a4a short research project
Studying spatial effects on stock dynamics of North Sea cod and plaice in the Skagerrak

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February 24, 2015

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1 Introduction

Under the scope of the a4a Initiative, the JRC is promoting cooperative activities between fisheries scientists with the aim to test, disseminate and promote a4a methods. These Small Research Projects (SRP) are focussed on (i) comparing the a4a statistical catch-at-age model with results from other assessment models, and (ii) exploring research questions using case studies.

The Workshop dedicated to the North Sea took place in Ispra, Italy, the 1st to the 5th of December. The main objectives were to study spatial effects on stock dynamics through the use of stock assessment models.

The terms of reference of the workshop were:

1. Use the a4a stock assessment framework to study spatial effects on stock dynamics;
2. Apply the methodology to the stocks of cod in the North Sea and plaice in the Skagerrak.
3. Report to STECF and other relevant management bodies.

1.1 The a4a Initiative

The volume and availability of data useful for fisheries stock assessment is continually increasing. Time series of traditional sources of information, such as surveys and landings data are not only getting longer, but also cover an increasing number of species.

For example, in Europe the 2009 revision of the Data Collection Regulation (EU, 2008a) has changed the focus of fisheries sampling programmes away from providing data for individual assessments of key stocks (i.e. those that are economically important) to documenting fishing trips, thereby shifting the perspective to a large marine monitoring programme. The result has been that data on growth and reproduction of fish stocks are being collected for more than 300 stocks in waters where the European fleets operate.

Recognizing that the context above required new methodological developments, the European Commission Joint Research Centre (JRC) started its Assessment for All Initiative (`a4a`), with the aim to develop, test, and distribute methods to assess large numbers of stocks in an operational time frame, and to build the necessary capacity/expertise on stock assessment and advice provision.

The long-term strategy of `a4a` is to increase the number of stock assessments while simultaneously promoting the inclusion of the major sources of uncertainty in scientific

advice. Our tactic is to reduce the required workload, by developing a software framework with the methods required to run the analysis a stock assessment needs (Jardim, et.al, 2014), including methods to deal with recognized bottlenecks, *e.g.* model averaging to deal with model selection (Millar, et.al, 2014). Moreover, we aim to make the analysis more intuitive, thereby attracting more experts to join stock assessment teams. Having more scientists/analysts working in fisheries management advice will increase the human resource basis, which is currently recognized to be limited. Regarding the former, `a4a` promotes a risk analysis approach to scