "year")], sum, na.rm = T)

# compute associated effort
df1 <- subset(df0, variable_code == "totkwfishdays")
eCEff <- tapply(df1$value, df1[, c("country_code", "fishing_tech", "vessel_length",
    "year")], sum, na.rm = T)

# check all levels of factors match
all.equal(dimnames(eC), dimnames(eCEff))

## [1] TRUE


# compute variable costs by unit effort
eCBar <- eC/eCEff
```

```
# build data.frame for glm and rename factors to make it easier ...
eC.df <- data.frame(expand.grid(dimnames(eC)), eC = c(eC), eCEff = c(eCEff),
    eCbar = c(eCBar))
eC.df <- subset(eC.df, !is.na(eCbar))
pairs(eC.df)
```




```r
names(eC.df)[1:4] <- c("ms", "gr", "loa", "y")
eC.df <- transform(eC.df, metier = paste(ms, gr, loa, sep = ":"))
```

```r
# summaries
table(eC.df$loa)
```

```
##
## VL0010 VL1012 VL1218 VL1824 VL2440 VL40XX
##     23     28     35     30     35     11
```

```r
tapply(eC.df$eCbar, eC.df$loa, median, na.rm = T)
```

```
## VL0010 VL1012 VL1218 VL1824 VL2440 VL40XX
##  2.627  3.079  4.186  5.231  4.589  4.561
```

```
bwplot(eCbar ~ loa, data = eC.df)
```

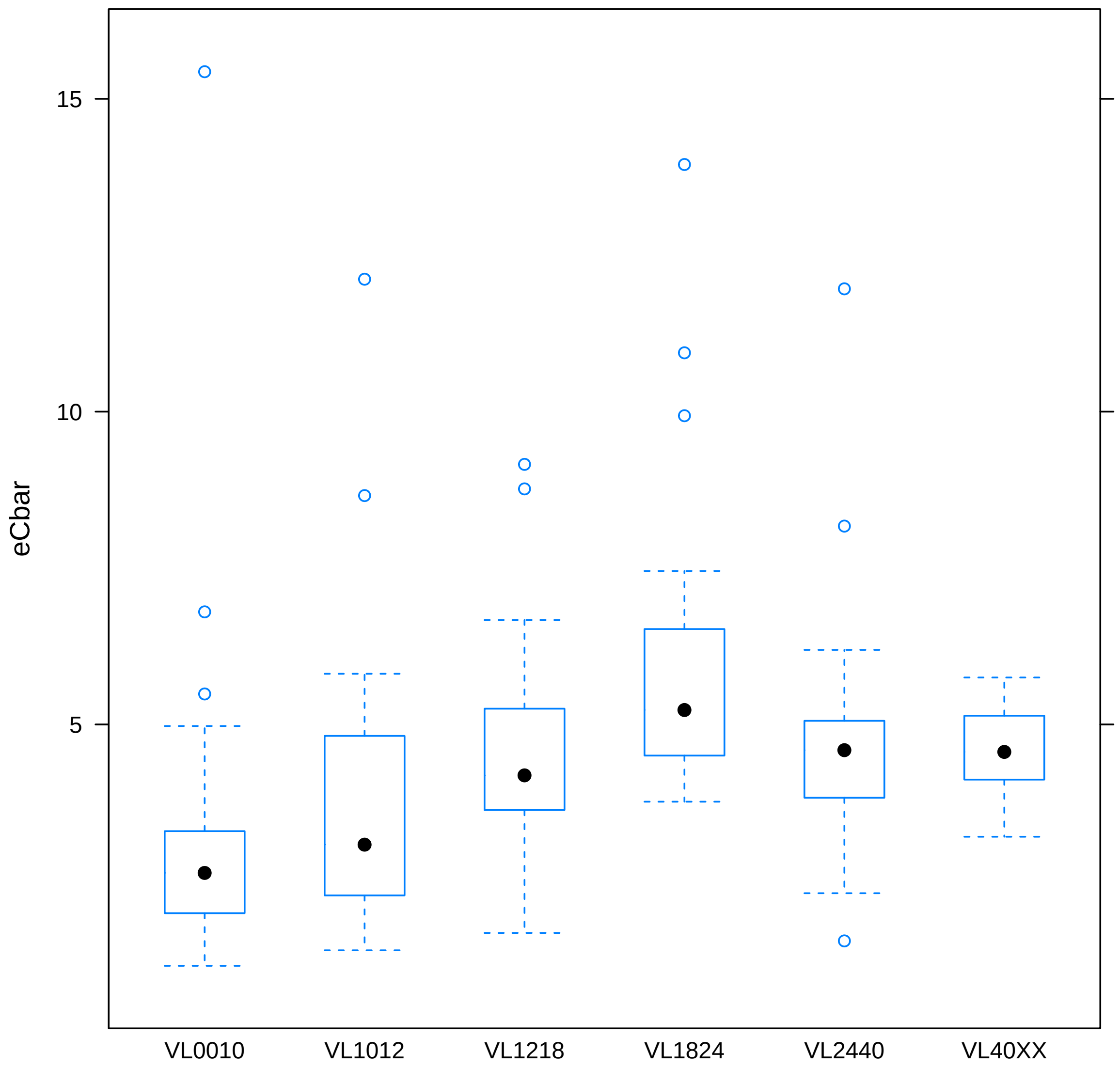


Figure 27: by fleet

```
table(eC.df$y)

##
## 2008 2009 2010
##   48   57   57

tapply(eC.df$eCbar, eC.df$y, mean, na.rm = T)

##  2008  2009  2010
## 4.800 4.397 4.456
```

```
bwplot(eCbar ~ y, data = eC.df)
```

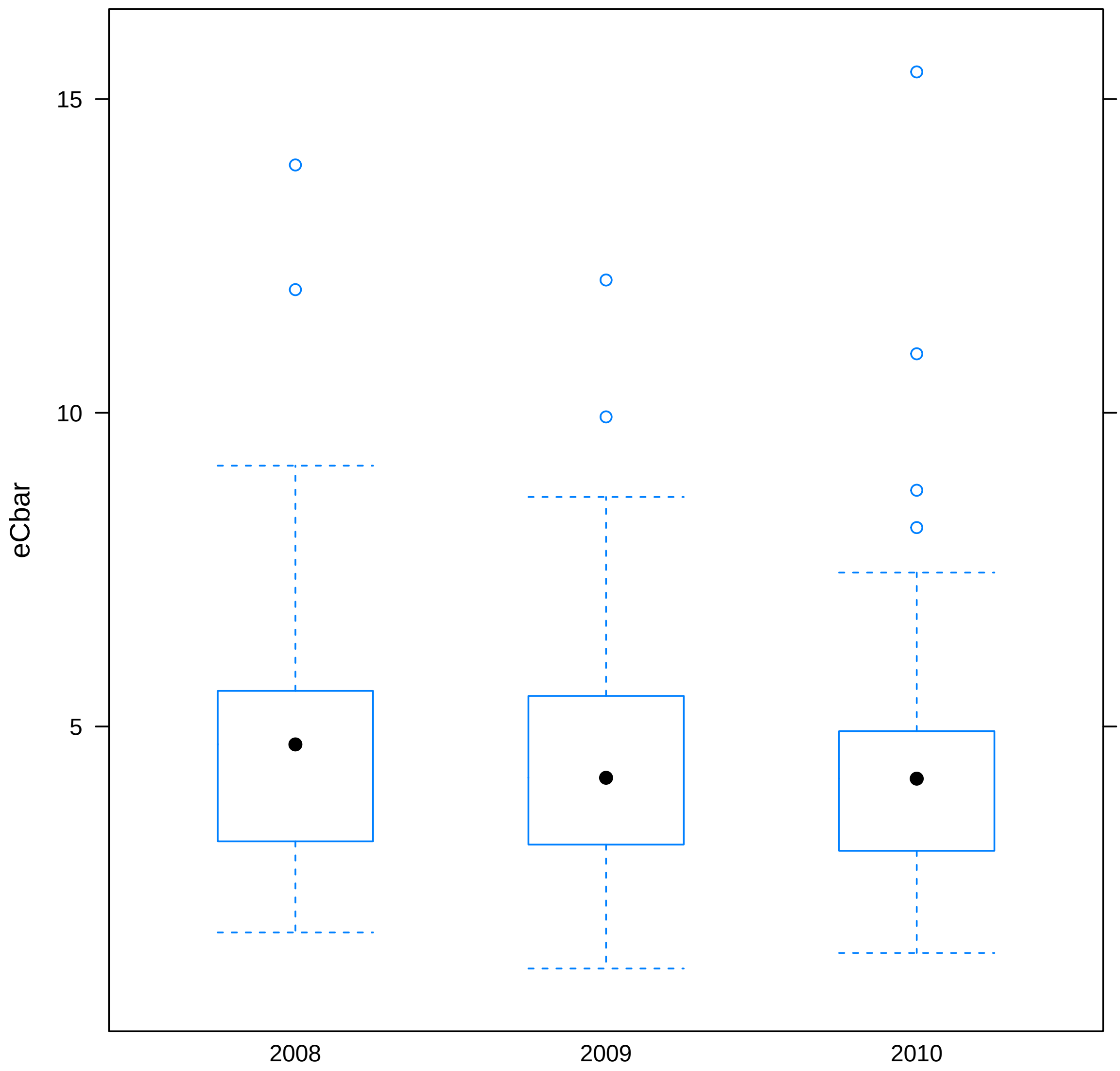


Figure 28: by year

```
table(eC.df$ms)

##
## BEL DEU DNK FRA GBR NLD
##  14  18  29  18  63  20

tapply(eC.df$eCbar, eC.df$ms, mean, na.rm = T)

##   BEL   DEU   DNK   FRA   GBR   NLD
## 7.074 4.083 3.790 4.768 4.106 5.403
```

```r
bwplot(eCbar ~ ms, data = eC.df)
```

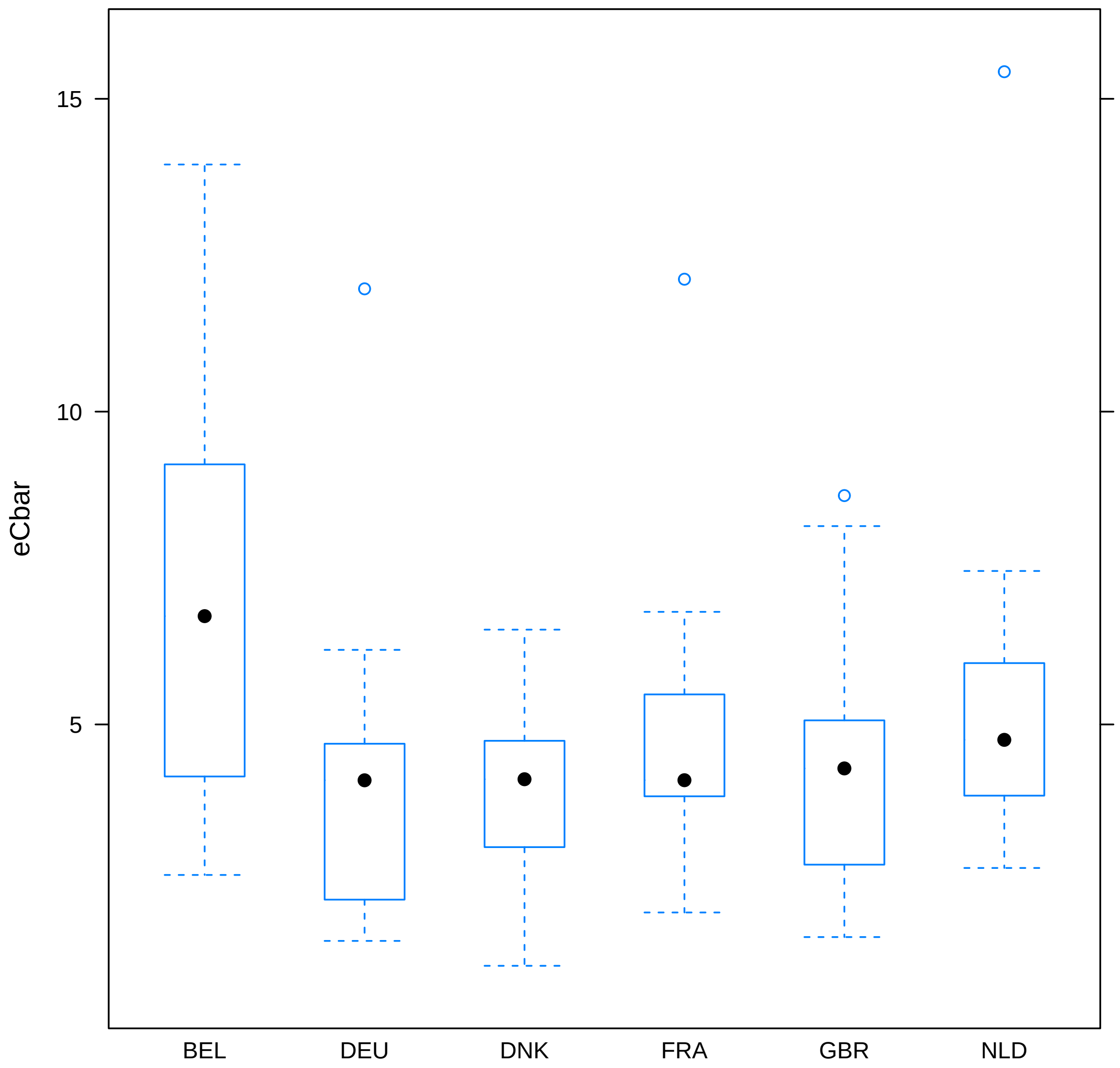


Figure 29: by member state

```r
table(eC.df$gr)

##
## DFN DTS FPO HOK PGP TBB
##  20  69   9   9  10  45

tapply(eC.df$eCbar, eC.df$gr, mean, na.rm = T)

##   DFN   DTS   FPO   HOK   PGP   TBB
## 3.605 4.619 3.187 4.395 4.104 5.221
```

```r
bwplot(eCbar ~ gr, data = eC.df)
```

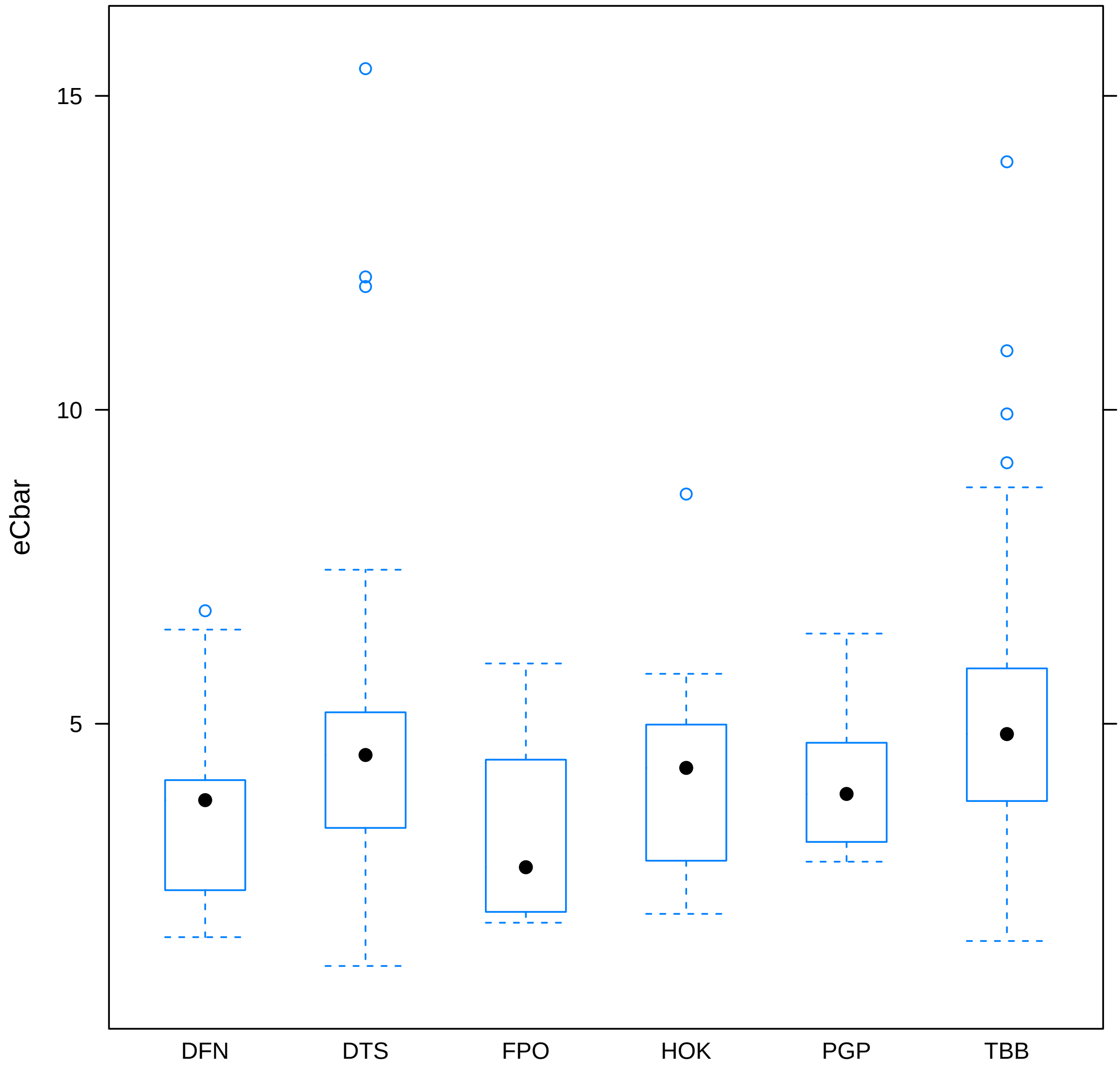


Figure 30: by gear

7.2.1 GLM

```r
# GLM for metier components
eC.df <- eC.df[rownames(eC.df) != "225", ]
eC.glm <- glm(eCbar ~ (loa + gr + ms + y)^2, family = Gamma("log"), data = eC.df)
anova(eC.glm, test = "F")

## Analysis of Deviance Table
##
## Model: Gamma, link: log
##
## Response: eCbar
```

```
##
## Terms added sequentially (first to last)
##
##
##         Df Deviance Resid. Df Resid. Dev     F  Pr(>F)
## NULL                      160       32.4
## loa      5     4.39       155       28.0 24.88 1.1e-14 ***
## gr       5     1.43       150       26.5  8.09 3.8e-06 ***
## ms       5     3.40       145       23.1 19.30 2.7e-12 ***
## y        2     0.28       143       22.9  3.92 0.02398 *
## loa:gr  15     5.84       128       17.0 11.04 1.7e-13 ***
## loa:ms  18     8.66       110        8.4 13.64 < 2e-16 ***
## loa:y   10     1.34       100        7.0  3.80 0.00035 ***
## gr:ms    6     2.54        94        4.5 12.01 2.1e-09 ***
## gr:y    10     1.19        84        3.3  3.38 0.00111 **
## ms:y     9     0.59        75        2.7  1.85 0.07387 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
par(mfrow = c(2, 2))
plot(eC.glm)
```

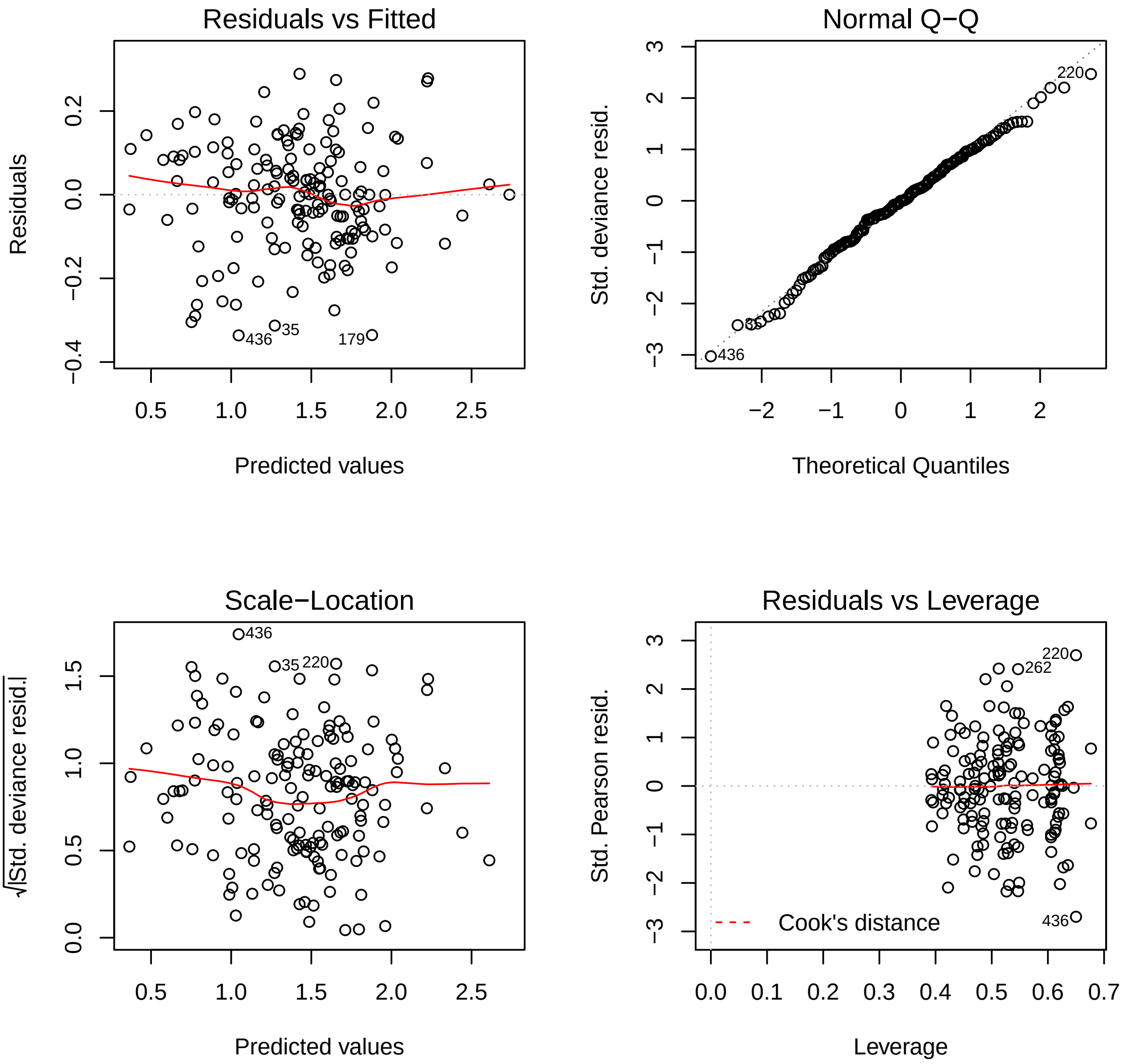


Figure 31: GLM diagnostics

```
xyplot(residuals(eC.glm) ~ predict(eC.glm) | eC.df$y, type = c("smooth", "p"),
    layout = c(3, 1), ylab = "", xlab = "")
```

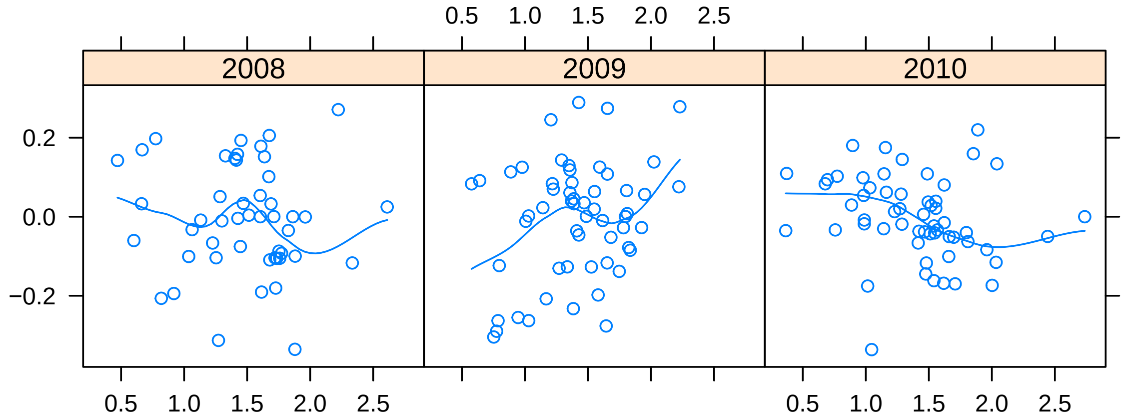


Figure 32: GLM residuals VS predicted by year

```r
xyplot(residuals(eC.glm) ~ predict(eC.glm) | eC.df$ms, type = c("smooth", "p"),
    ylab = "", xlab = "")
```

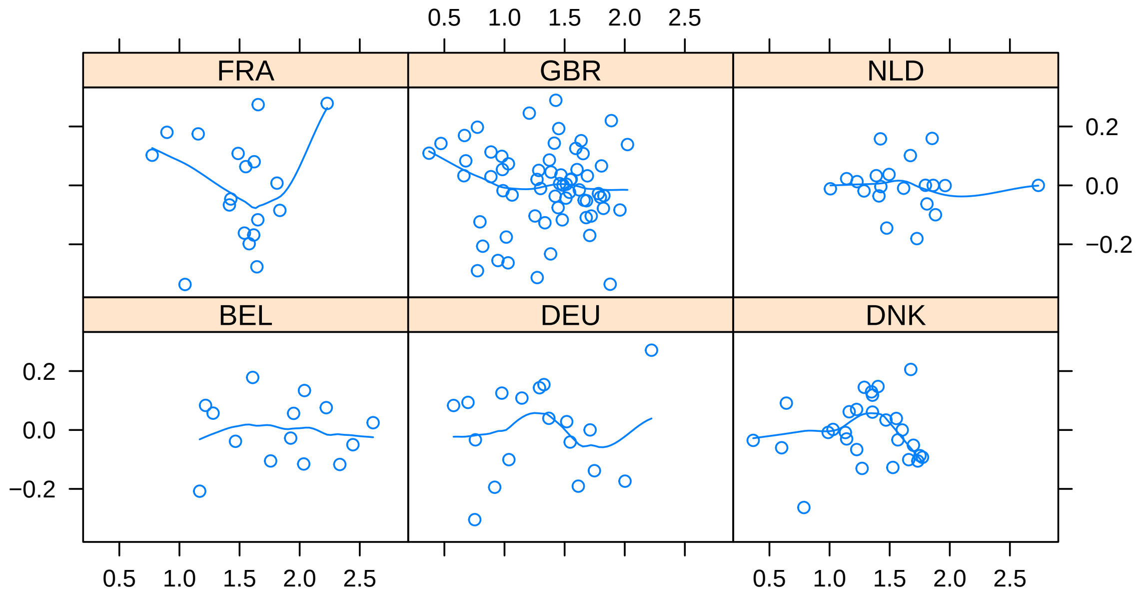


Figure 33: GLM residuals VS predicted by MS

```r
xyplot(residuals(eC.glm) ~ predict(eC.glm) | eC.df$gr, type = c("smooth", "p"),
    ylab = "", xlab = "")
```

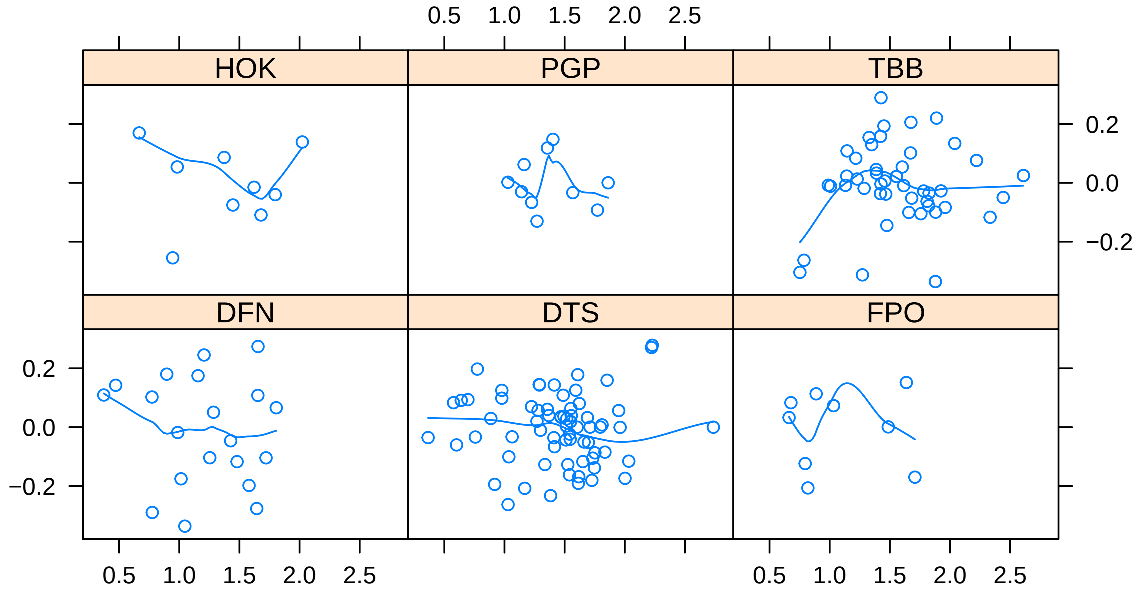


Figure 34: GLM residuals VS predicted by gear

```
xyplot(residuals(eC.glm) ~ predict(eC.glm) | eC.df$loa, type = c("smooth", "p"),
    ylab = "", xlab = "")
```

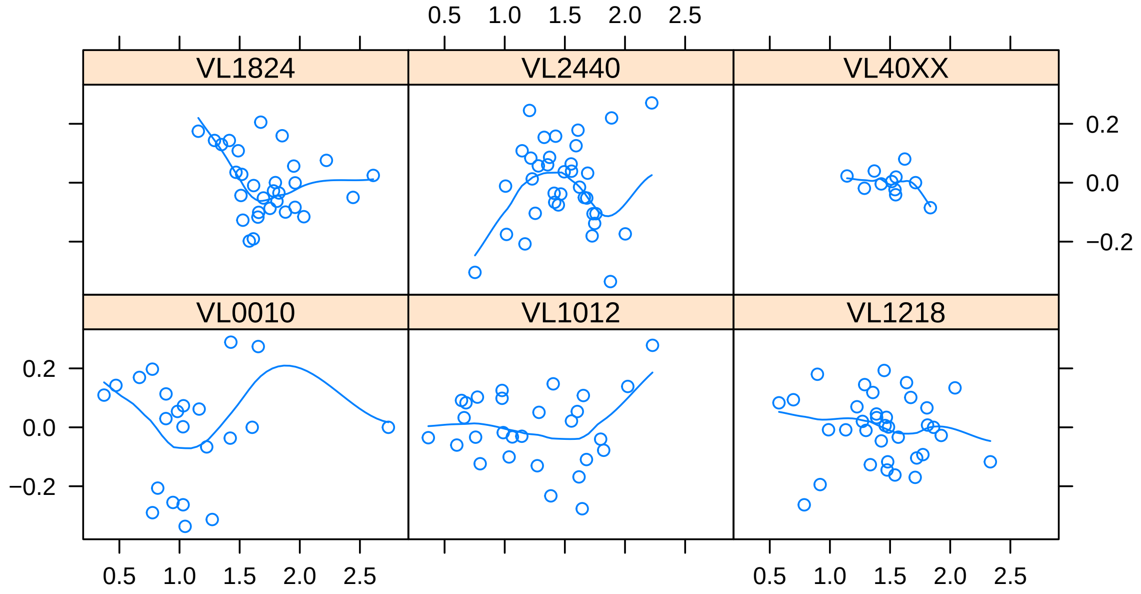


Figure 35: GLM residuals VS predicted by vessel length category

7.2.2 Predictions

```r
eCnew.df <- do.call("rbind", strsplit(unique(with(wg2eco, paste(country_code,
    gear_code, vessel_length_code, sep = ":"))), ":"))
eCnew.df <- data.frame(eCnew.df, factor(rep(yrs, rep(nrow(eCnew.df), 3))))
names(eCnew.df) <- c("ms", "gr", "loa", "y")
eCnew.df <- eCnew.df[eCnew.df$loa != "NA" & eCnew.df$loa != "VL24XX" & eCnew.df$ms !=
    "NOR", ]
eCnew.df <- transform(eCnew.df, metier = paste(ms, gr, loa, sep = ":"))
eCnew.df$eCpred <- predict(eC.glm, newdata = eCnew.df, type = "response")
```

```r
dotplot(reorder(metier, eCpred) ~ eCpred | y, type = c("p", "h"), layout = c(3,
    1), data = eCnew.df, xlab = "cost (euro/kwday)")
```

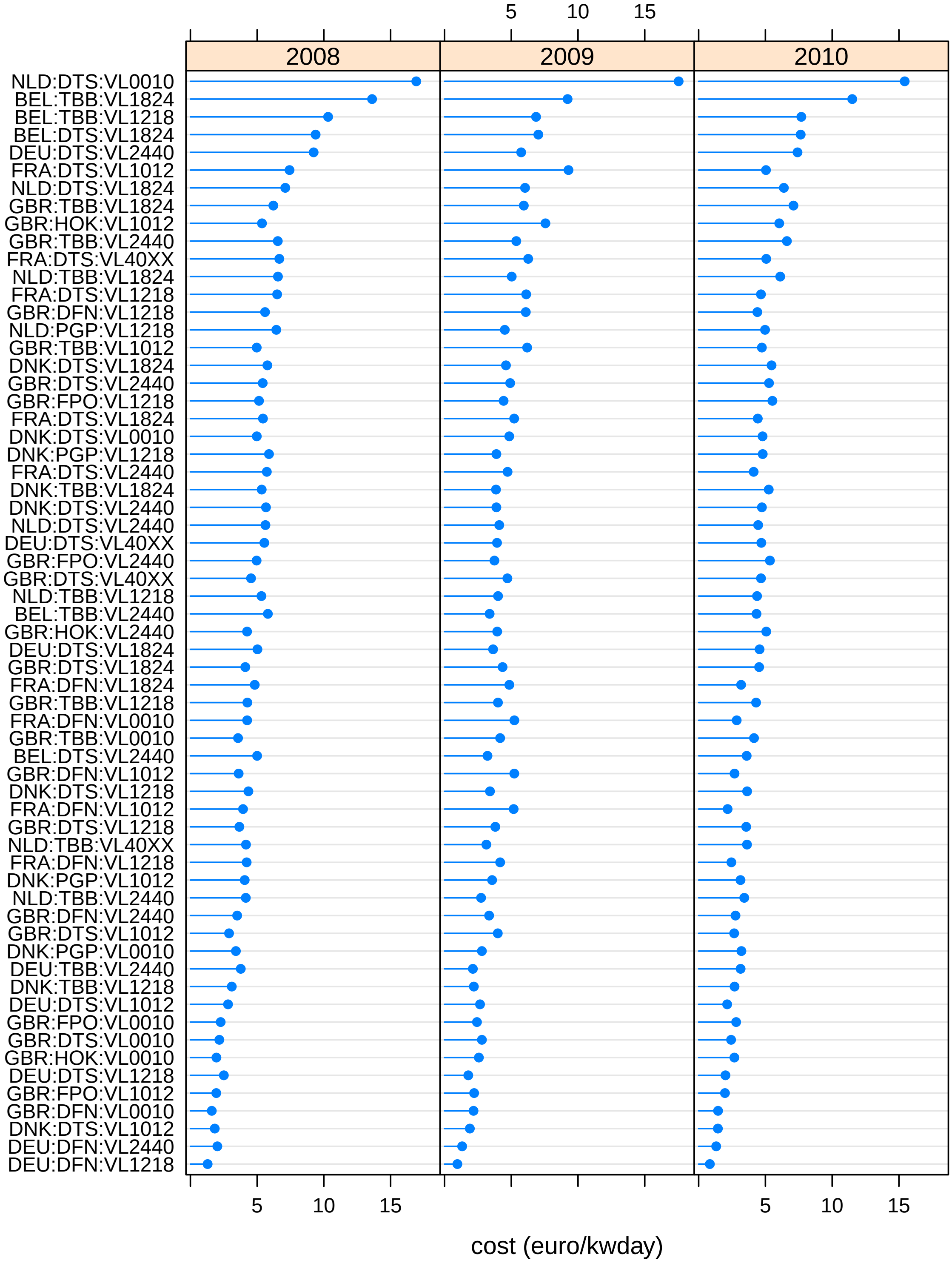


Figure 36: Estimates of effort related costs by effort unit for all metiers

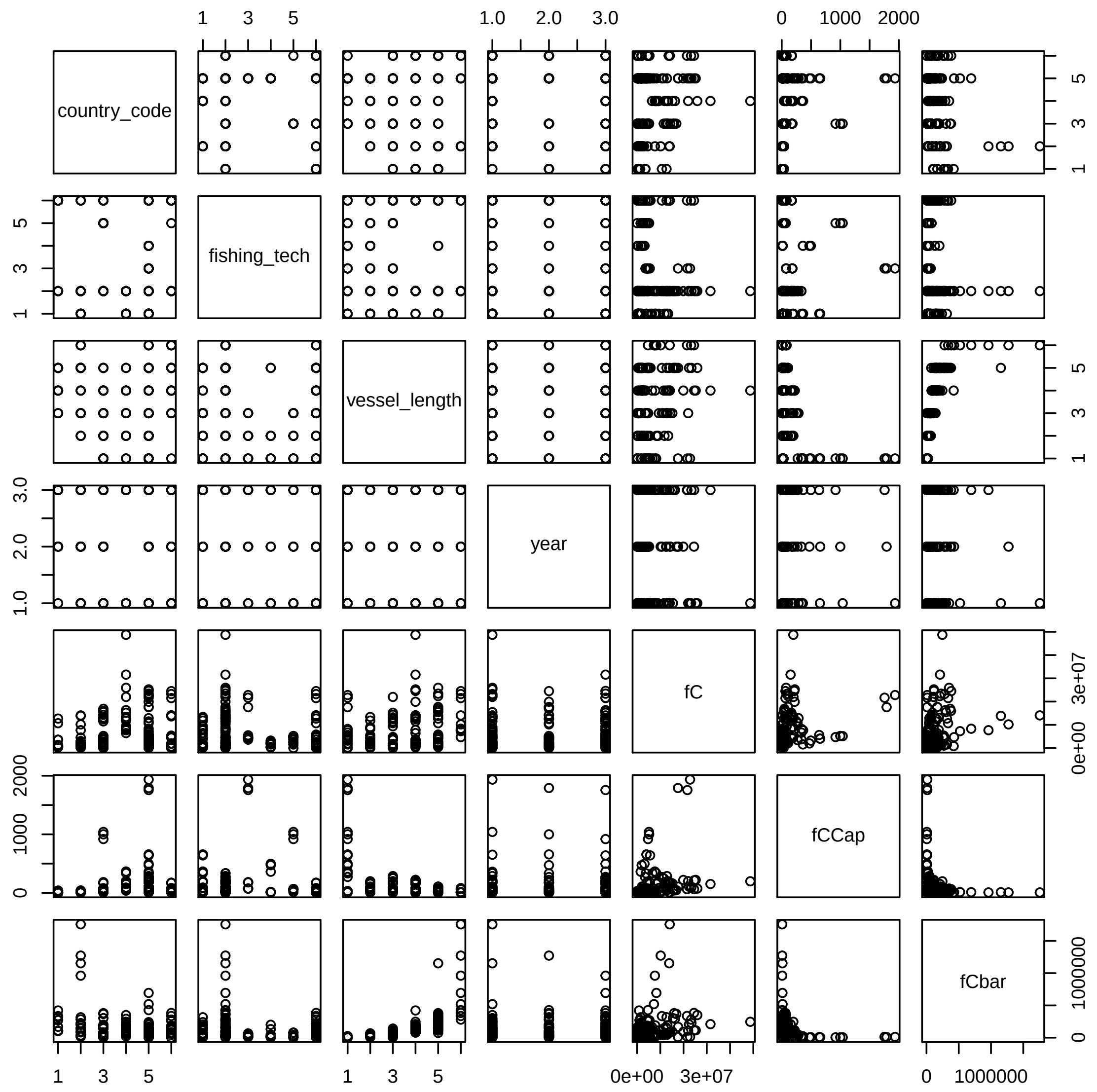
7.3 Fixed costs by vessel

The information from the AER was aggregated at the region level (Area 27), Member State, fleet segment, fishing gear, vessel length and year.

Fixed costs by vessel were computed by year as $fC = (nvC + dC + OPR).cap^{-1}$, while for years without information a weighted average between 2008 and 2010 was used, $\bar{fC} = \sum_{t=2008}^{2010} (nvC + dC + OPR)_t.(\sum_{t=2008}^{2010} (cap)_t)^{-1}$, where fC is *fixed costs*, OPR is *opportunity costs of capital*, dC is *depreciation costs*, nvC is *other non-variable costs* and cap is *capacity* in number of vessels.

```
df0 <- subset(ecoFix, variable_code %in% c("totdepcost", "totnovarcost", "OPR",
    "totves") & year %in% yrs)
df0 <- transform(df0, id = paste(country_code, fishing_tech, vessel_length,
    year, sep = ":"))
# remove cases that don't have all the information required
errvec <- unique(subset(df0, value <= 0)$id)
df0 <- subset(df0, !(id %in% errvec))

# compute fixed costs
df1 <- subset(df0, variable_code != "totves")
fC <- tapply(df1$value, df1[, c("country_code", "fishing_tech", "vessel_length",
    "year")], sum, na.rm = T)

# compute associated capacity
df1 <- subset(df0, variable_code == "totves")
fCCap <- tapply(df1$value, df1[, c("country_code", "fishing_tech", "vessel_length",
    "year")], sum, na.rm = T)

# check all levels of factors match
all.equal(dimnames(fC), dimnames(fCCap))

## [1] TRUE


# compute fixed costs by unit capacity
fCbar <- fC/fCCap
```

```
# build data.frame for glm and rename factors to make it easier ...
fC.df <- data.frame(expand.grid(dimnames(fC)), fC = c(fC), fCCap = c(fCCap),
    fCbar = c(fCbar))
fC.df <- subset(fC.df, !is.na(fCbar))
fC.df <- subset(fC.df, fCbar > 0)
pairs(fC.df)
```




```
names(fC.df)[1:4] <- c("ms", "gr", "loa", "y")
fC.df <- transform(fC.df, metier = paste(ms, gr, loa, sep = ":"))
```

```
# summaries
table(fC.df$loa)
```

```
##
## VL0010 VL1012 VL1218 VL1824 VL2440 VL40XX
##     23     28     37     29     36      9
```

```
tapply(fC.df$fCbar, fC.df$loa, mean, na.rm = T)
```

```
## VL0010 VL1012 VL1218 VL1824 VL2440 VL40XX
##   9239  30071  60053 148331 245987 736565
```

```
bwplot(fCbar ~ loa, data = fC.df)
```

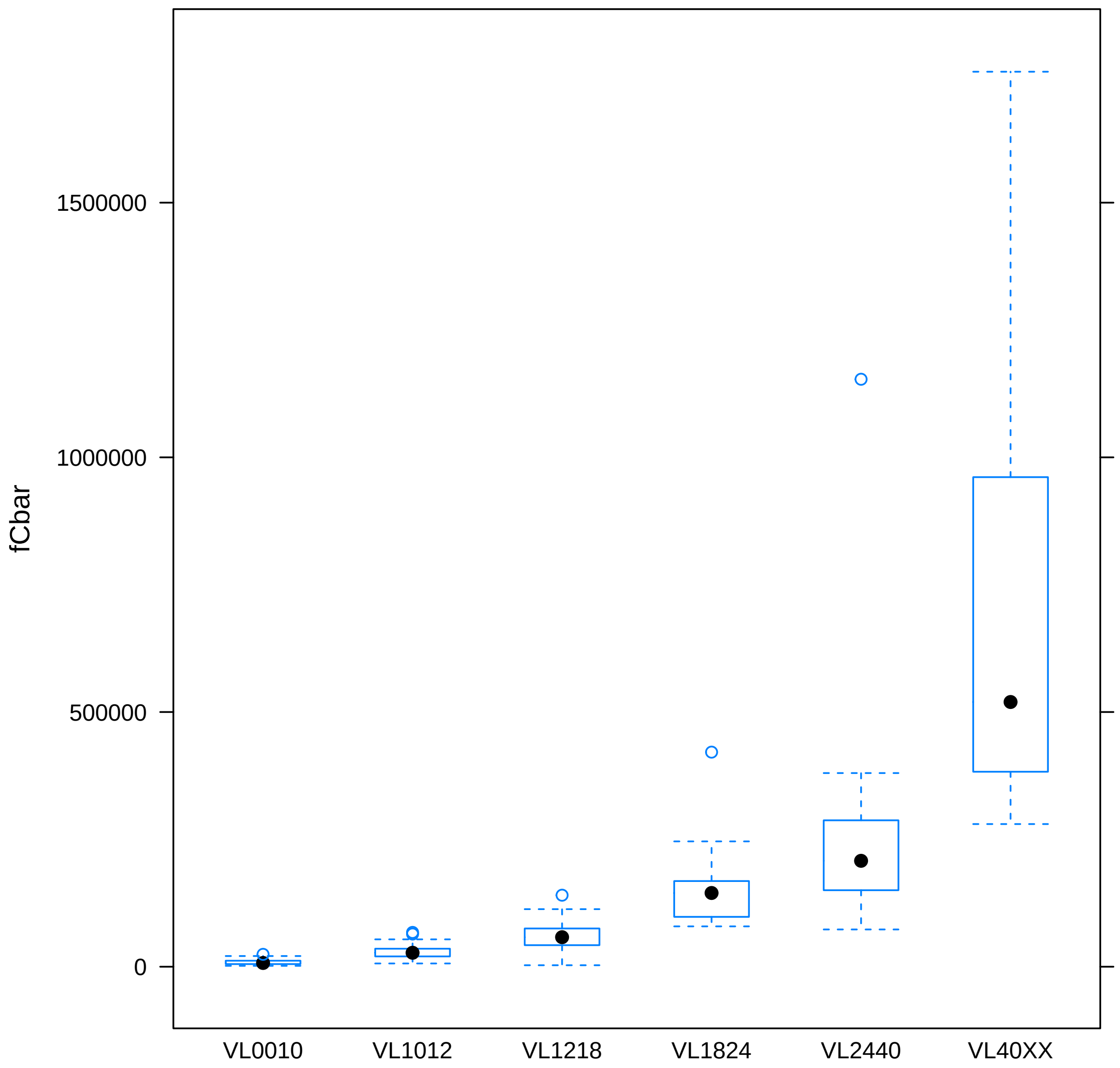


Figure 37: by fleet

```
table(fC.df$y)

##
## 2008 2009 2010
##   55   49   58

tapply(fC.df$fCbar, fC.df$y, mean, na.rm = T)

##   2008   2009   2010
## 153115 132170 140775
```

```r
bwplot(fCbar ~ y, data = fC.df)
```

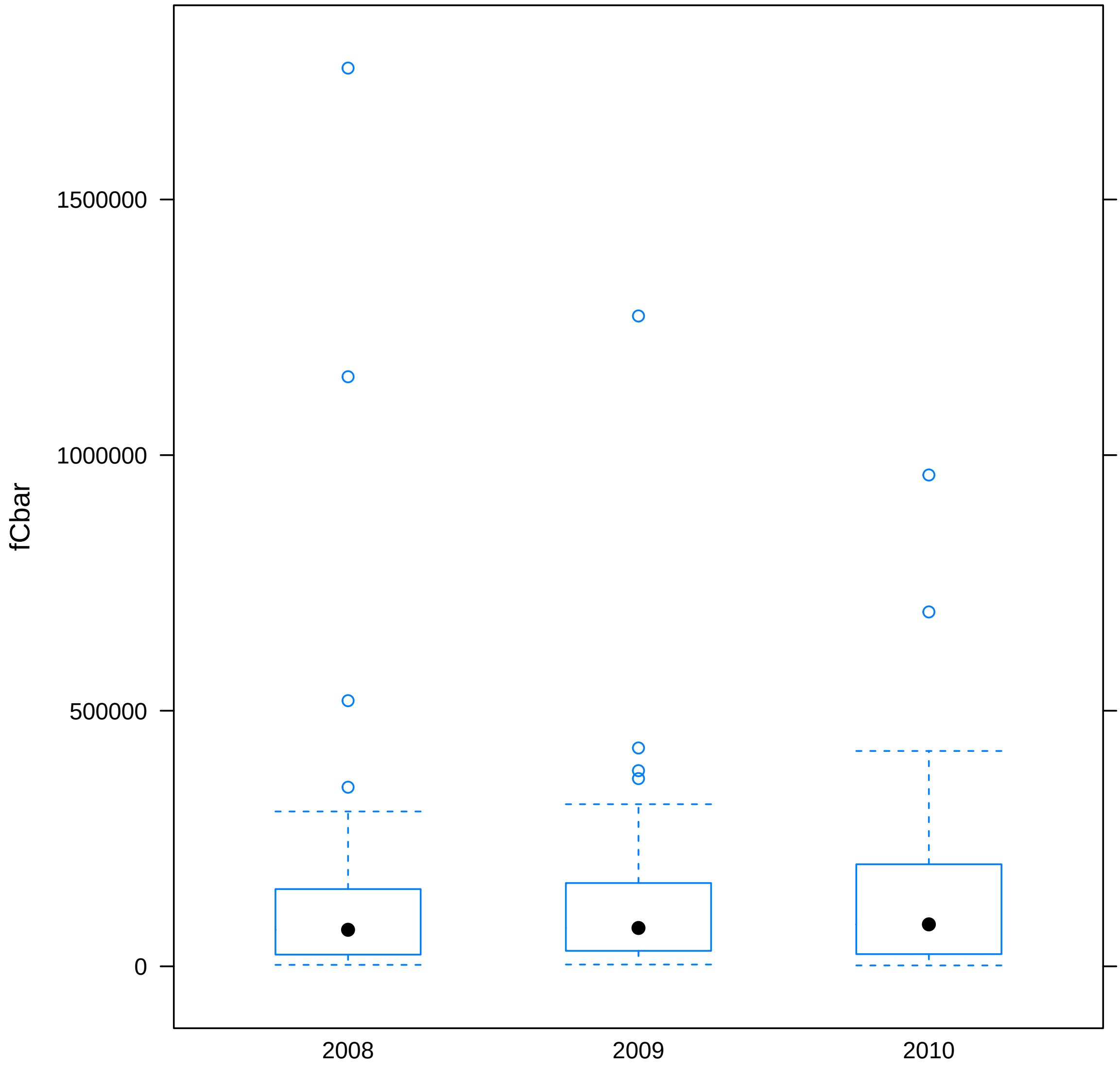


Figure 38: by year

```r
table(fC.df$ms)

##
## BEL DEU DNK FRA GBR NLD
##  11  24  29  16  62  20

tapply(fC.df$fCbar, fC.df$ms, mean, na.rm = T)

##    BEL    DEU    DNK    FRA    GBR    NLD
## 210503 303686  99120 136765  86612 151300
```

```r
bwplot(fCbar ~ ms, data = fC.df)
```

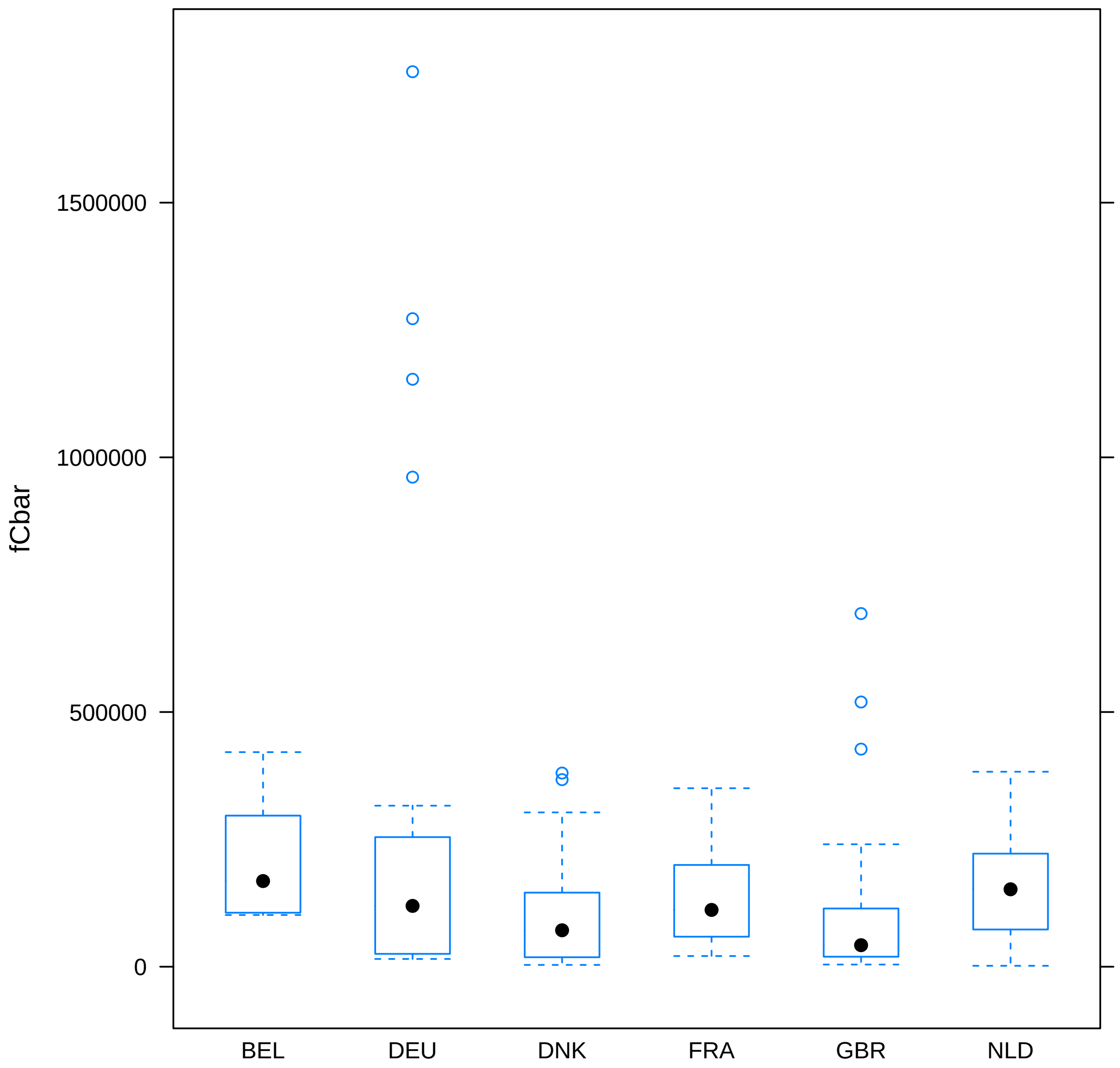


Figure 39: by member state

```r
table(fC.df$gr)

##
## DFN DTS FPO HOK PGP TBB
##  26  67   9   8  10  42

tapply(fC.df$fCbar, fC.df$gr, mean, na.rm = T)

##    DFN    DTS    FPO    HOK    PGP    TBB
##  88318 215931  31924  55804  34906 124196
```

```r
bwplot(fCbar ~ gr, data = fC.df)
```

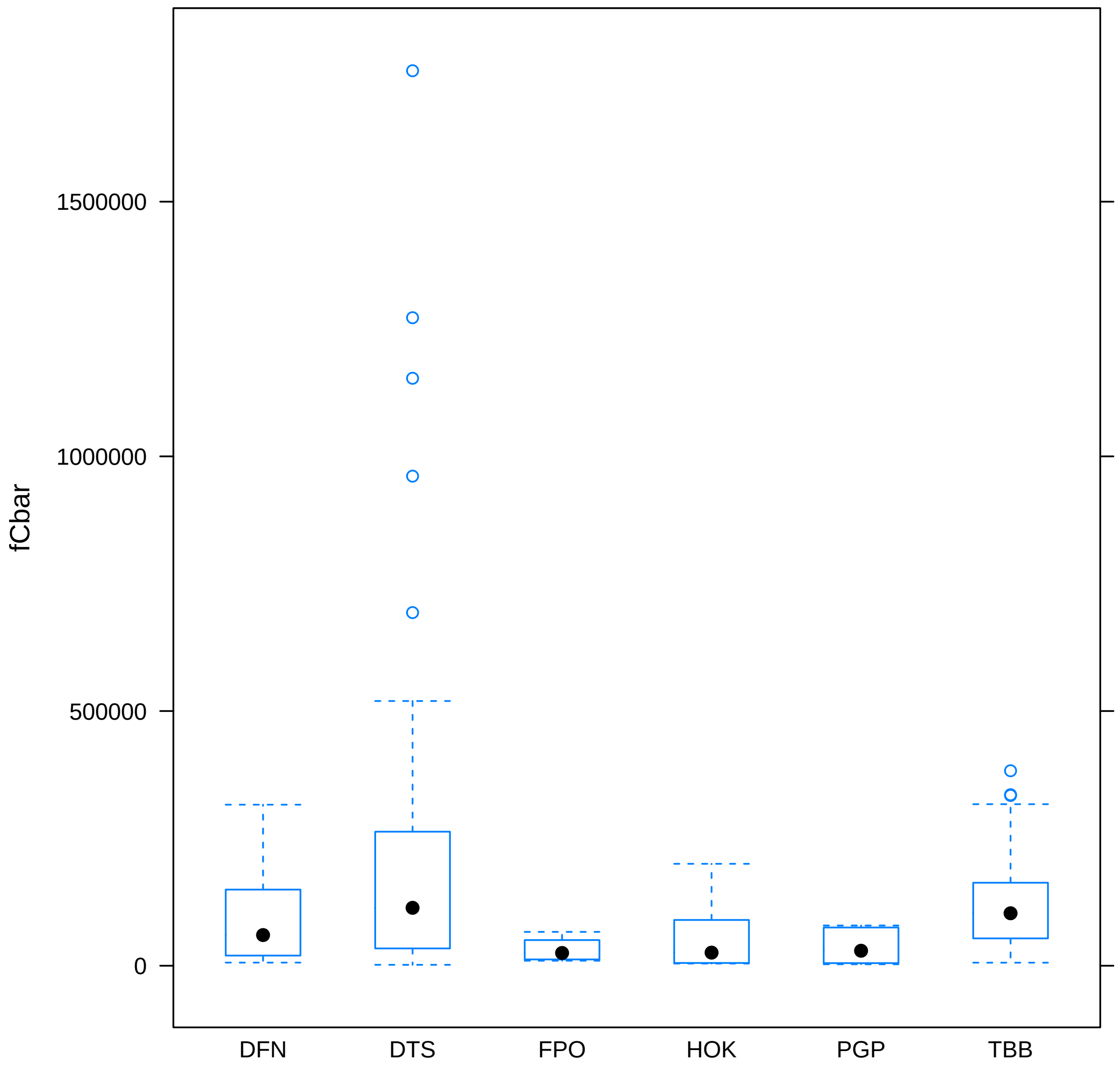


Figure 40: by gear

7.3.1 GLM

```r
# GLM for metier components
fC.glm <- glm(fCbar ~ (loa + gr + ms + y)^2, family = Gamma("log"), data = fC.df)
anova(fC.glm, test = "F")

## Analysis of Deviance Table
##
## Model: Gamma, link: log
##
## Response: fCbar
##
```

```
## Terms added sequentially (first to last)
##
##
##         Df Deviance Resid. Df Resid. Dev      F  Pr(>F)
## NULL                      161      251.0
## loa      5    205.4       156       45.6 521.82 < 2e-16 ***
## gr       5      2.8       151       42.8   7.18 1.5e-05 ***
## ms       5     10.1       146       32.7  25.56 5.0e-15 ***
## y        2      0.1       144       32.6   0.56   0.575
## loa:gr  15      5.7       129       27.0   4.81 2.0e-06 ***
## loa:ms  17     11.6       112       15.3   8.68 8.4e-12 ***
## loa:y   10      1.8       102       13.6   2.22   0.025 *
## gr:ms    7      4.9        95        8.6   8.96 5.3e-08 ***
## gr:y    10      0.7        85        7.9   0.94   0.503
## ms:y     9      1.8        76        6.1   2.50   0.015 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

# year is not significant
fC.glm <- glm(fCbar ~ (loa + gr + ms)^2, family = Gamma("log"), data = fC.df)
anova(fC.glm, test = "F")

## Analysis of Deviance Table
##
## Model: Gamma, link: log
##
## Response: fCbar
##
## Terms added sequentially (first to last)
##
##
##         Df Deviance Resid. Df Resid. Dev      F  Pr(>F)
## NULL                      161      251.0
## loa      5    205.4       156       45.6 426.20 < 2e-16 ***
## gr       5      2.8       151       42.8   5.86 7.9e-05 ***
## ms       5     10.1       146       32.7  20.87 1.7e-14 ***
## loa:gr  15      5.7       131       27.0   3.95 1.3e-05 ***
## loa:ms  17     11.6       114       15.4   7.10 3.2e-11 ***
## gr:ms    7      5.1       107       10.3   7.49 2.5e-07 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
par(mfrow = c(2, 2))
plot(fC.glm)
```

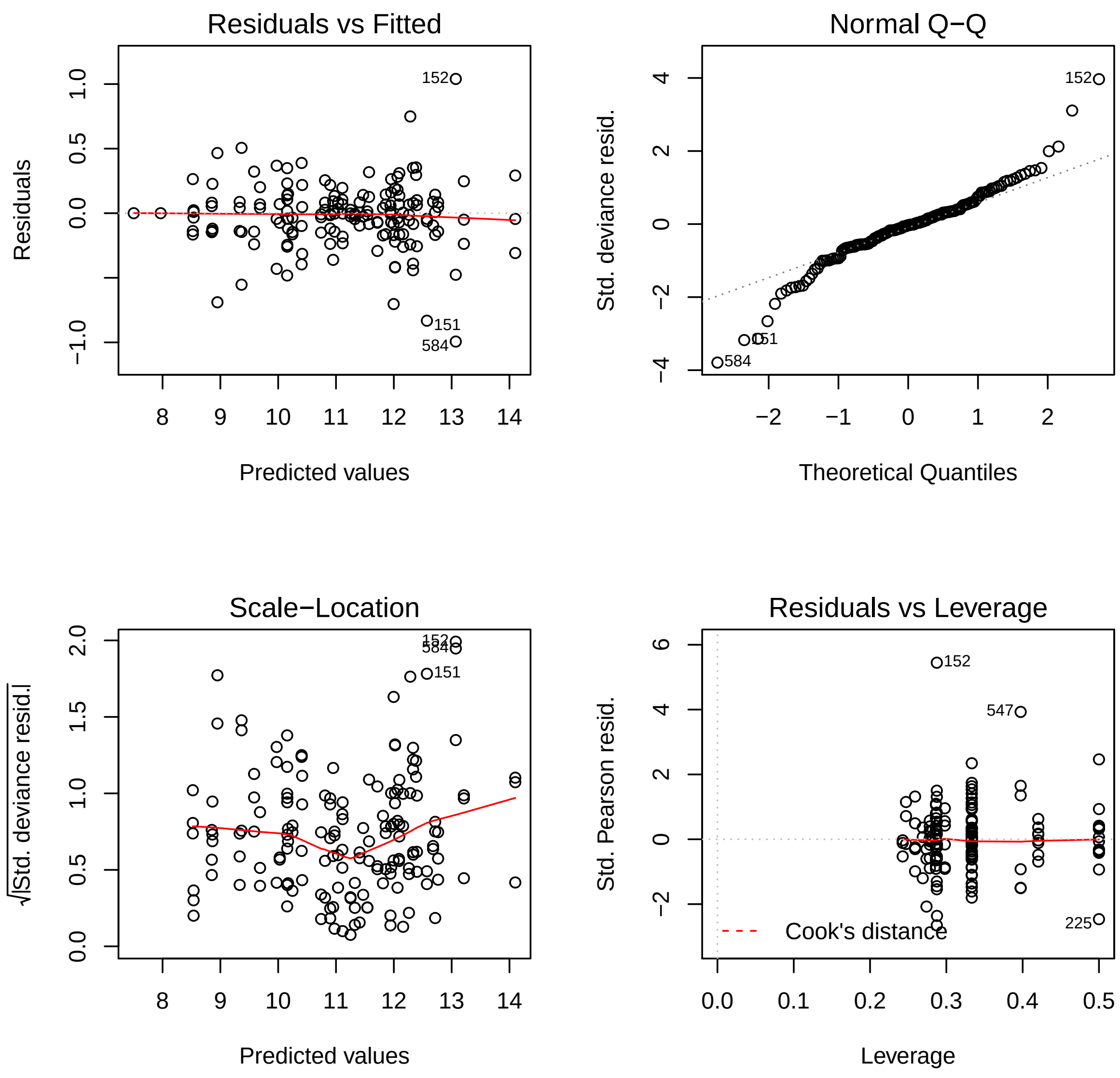


Figure 41: GLM diagnostics

```
xyplot(residuals(fC.glm) ~ predict(fC.glm) | fC.df$ms, type = c("smooth", "p"),
    ylab = "", xlab = "")
```

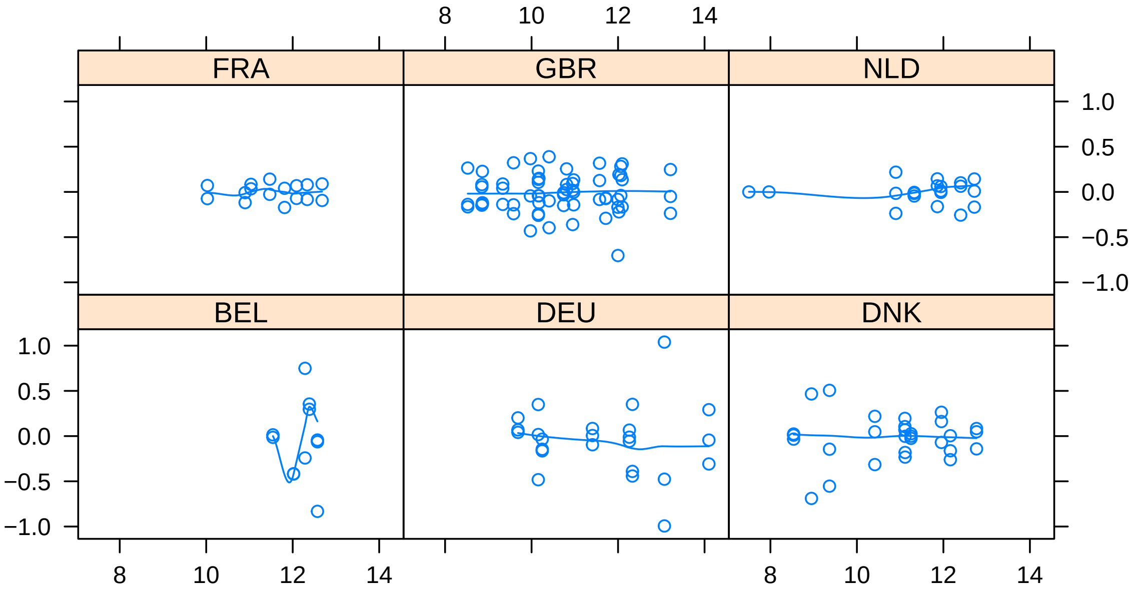


Figure 42: GLM residuals VS predicted by MS

```r
xyplot(residuals(fC.glm) ~ predict(fC.glm) | fC.df$gr, type = c("smooth", "p"),
    ylab = "", xlab = "")
```

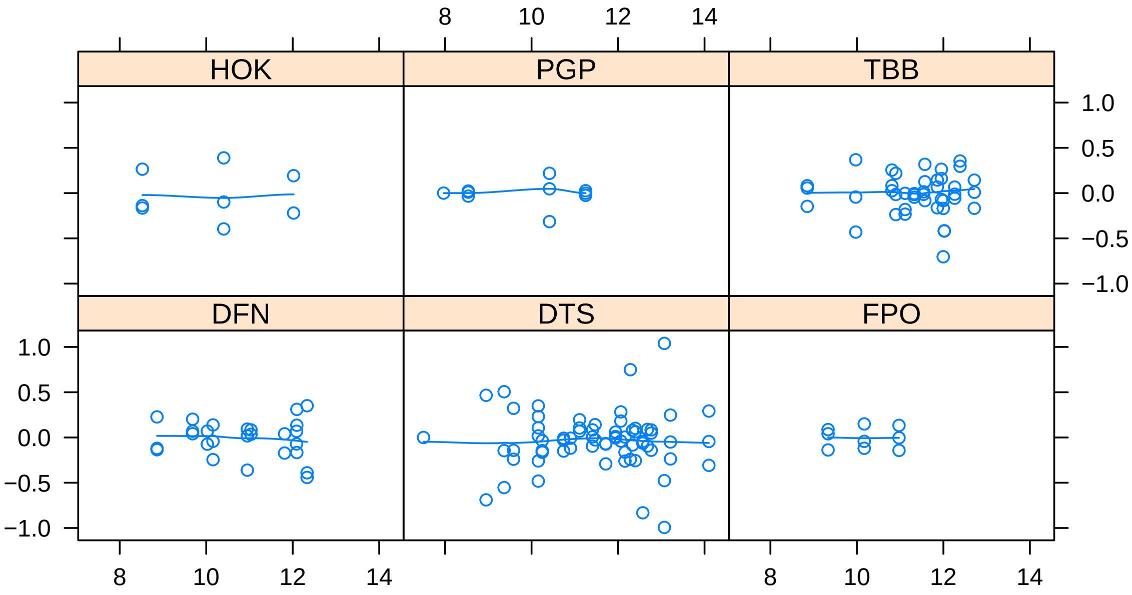


Figure 43: GLM residuals VS predicted by gear

```r
xyplot(residuals(fC.glm) ~ predict(fC.glm) | fC.df$loa, type = c("smooth", "p"),
    ylab = "", xlab = "")
```

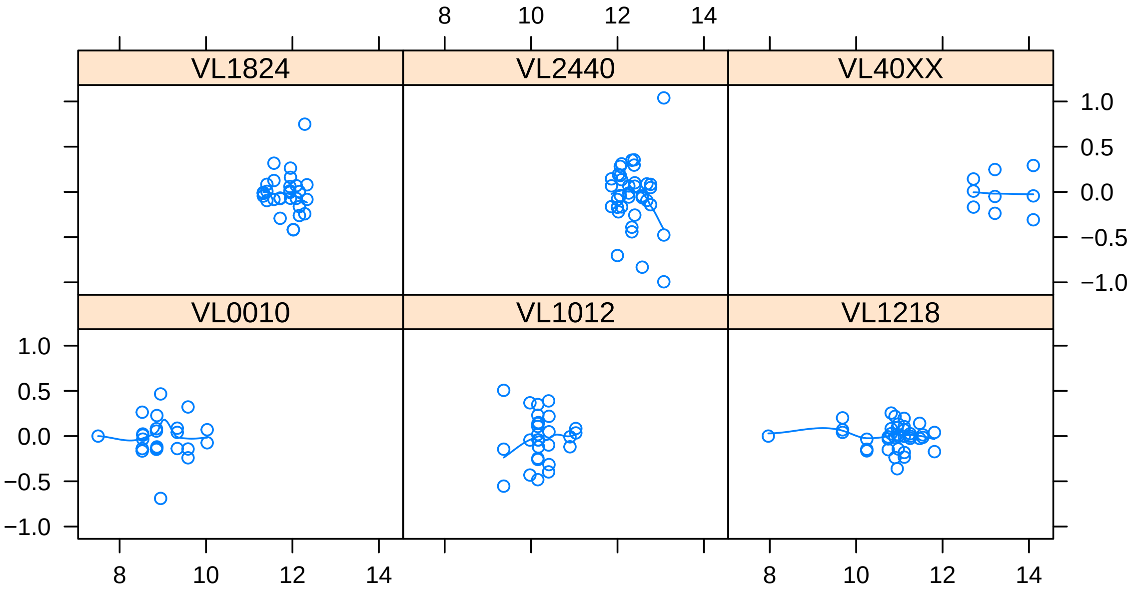


Figure 44: GLM residuals VS predicted by vessel length category

7.3.2 Predictions

```
fCnew.df <- do.call("rbind", strsplit(unique(with(wg2eco, paste(country_code,
    gear_code, vessel_length_code, sep = ":"))), ":"))
fCnew.df <- data.frame(fCnew.df)
names(fCnew.df) <- c("ms", "gr", "loa")
fCnew.df <- fCnew.df[fCnew.df$loa != "NA" & fCnew.df$loa != "VL24XX" & fCnew.df$ms !=
    "NOR", ]
fCnew.df <- transform(fCnew.df, metier = paste(ms, gr, loa, sep = ":"))
fCnew.df$fCpred <- predict(fC.glm, newdata = fCnew.df, type = "response")
```

```
dotplot(reorder(metier, fCpred) ~ fCpred, type = c("p", "h"), data = fCnew.df,
    xlab = "cost (euro/vessel)")
```

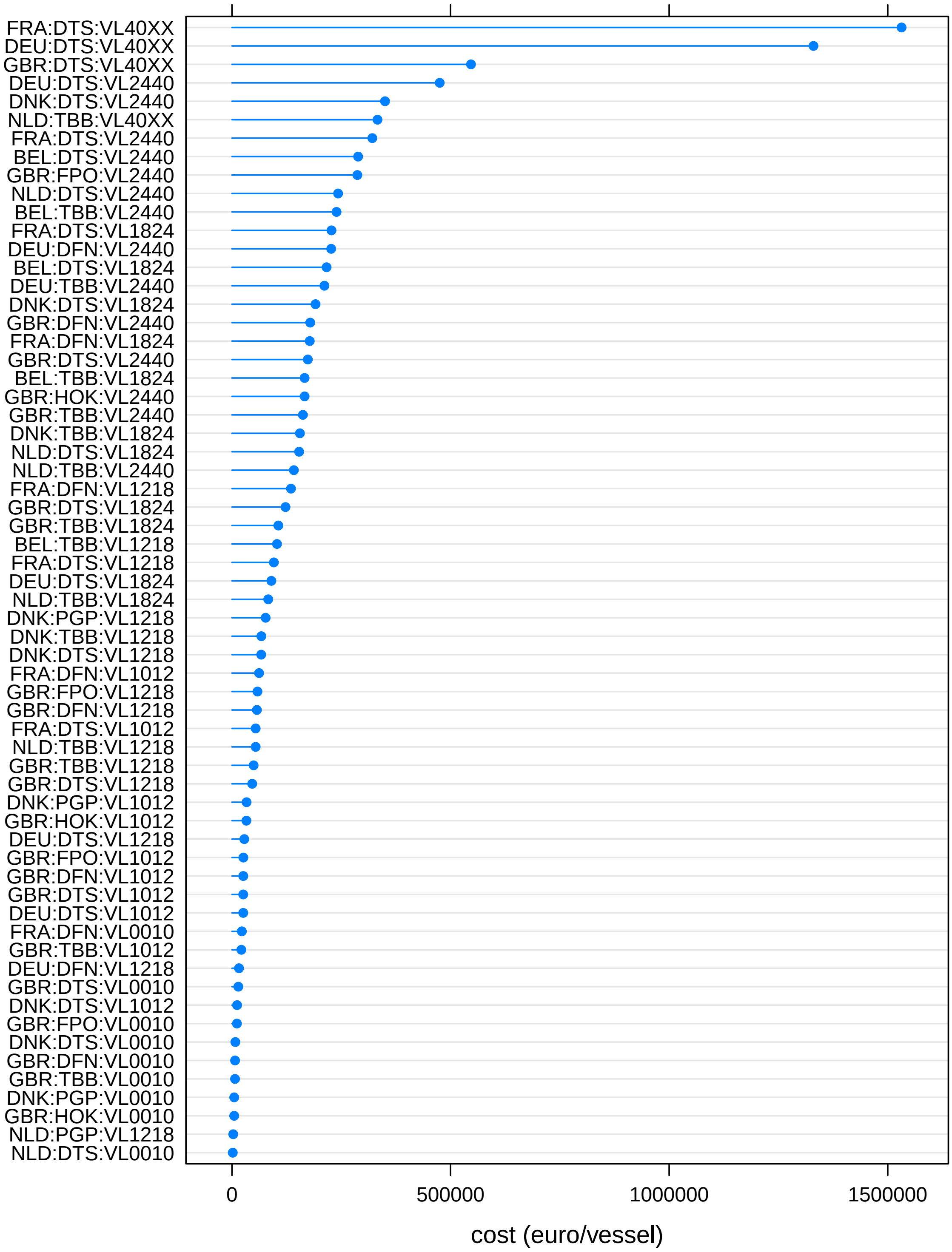


Figure 45: Estimates of fixed costs by vessel for all metiers

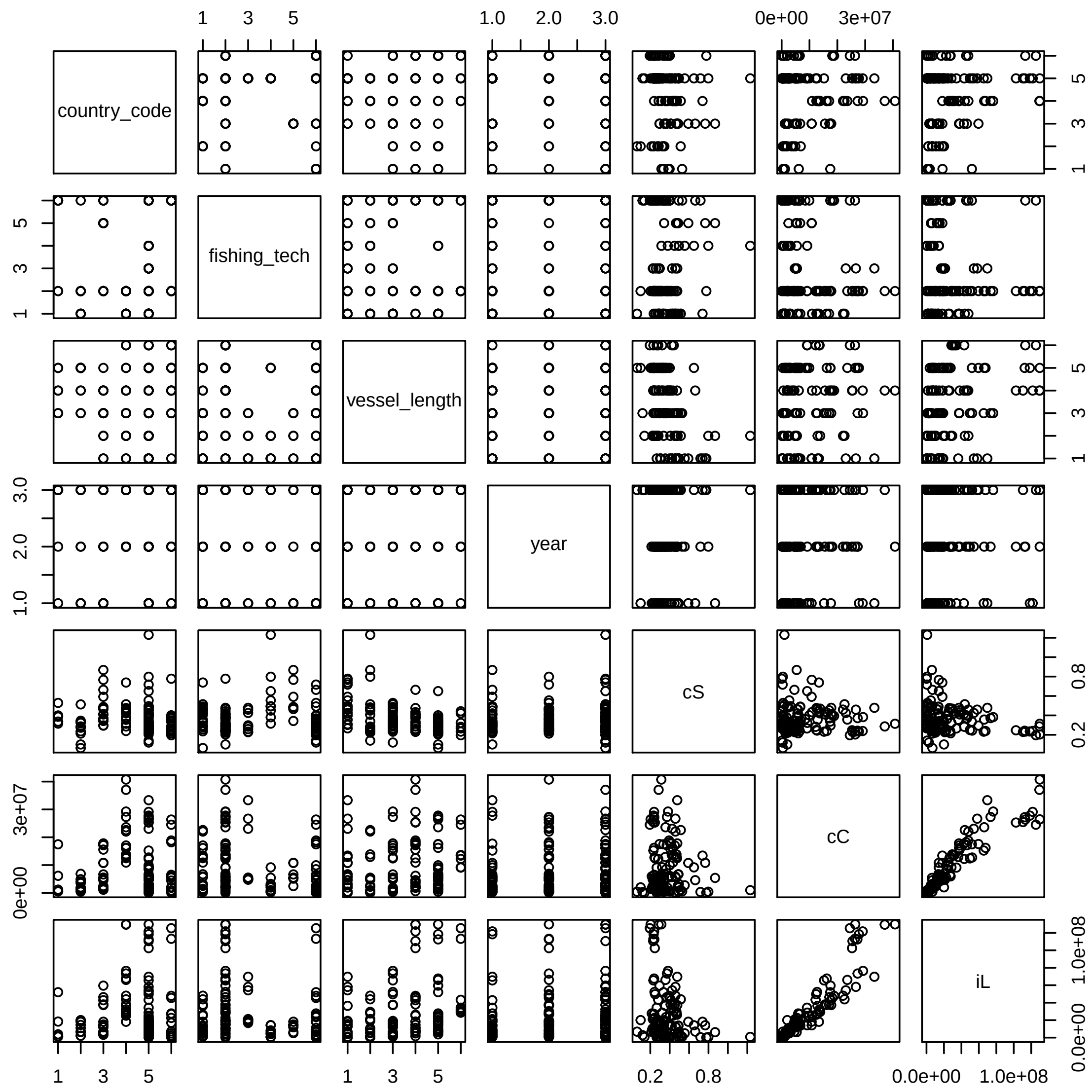
7.4 Crewshare by landing income

The information from the AER was aggregated at the region level (Area 27), Member State, fleet segment, fishing gear, vessel length and year.

Crew share by income were computed by year as $cS = (cC+uL).iL^{-1}$, while for years without information a weighted average between 2008 and 2010 was used, $\bar{cS} = \sum_{t=2008}^{2010} (cC + uL)_t.(\sum_{t=2008}^{2010} (iL)_t)^{-1}$, where cS is *crew share*, cC is *crew costs*, uL is *unpaid labour costs* and iL is *value of landings* in euros.

```
# subset
df0 <- subset(ecoFix, variable_code %in% c("totcrewwage", "totunpaidlab", "totvallandg") &
    year %in% yrs)
df0 <- transform(df0, id = paste(country_code, fishing_tech, vessel_length,
    year, sep = ":"))
# remove cases that don't have all the information required
errvec <- unique(subset(df0, variable_code %in% c("totcrewwage", "totvallandg") &
    value <= 0)$id)
df0 <- subset(df0, !(id %in% errvec))

# compute total costs
df1 <- subset(df0, variable_code != "totvallandg")
cC <- tapply(df1$value, df1[, c("country_code", "fishing_tech", "vessel_length",
    "year")], sum, na.rm = T)

# compute total income from landings
df1 <- subset(df0, variable_code == "totvallandg")
iL <- tapply(df1$value, df1[, c("country_code", "fishing_tech", "vessel_length",
    "year")], sum, na.rm = T)

# check all levels of factors match
all.equal(dimnames(cC), dimnames(iL))

## [1] TRUE


# compute fixed costs by unit capacity
cS <- cC/iL
```

```
# build data.frame for glm and rename factors to make it easier ...
cS.df <- data.frame(expand.grid(dimnames(cS)), cS = c(cS), cC = c(cC), iL = c(iL))
cS.df <- subset(cS.df, !is.na(cS))
cS.df <- subset(cS.df, cS > 0)
pairs(cS.df)
```




```
names(cS.df)[1:4] <- c("ms", "gr", "loa", "y")
cS.df <- transform(cS.df, metier = paste(ms, gr, loa, sep = ":"))
```

```
# summaries
table(cS.df$loa)
```

```
##
## VL0010 VL1012 VL1218 VL1824 VL2440 VL40XX
##     20     21     30     22     28      7
```

```
tapply(cS.df$cS, cS.df$loa, mean, na.rm = T)
```

```
## VL0010 VL1012 VL1218 VL1824 VL2440 VL40XX
## 0.4995 0.4247 0.3456 0.3458 0.2856 0.3091
```

```r
bwplot(cS ~ loa, data = cS.df)
```

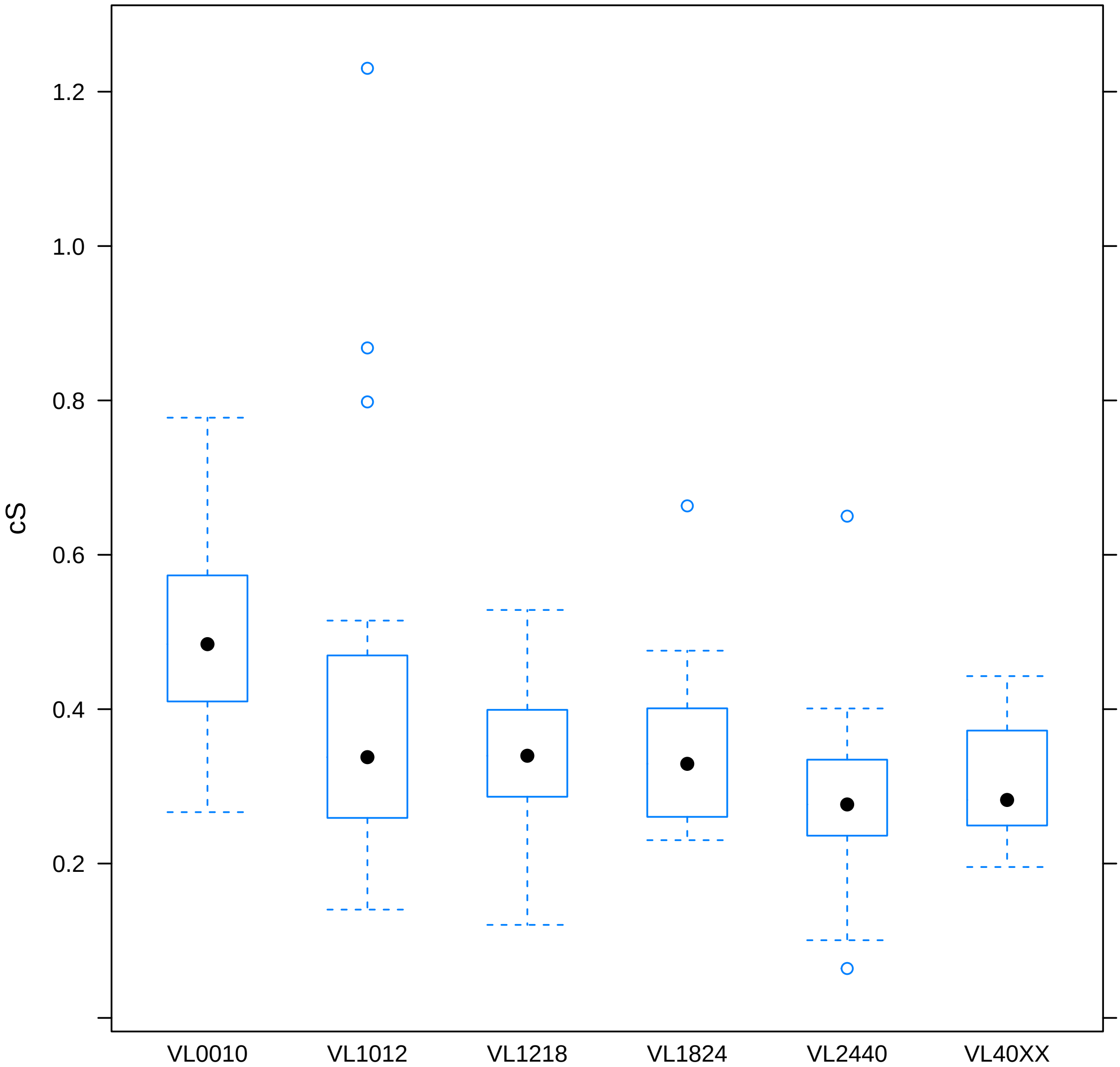


Figure 46: by fleet

```r
table(cS.df$y)

##
## 2008 2009 2010
##   34   43   51

tapply(cS.df$cS, cS.df$y, mean, na.rm = T)

##   2008   2009   2010
## 0.3534 0.3717 0.3735
```

```r
bwplot(cS ~ y, data = cS.df)
```

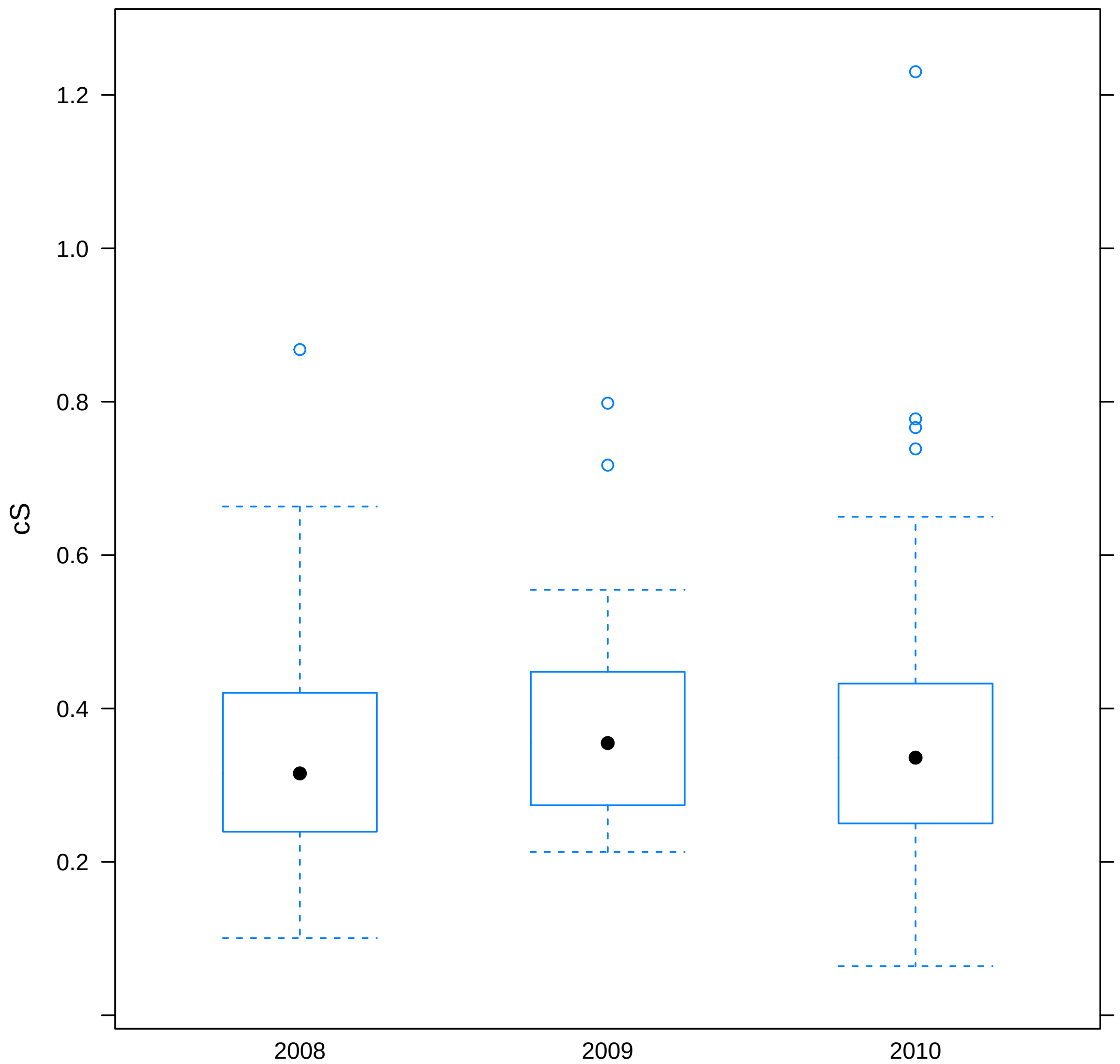


Figure 47: by year

```r
table(cS.df$ms)

##
## BEL DEU DNK FRA GBR NLD
##   6  10  16  18  63  15

tapply(cS.df$cS, cS.df$ms, mean, na.rm = T)

##    BEL    DEU    DNK    FRA    GBR    NLD
## 0.3834 0.2691 0.4778 0.4230 0.3473 0.3277
```

```
bwplot(cS ~ ms, data = cS.df)
```

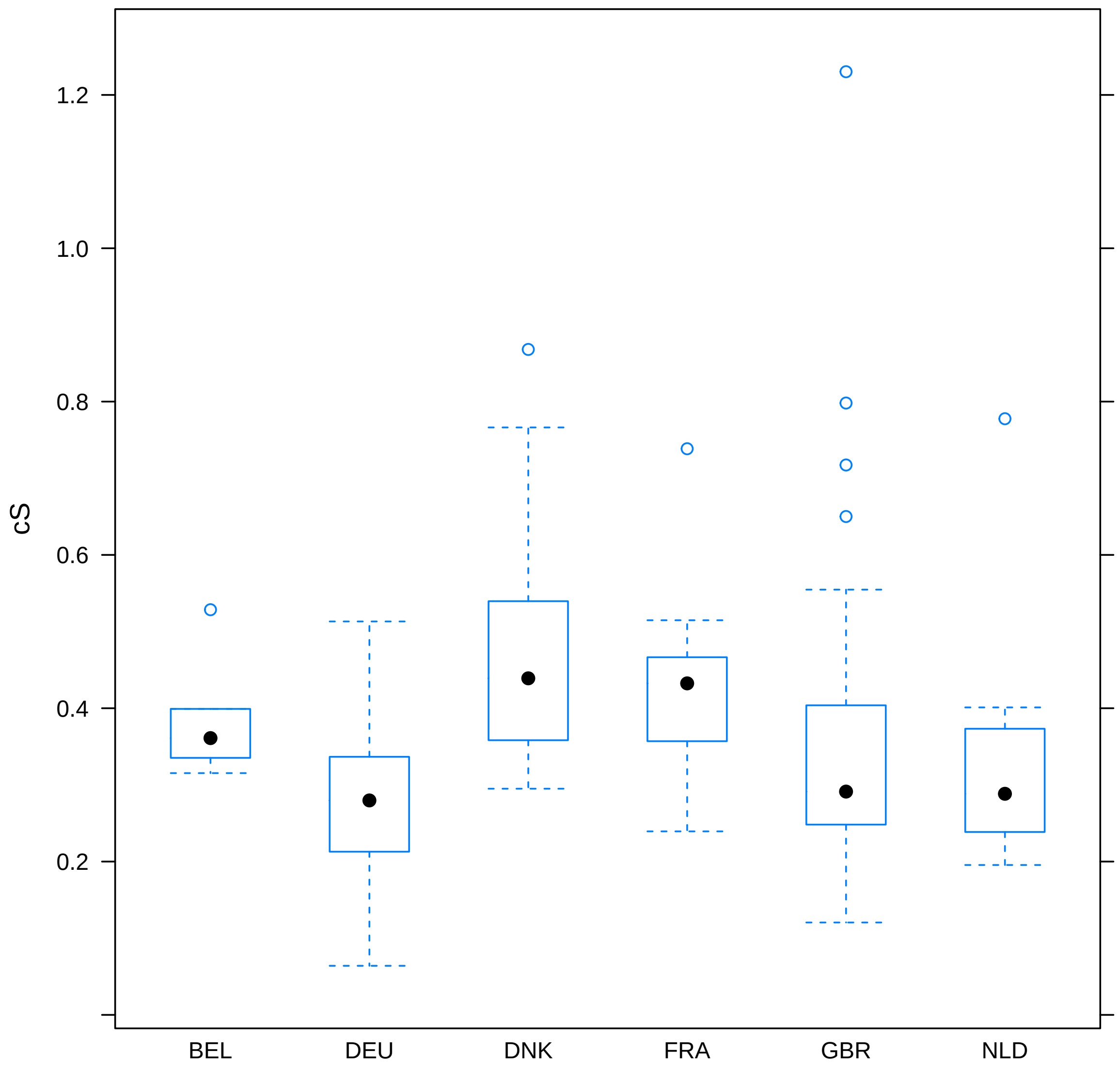


Figure 48: by member state

```
table(cS.df$gr)

##
## DFN DTS FPO HOK PGP TBB
##  24  45   9   9   7  34

tapply(cS.df$cS, cS.df$gr, mean, na.rm = T)

##    DFN    DTS    FPO    HOK    PGP    TBB
## 0.3811 0.3205 0.3276 0.5963 0.5719 0.3282
```

```r
bwplot(cS ~ gr, data = cS.df)
```

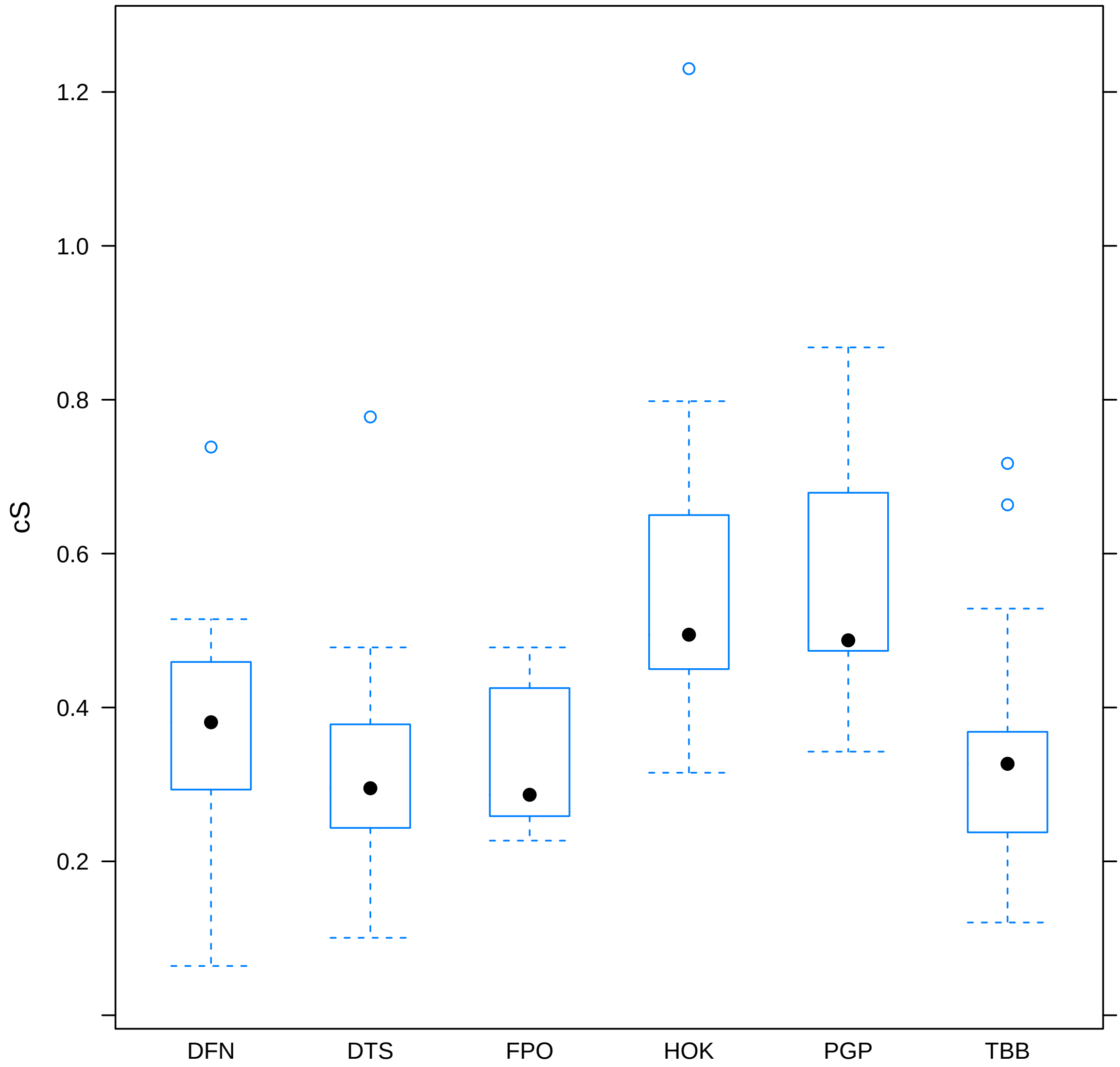


Figure 49: by gear

7.4.1 GLM

```r
# GLM for metier components
cS.df <- subset(cS.df, cS <= 1 & cS >= 0)
cS.glm <- glm(cS ~ (loa + gr + ms + y)^2, family = Gamma("logit"), data = cS.df)
anova(cS.glm, test = "F")

## Analysis of Deviance Table
##
## Model: Gamma, link: logit
##
## Response: cS
```

```
##
## Terms added sequentially (first to last)
##
##
##        Df Deviance Resid. Df Resid. Dev     F  Pr(>F)
## NULL                     126      18.60
## loa     5     4.12       121      14.48 11.93 2.2e-07 ***
## gr      5     3.07       116      11.42  8.88 6.3e-06 ***
## ms      5     2.76       111       8.66  7.99 1.9e-05 ***
## y       2     0.20       109       8.46  1.45   0.245
## loa:gr 15     1.29        94       7.17  1.24   0.278
## loa:ms 14     2.16        80       5.02  2.23   0.021 *
## loa:y  10     0.19        70       4.83  0.27   0.984
## gr:ms   6     0.40        64       4.43  0.96   0.460
## gr:y   10     0.80        54       3.63  1.15   0.346
## ms:y    9     0.37        45       3.27  0.59   0.798
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

# year and some interactions not significative
cS.glm <- glm(cS ~ loa + gr + ms + loa:ms, family = Gamma("logit"), data = cS.df)
anova(cS.glm, test = "F")

## Analysis of Deviance Table
##
## Model: Gamma, link: logit
##
## Response: cS
##
## Terms added sequentially (first to last)
##
##
##        Df Deviance Resid. Df Resid. Dev     F  Pr(>F)
## NULL                     126      18.60
## loa     5     4.12       121      14.48 13.50 6.4e-10 ***
## gr      5     3.07       116      11.42 10.05 9.9e-08 ***
## ms      5     2.76       111       8.66  9.04 4.8e-07 ***
## loa:ms 17     2.38        94       6.28  2.29  0.0061 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
par(mfrow = c(2, 2))
plot(cS.glm)
```

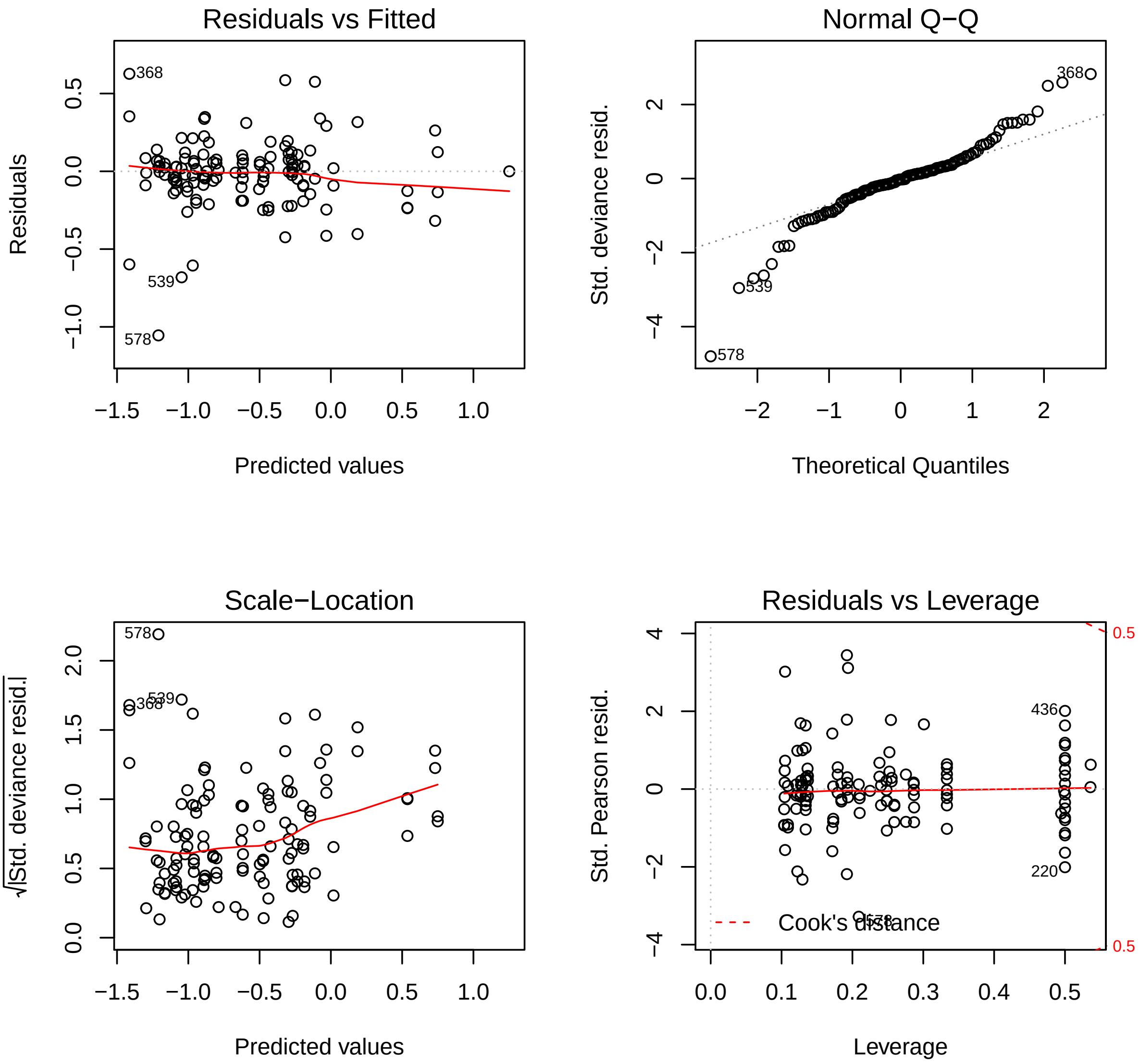


Figure 50: GLM diagnostics

```
xyplot(residuals(cS.glm) ~ predict(cS.glm) | cS.df$ms, type = c("smooth", "p"),
    ylab = "", xlab = "")
```

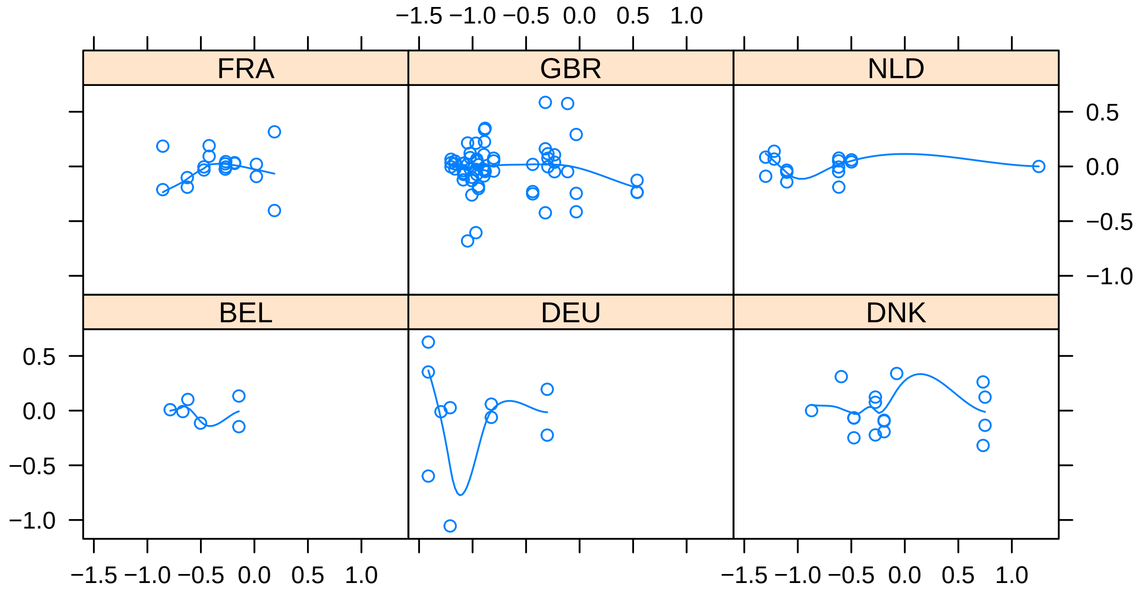


Figure 51: GLM residuals VS predicted by MS

```
xyplot(residuals(cS.glm) ~ predict(cS.glm) | cS.df$gr, type = c("smooth", "p"),
    ylab = "", xlab = "")
```

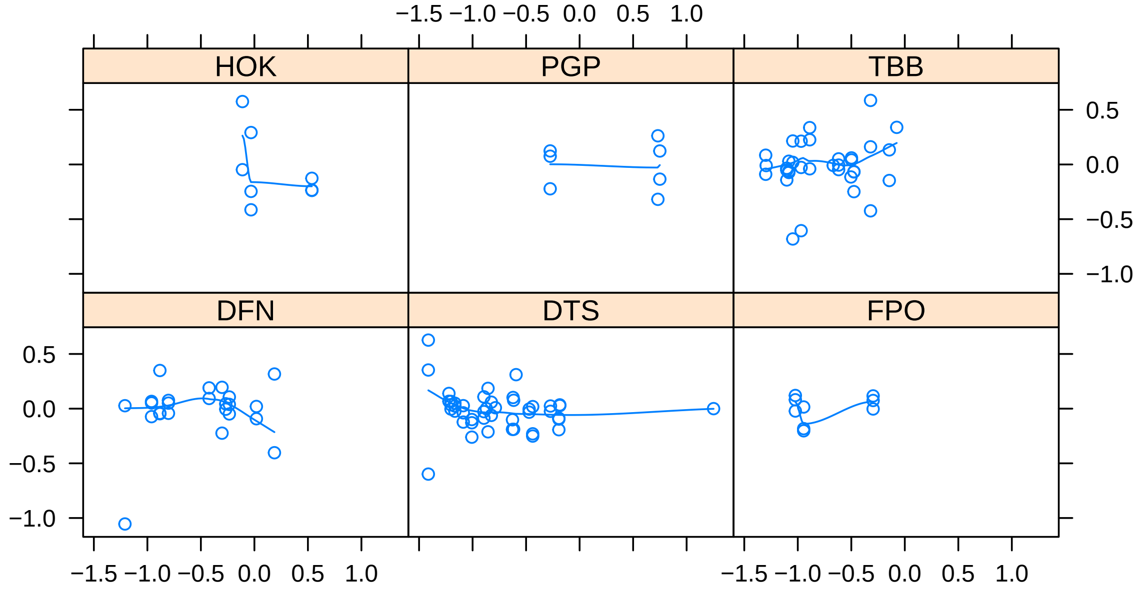


Figure 52: GLM residuals VS predicted by gear

```
xyplot(residuals(cS.glm) ~ predict(cS.glm) | cS.df$loa, type = c("smooth", "p"),
    ylab = "", xlab = "")
```

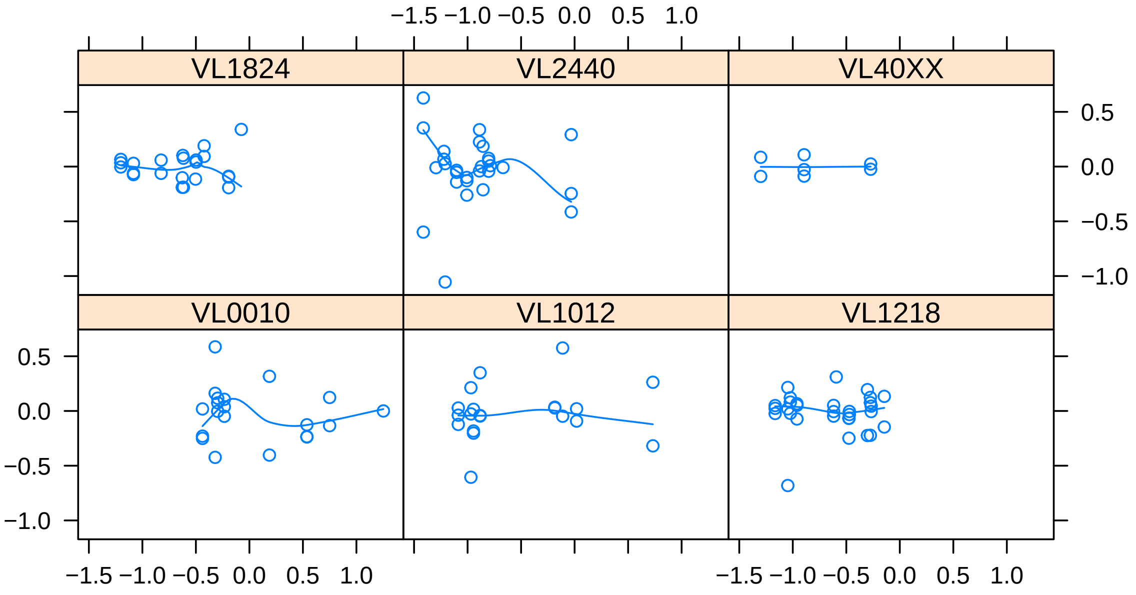


Figure 53: GLM residuals VS predicted by vessel length category

7.4.2 Predictions

```
cSnew.df <- do.call("rbind", strsplit(unique(with(wg2eco, paste(country_code,
    gear_code, vessel_length_code, sep = ":"))), ":"))
cSnew.df <- data.frame(cSnew.df)
names(cSnew.df) <- c("ms", "gr", "loa")
cSnew.df <- cSnew.df[cSnew.df$loa != "NA" & cSnew.df$loa != "VL24XX" & cSnew.df$ms !=
    "NOR", ]
cSnew.df <- transform(cSnew.df, metier = paste(ms, gr, loa, sep = ":"))
cSnew.df$cSpred <- predict(cS.glm, newdata = cSnew.df, type = "response")
```

```
dotplot(reorder(metier, cSpred) ~ cSpred, type = c("p", "h"), data = cSnew.df,
    xlab = "%")
```

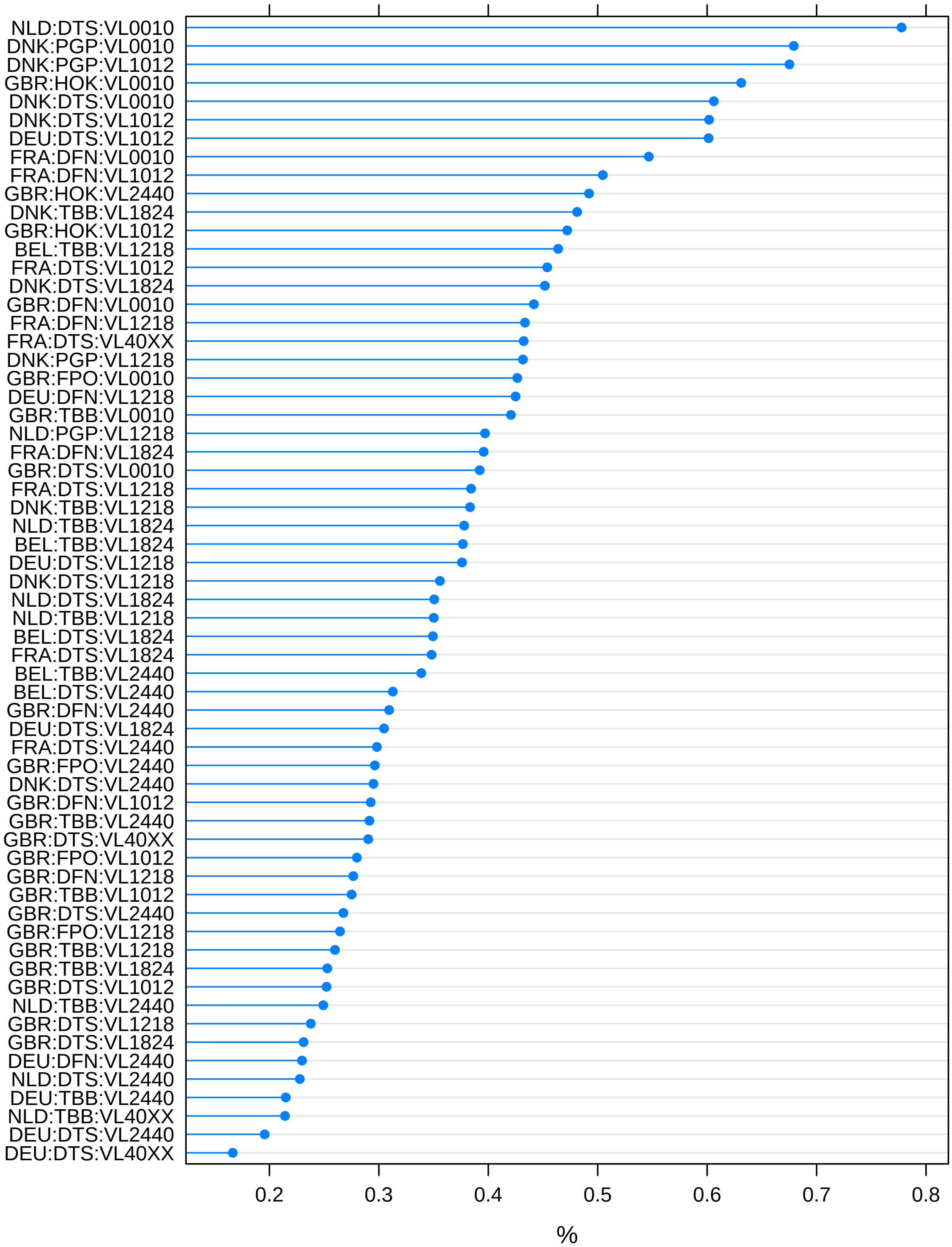


Figure 54: Crew share for all metiers

8 Computing Economic Indicators for the WGMIXFISH dataset

Economic indicators for the demersal fisheries in the North Sea were estimated by scaling the indices obtained in the previous section with the WGMIXFISH informaion.

8.1 Putting it all together

```
# merging
ecoPred.df <- merge(cS.df, cSnew.df, all = T)
ecoPred.df <- merge(ecoPred.df, fC.df, all = T)
ecoPred.df <- merge(ecoPred.df, fCnew.df, all = T)
ecoPred.df <- merge(ecoPred.df, eC.df, all = T)
ecoPred.df <- merge(ecoPred.df, eCnew.df, all = T)
ecoPred.df <- merge(ecoPred.df, vR.df, all = T)
ecoPred.df <- merge(ecoPred.df, vRnew.df, all = T)
ecoPred.df <- merge(ecoPred.df, wg2eco, by.x = c(1, 2, 3), by.y = c(2, 3, 4),
    all = TRUE)
```

```
# computing
ecoPredBar <- lapply(split(ecoPred.df, ecoPred.df$wgmix_code), function(x) {
    df0 <- x[1, c("wgmix_code", "cS", "cC", "iL", "cSpred", "fC", "fCCap", "fCbar",
        "fCpred", "eC", "eCEff", "eCbar", "eCpred", "vI", "vO", "vR", "vRpred")]
    df0[c("cC", "iL", "fC", "fCCap", "eC", "eCEff", "vI", "vO")] <- apply(x[,
        c("cC", "iL", "fC", "fCCap", "eC", "eCEff", "vI", "vO")], 2, sum)
    df0["cS"] <- weighted.mean(x$cS, x$iL)
    df0["cSpred"] <- median(x$cSpred, na.rm = T)
    df0["fCbar"] <- weighted.mean(x$fCbar, x$fCCap)
    df0["fCpred"] <- median(x$fCpred, na.rm = T)
    df0["eCbar"] <- weighted.mean(x$eCbar, x$eCEff)
    df0["eCpred"] <- median(x$eCpred, na.rm = T)
    df0["vR"] <- df0[, "vI"]/df0[, "vO"]
    df0["vRpred"] <- median(x$vRpred, na.rm = T)
    df0
})
ecoPredBar <- do.call("rbind", ecoPredBar)
ecoPredBar <- merge(data.frame(wgmix_code = names(fltscn[[1]])), ecoPredBar,
    all = T)
```

8.2 Allocating estimates to WGMIXFISH fleets

```
df0 <- ecoPredBar[, c("wgmix_code", "fCpred", "cSpred", "eCpred", "vRpred")]

# UK must be allocated to SC & EN.
ecoPredBar[ecoPredBar$wgmix_code == "SC_Otter<24", c("fCpred", "cSpred", "eCpred",
    "vRpred")] <- subset(df0, wgmix_code == "UK_Otter<24")[, -1]
ecoPredBar[ecoPredBar$wgmix_code == "EN_Otter<24", c("fCpred", "cSpred", "eCpred",
    "vRpred")] <- subset(df0, wgmix_code == "UK_Otter<24")[, -1]
ecoPredBar[ecoPredBar$wgmix_code == "SC_U10_OTB", c("fCpred", "cSpred", "eCpred",
    "vRpred")] <- subset(df0, wgmix_code == "UK_Beam<10")[, -1]
ecoPredBar[ecoPredBar$wgmix_code == "EN_U10", c("fCpred", "cSpred", "eCpred",
    "vRpred")] <- subset(df0, wgmix_code == "UK_Beam<10")[, -1]
ecoPredBar[ecoPredBar$wgmix_code == "EN_Otter24-40", c("fCpred", "cSpred", "eCpred",
    "vRpred")] <- subset(df0, wgmix_code == "UK_Otter24-40")[, -1]
ecoPredBar[ecoPredBar$wgmix_code == "SC_Otter>=24", c("fCpred", "cSpred", "eCpred",
    "vRpred")] <- subset(df0, wgmix_code == "UK_Otter24-40")[, -1]

# FDF can have the same cost structure as similar non-FDF Otters to be
# allocated to FDF (DK mean)
ecoPredBar[ecoPredBar$wgmix_code == "DK_FDF", c("fCpred", "cSpred", "eCpred",
    "vRpred")] <- apply(subset(df0, wgmix_code %in% c("DK_Otter<24", "DK_Otter24-40"))[,
```

```
    -1], 2, mean)
ecoPredBar[ecoPredBar$wgmix_code == "EN_FDF", c("fCpred", "cSpred", "eCpred",
    "vRpred")] <- subset(df0, wgmix_code == "UK_Otter<24")[, -1]
ecoPredBar[ecoPredBar$wgmix_code == "SC_FDF", c("fCpred", "cSpred", "eCpred",
    "vRpred")] <- subset(df0, wgmix_code == "UK_Otter<24")[, -1]

# NOR data allocated matching gear and loa as much as possible

ecoPredBar[ecoPredBar$wgmix_code == "NO_Otter>=40", c("fCpred", "cSpred", "eCpred",
    "vRpred")] <- apply(subset(df0, wgmix_code %in% ecoPredBar$wgmix_code[grep("Otter>=40",
    ecoPredBar$wgmix_code)])[, -1], 2, mean, na.rm = T)

v <- ecoPredBar$wgmix_code[grep("Otter", ecoPredBar$wgmix_code)]
ecoPredBar[ecoPredBar$wgmix_code == "NO_Otter<40", c("fCpred", "cSpred", "eCpred",
    "vRpred")] <- apply(subset(df0, wgmix_code %in% v[-grep(">=40", v)])[, -1],
    2, mean, na.rm = T)

# overall mean for unknown (alloc and OTH and ...)

ecoPredBar[ecoPredBar$wgmix_code %in% c("DK_OTH", "DK_Pelagic", "NO_Pelagic",
    "NO_Static", "OTH_OTH", "unalloc", "NO_OTH"), "eCpred"] <- mean(df0$eCpred,
    na.rm = TRUE)

ecoPredBar[ecoPredBar$wgmix_code %in% c("DK_OTH", "DK_Pelagic", "NO_Pelagic",
    "NO_Static", "OTH_OTH", "unalloc", "NO_OTH"), "fCpred"] <- mean(df0$fCpred,
    na.rm = TRUE)

ecoPredBar[ecoPredBar$wgmix_code %in% c("DK_OTH", "DK_Pelagic", "NO_Pelagic",
    "NO_Static", "OTH_OTH", "unalloc", "NO_OTH"), "cSpred"] <- mean(df0$cSpred,
    na.rm = TRUE)

ecoPredBar[ecoPredBar$wgmix_code %in% c("DK_OTH", "DK_Pelagic", "NO_Pelagic",
    "NO_Static", "OTH_OTH", "unalloc", "NO_OTH"), "vRpred"] <- mean(df0$vRpred,
    na.rm = TRUE)
```

```
dotplot(reorder(wgmix_code, vRpred) ~ vRpred, type = c("p", "h"), data = ecoPredBar,
    xlab = "ratio")
```

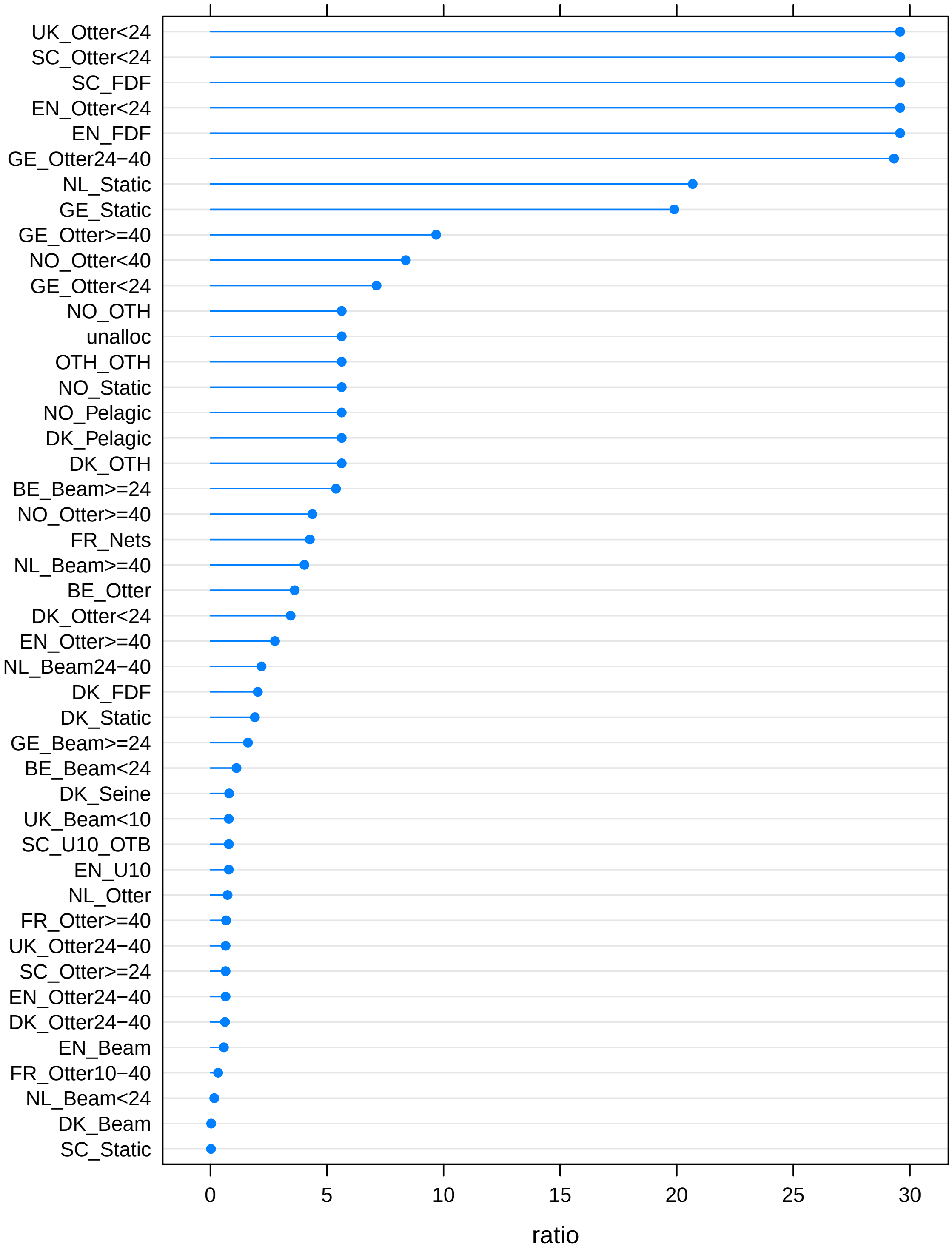


Figure 55: Ratio of the value of landings between species included in WGMIXFISH and other species

```
dotplot(reorder(wgmix_code, eCpred) ~ eCpred, type = c("p", "h"), data = ecoPredBar,
    xlab = "cost (euro/kwday)")
```

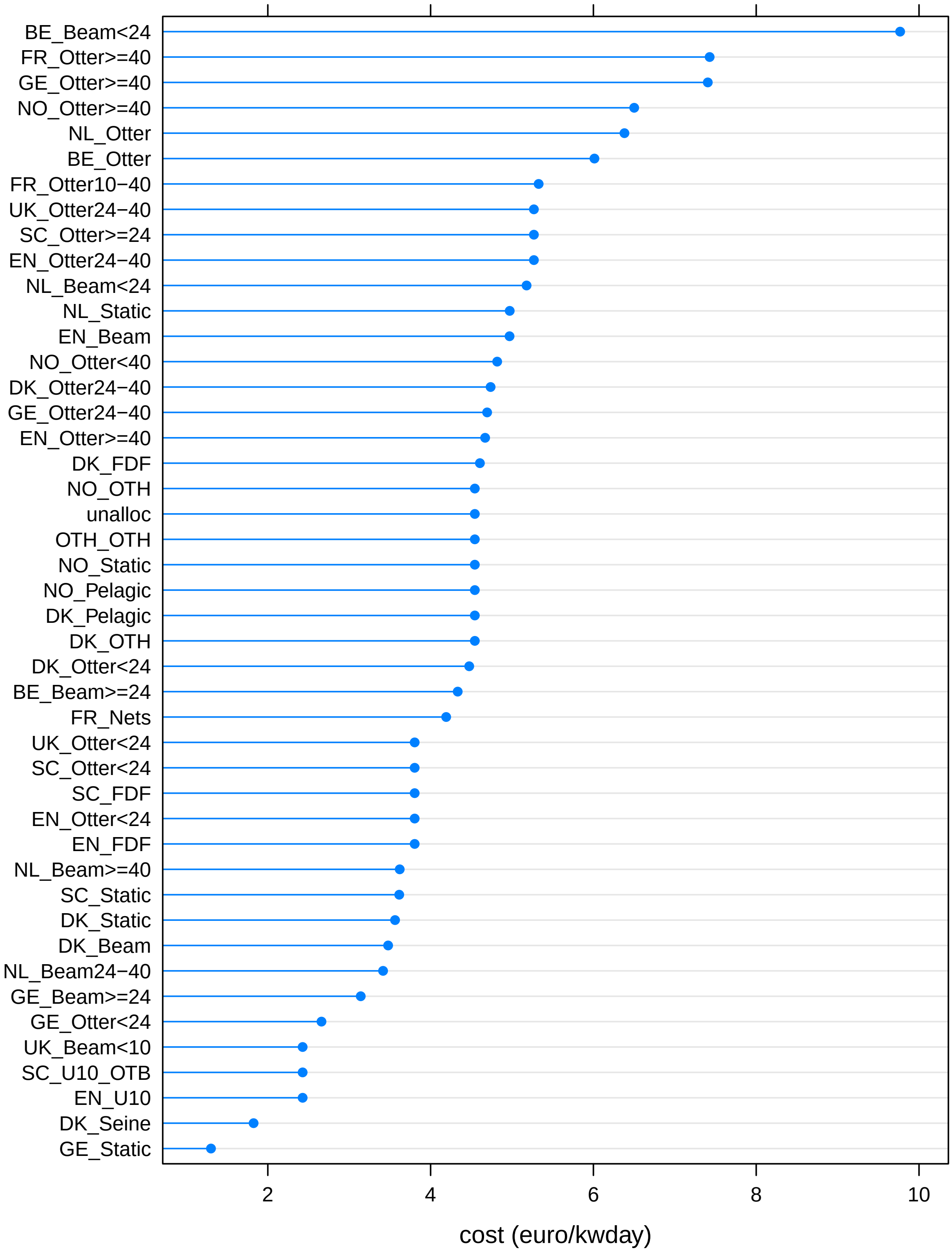


Figure 56: Effort costs

```
dotplot(reorder(wgmix_code, fCpred) ~ fCpred, type = c("p", "h"), data = ecoPredBar,
    xlab = "cost (euro/vessel)")
```

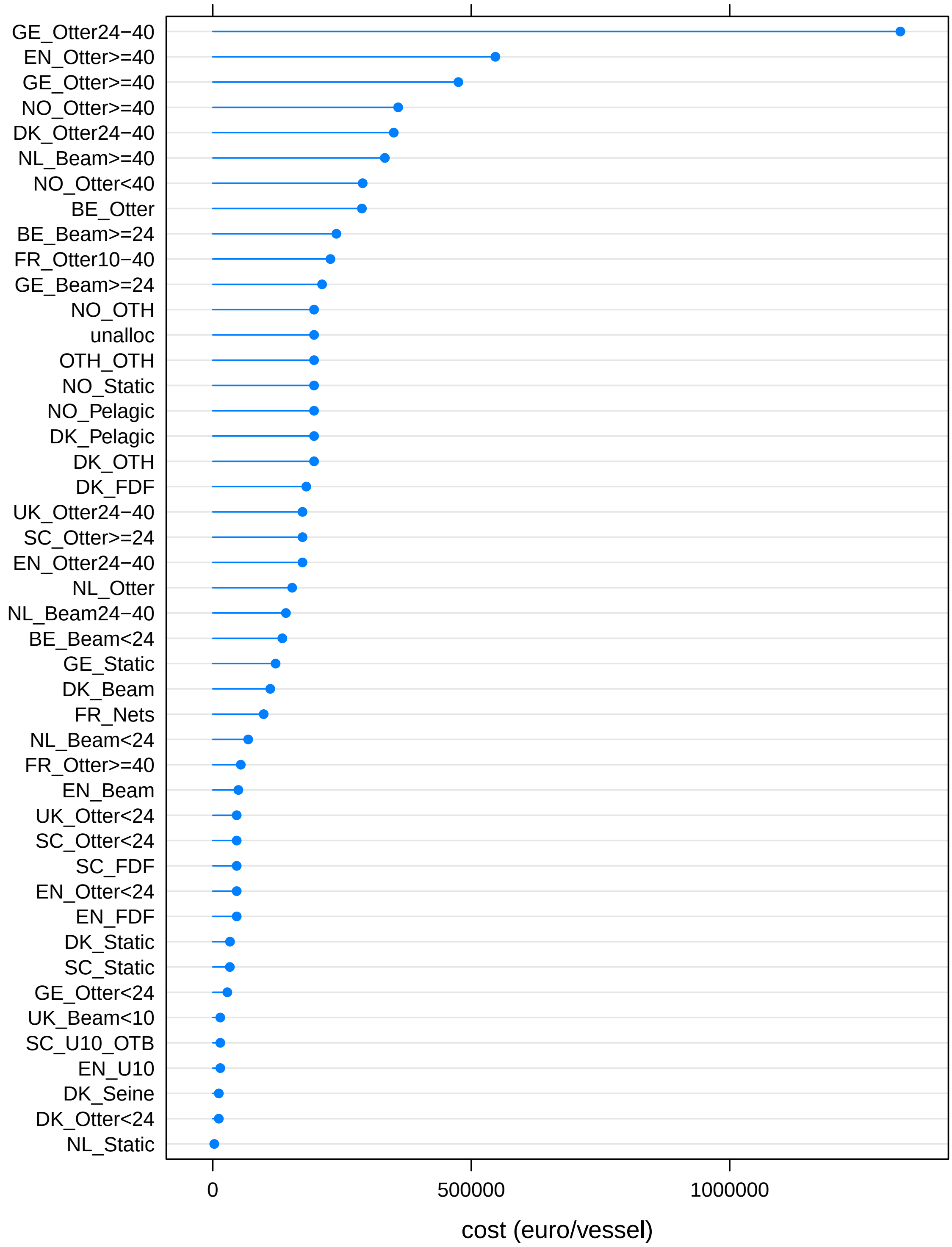


Figure 57: Fixed costs

```
dotplot(reorder(wgmix_code, cSpred) ~ cSpred, type = c("p", "h"), data = ecoPredBar,
    xlab = "%")
```

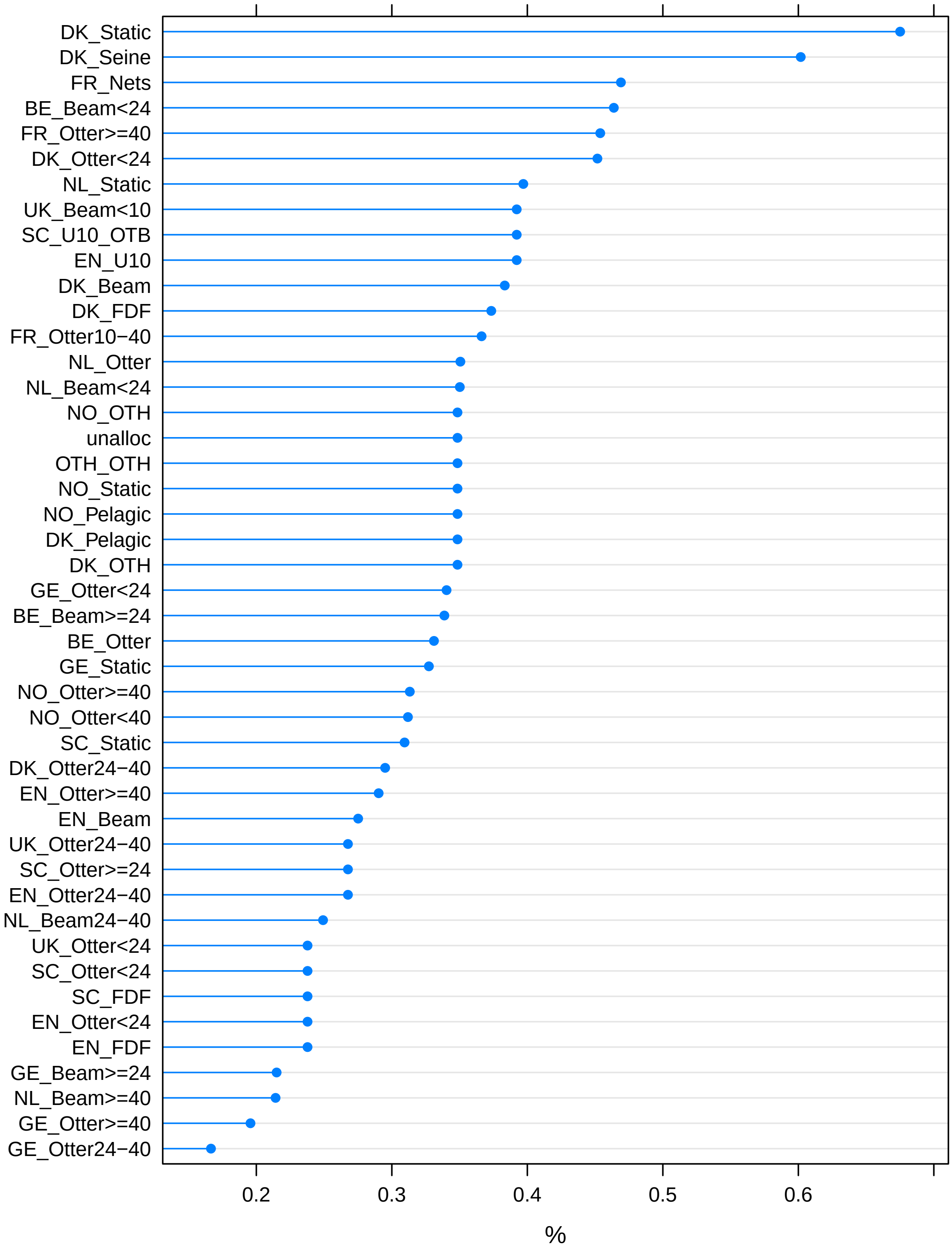


Figure 58: Crew share

8.3 Estimate economic indicators for WGMIXFISH

```
fltscn <- lapply(fltscn, function(flt) {
    # remove unalloc, it's not working
```

```
    flt <- flt[names(flt) != "unalloc"]
    lapply(flt, function(x) {
        cat(name(x), "\n")
        v <- subset(ecoPredBar, wgmix_code == name(x))
        attr(x, "fCostpves") <- v$fCpred
        # (math mambo jambo because I computed vIn/vOut instead of vAll/vIn)
        attr(x, "incomeRatio") <- 1/v$vRpred + 1
        cap <- c(capacity(x))
        if (sum(cap < 1 | is.na(cap)) > 0) {
            fcost(x)[] <- NA
        } else {
            fcost(x) <- capacity(x) * v$fCpred
        }
        crewshare(x) <- v$cSpred
        metiers(x) <- lapply(metiers(x), function(y) {
            # effort costs
            attr(y, "eCostpue") <- v$eCpred
            attr(y, "eCost") <- effshare(y) * effort(x) * 1000 * v$eCpred
            # crew costs
            attr(y, "cCost") <- revenue(y) * v$cSpred
            # variable cost
            vcost(y) <- attr(y, "eCost") + attr(y, "cCost")
            y
        })
        x
    })
})
```

9 Results

The economic indicators were aggregated by scenario.

```
nms <- list(year = 2008:2012, indicator = c("wgval", "nsval", "fixCost", "effCost",
    "crewCost", "totCost"), type = c("absolute", "rel2value"), scn = names(fltscn))
eco.wg <- array(NA, dimnames = nms, dim = unlist(lapply(nms, length)))

for (i in names(fltscn)) {
    # AER REVENUES (after using AER average prices for WGMIX dataset)
    lst <- lapply(fltscn[[i]][-41], revenue, na.rm = T)
    i0 <- apply(do.call("rbind", lst), 2, sum, na.rm = T)/1e+06

    # REVENUES SCALED BY RATIO (using AER average prices for WGMIX dataset)
    lst <- lapply(fltscn[[i]][-41], fixedRevenue, na.rm = T)
    i1 <- apply(do.call("rbind", lst), 2, sum, na.rm = T)/1e+06

    # CREW COSTS SCALED BY RATIO (using AER average prices for WGMIX dataset)
    lst <- lapply(fltscn[[i]][-41], fixedcCost, na.rm = T)
    c1 <- apply(do.call("rbind", lst), 2, sum, na.rm = T)/1e+06

    # FIXED COSTS (using AER average prices for WGMIX dataset)
    lst <- lapply(fltscn[[i]][-41], fcost)
    c2 <- apply(do.call("rbind", lst), 2, sum, na.rm = T)/1e+06

    # EFFORT COSTS (using AER average prices for WGMIX dataset)
    lst <- lapply(fltscn[[i]][-41], ecost)
```

```
    c3 <- apply(do.call("rbind", lapply(lst, do.call, what = "rbind")), 2, sum,
        na.rm = T)/1e+06
    eco.wg[, , 1, i] <- c(i0[6:10], i1[6:10], c2[6:10], c3[6:10], c1[6:10],
        c2[6:10] + c3[6:10] + c1[6:10])
    eco.wg[, , 2, i] <- sweep(eco.wg[, , 1, i], 1, eco.wg[, "nsval", 1, i],
        "/")
}
```

9.1 Comparing economic indicators between AER and WGMIXFISH

The following tables show the value of landings on the North Sea computed from the AER dataset and the WGMIXFISH dataset. The values estimated are higher in the WGMIXFISH estimates by about 6% to 9%. These may have an impact on the estimation of crew costs, which are a percentage of revenue.

```
#
# ------------------------------------------------------------------------------
# AER
# ------------------------------------------------------------------------------
eco.aer[as.character(2008:2010), "nsval", "absolute"]

##  2008  2009  2010
## 770.2 759.0 828.1



#
# ------------------------------------------------------------------------------
# Estimated
# ------------------------------------------------------------------------------
eco.wg[as.character(2008:2010), "nsval", "absolute", "sq_E"]

##  2008  2009  2010
## 842.5 804.9 906.9
```

The absolute values of economic indicators are not comparable between the two datasets because the areas covered by both datasets are different. The AER costs refer to area 27 while the estimates for the WGMIXFISH refer to the North Sea. The analysis were made using the percentage of income each cost category represent, which could be seen as a standardized cost structure.

```
#
# ------------------------------------------------------------------------------
# AER
# ------------------------------------------------------------------------------
eco.aer[as.character(2008:2010), , "rel2value"]

##       indicator
## year    nsval value fixCost effCost crewCost totCost
##   2008 0.6782     1  0.3756  0.5094   0.4665  1.3515
##   2009 0.5298     1  0.2189  0.3190   0.3505  0.8884
##   2010 0.5363     1  0.2341  0.3189   0.3231  0.8761



#
# ------------------------------------------------------------------------------
# Estimated
# ------------------------------------------------------------------------------
eco.wg[as.character(2008:2010), , "rel2value", "sq_E"]
```

```
##       indicator
## year    wgval nsval fixCost effCost crewCost totCost
##   2008 0.5608     1  0.3609  0.6173   0.2973   1.275
##   2009 0.5443     1  0.3697  0.6539   0.2955   1.319
##   2010 0.5425     1  0.2363  0.5406   0.2930   1.070
```

The major differences between the two sets of economic indicators are the higher values of effort related costs and lower values of crew costs the North Sea indicators present. These constitute the variable costs of exploitation, which being a ratio with revenue also reflects the higher revenue estimated by the modelling approach.

Overall, the results show about 20% losses on the estimated values while the AER show about 12% gains in 2009 and 2010.

9.2 Fcube-based Economic Indicators' Trends

Although the relative values shows different results, a comparison between scenarios in terms of relative changes can be informative.

```
#
# ------------------------------------------------------------------------------
# Fixed costs
# ------------------------------------------------------------------------------
(eco.wg["2012", "fixCost", "rel2value", ] - eco.wg["2010", "fixCost", "rel2value",
    ])/eco.wg["2010", "fixCost", "rel2value", ]


##       max       min       cod      sq_E    Ef_Mgt
## -0.106095  0.515451  0.105537  0.006534  0.238015
```

Fixed costs dynamics are not well represented because Fcube does not include in/out strategies from the fleet, so it simply reflects the lower income by vessel, which is mostly driven by effort in the short term. Fixed costs relative to income will decrease in a "max" strategy while the "min" strategy showed the largest increase.

```
#
# ------------------------------------------------------------------------------
# Crew costs
# ------------------------------------------------------------------------------
(eco.wg["2012", "crewCost", "rel2value", ] - eco.wg["2010", "crewCost", "rel2value",
    ])/eco.wg["2010", "crewCost", "rel2value", ]


##     max     min     cod    sq_E  Ef_Mgt
## 0.05969 0.06756 0.06724 0.06703 0.08316
```

Crew costs depend on the distribution of landings in value by fleet, once that each fleet has a different crew share, landings composition and each species has a distinct price. If one scenario results in an increase of landings of the most expensive species, the income for the fleets landing these species will be higher, and crew costs will increase accordingly. The results obtained are not too different, between 6% and 8% increase in 2012 with regards to 2010. Meaning that a largest share of income will have to be allocated to labour costs in 2012 when compared to 2010.

```
#
# ------------------------------------------------------------------------------
# Effort costs
# ------------------------------------------------------------------------------
(eco.wg["2012", "effCost", "rel2value", ] - eco.wg["2010", "effCost", "rel2value",
    ])/eco.wg["2010", "effCost", "rel2value", ]
```

```
##       max       min       cod      sq_E    Ef_Mgt
##  0.029657 -0.040702  0.007531  0.021220  0.043433
```

Effort costs reflect directly the changes in effort between scenarios. As expected the "min" scenario shows the lowest increase, in fact a decrease. The "Ef_Mgt" scenario shows the highest increase in the percentage of income allocated to effort costs.

```
#
# ------------------------------------------------------------------------------
# Income
# ------------------------------------------------------------------------------
(eco.wg["2012", "nsval", "absolute", ] - eco.wg["2010", "nsval", "absolute",
    ])/eco.wg["2010", "nsval", "absolute", ]

##       max       min       cod      sq_E    Ef_Mgt
##  0.230644 -0.274091 -0.004937  0.092938 -0.111417
```

With regards to income, as value of landings, only scenarios with high effort will increase their income, "max" and "sq_E". The other scenarios show a decrease in income, with "min" showing the highest decrease, about 30%.

```
#
# ------------------------------------------------------------------------------
# Total costs
# ------------------------------------------------------------------------------
(eco.wg["2012", "totCost", "rel2value", ] - eco.wg["2010", "totCost", "rel2value",
    ])/eco.wg["2010", "totCost", "rel2value", ]

##      max      min      cod     sq_E   Ef_Mgt
## 0.007903 0.111758 0.045524 0.030522 0.097281
```

Finally, the share of income allocated to total costs, which reflects changes in the gross profit of each scenario, shows that in all cases the situation will get worst, with the best scenario being "max".

10 Final comments

The approach followed is promising but the results presented have to be taken with care. There are still some issues that require improvement:

- revise data
- complete information from all countries and all variables;
- improve modelling
  - deal with high residuals through outlier analysis or alternative error models to deal with overdispersion;
  - explore alternatives to GLM;
- explore the results at the fleet level to better identify data problems and improvements on modelling;
- explore methods to define how uncertainty on models can be included in the economic indicators;

The major challenge of this analysis was to use information at distinct aggregation levels to compute all necessary indicators, the AER data is aggregated at the FAO region 27, while the WGMIXFISH dataset is aggregated to the North Sea. The rescaling mechanism adopted overcomes this problem but assumes that the costs per operational unit are constant for all area 27. This assumption is clearly sensitive to the relation between steaming and fishing each fleet segment has when fishing in the North Sea or outside the North Sea. In any case there was no information to inspect this assumption.

Several data problems were found during the exercise. The WGMIXFISH dataset information about prices is not coherent and some member states submitted data in different units for the same time series. With regards to the capacity information some member states did not provide information. As expected, the AER dataset is more consistent with regards to the economic information. However, there are several cases of incomplete information, *e.g.* providing fixed costs but not capacity. In both cases the expert's reports are valuable resources and both are available on STECF and ICES websites, respectively.

The definition of effort can be a major source of error when merging the datasets. Both the criteria used for allocation of fishing activity to segments/metiers and the unit of effort can be potentially problematic.

In the case of the allocation criteria there is a fundamental difference between the economic and the biological analysis. For economics the boat is the unit of analysis, and the fact that more fishing mortality may be executed by having more than one gear is not relevant. It simply reflects a different relationship between costs and income, when compared with a vessel using a single gear. However, for conservation purposes it's extremely important to know which gears a fleet can use and their selectivity. The dynamics associated with multi-gear fishing have a huge impact on the stocks' conservation and can not be ignored when forecasting. In this perspective, the AER criteria of allocating each vessel's effort to the dominant gear (used >50% of the time) may result in an underestimation of effort for multi-gear fleets, once that the effort of the non-dominant gears is not accounted. The WGMIXFISH data call does not state effort allocation criteria explicitly and seems to rely on the definition of metier.

With regards to the effort unit, neither data call states it explicitly, leaving the definition for the relevant regulations, and ultimately to the Members States' interpretation. One potential problem with the loose definitions of units for measuring fishing effort is the usage of "days-at-sea" and "days-fishing" interchangeably. If days-at-sea are recorded and supplied, then the steaming time of the vessel between the harbour and the fishing grounds is included. If days-fishing is supplied, then the steaming time is generally excluded from the data. For coastal fleets this shouldn't be too problematic but for fleets that go to faraway fishing grounds it may have some impact.

Potentially, there are discrepancies in the methods for effort allocation and the effort unit definition, which make it difficult to understand if both series are comparable. As a matter of fact, even within each data set the internal consistency of effort values between countries is not guaranteed.

Comparing CPUEs computed from each dataset for the same fleet reflect the problem of different effort definitions. Figure 59 shows an example for cod, where it is clear that differences between both datasets exist. The impact of this inconsistency was not further explored, but there is potential to change the relation between costs and revenues.

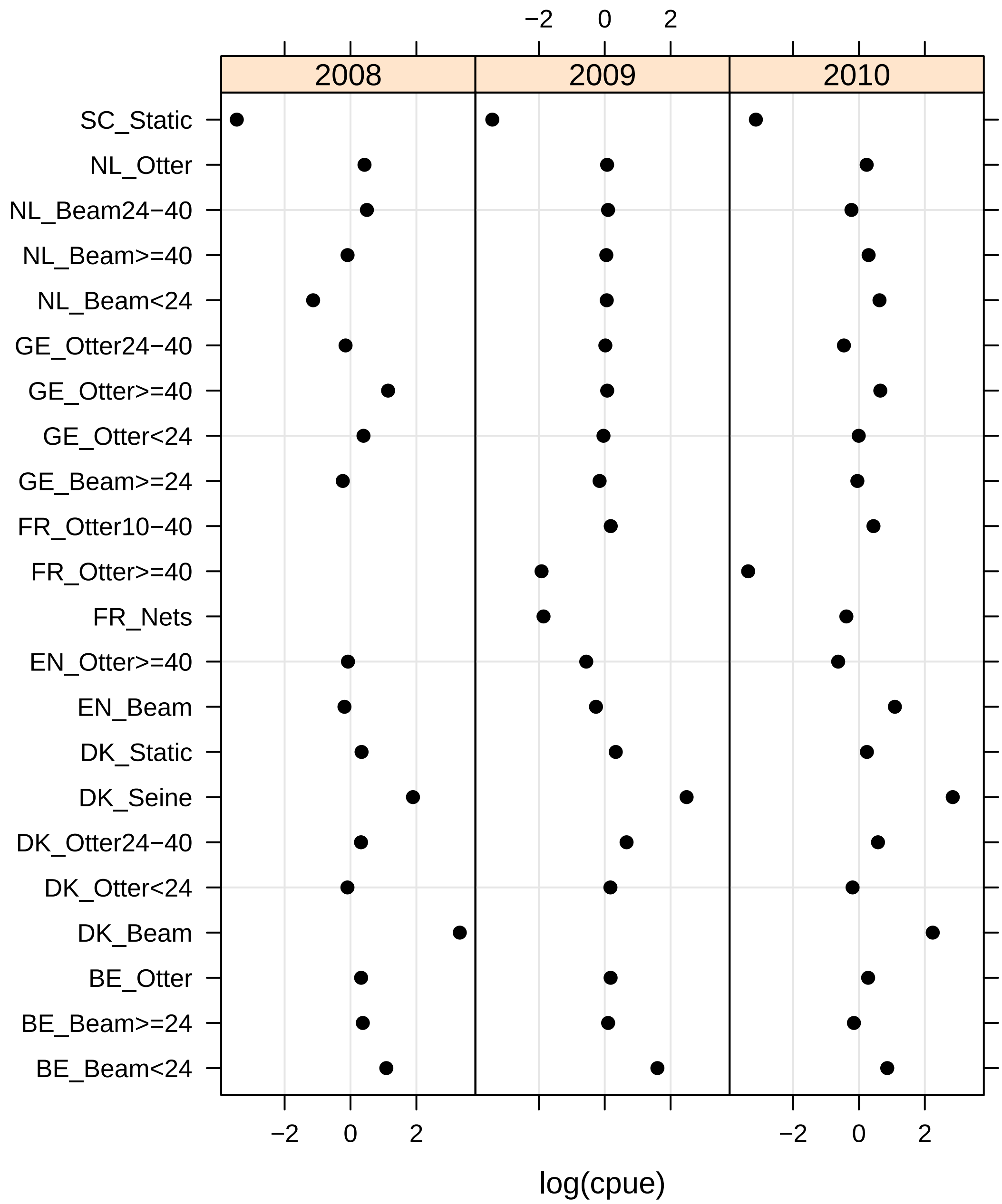


Figure 59: Log CPUE ratios. AER CPUE over WGMIXFISH CPUE

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Abstract

The main objectives of the study presented in this report were to test the FLBEIA API, condition an operating model for the North Sea mixed fisheries and provide feedback on bioeconomic modelling limitations. Additionally, Fishrent and Fcube were also tested. FLR, FLBEIA, Fishrent and Fcube are software packages implemented by the scientific community studying fisheries to run bioeconomic models. A large test was carried out on FLBEIA by both running existing examples and trying to implement a bioeconomic model for the North Sea. In general the group felt FLBEIA is on the correct path to provide a bioeconomic modeling framework, although some work is still required. FLBEIA is not ready yet for production. A list of bugs and improvements was assembled. Conditioning a bioeconomic operating model for the North Sea showed the difficulties of merging economic and biological information. Inconsistencies on the effort definition seem to create additional problems when relating both sources of information. This subject must be further explored. The exercise was successful but data problems prevented the performance of a full economic analysis, although trend analysis on economic indicators for each scenario tested was possible. Nevertheless, these results must be taken carefully.

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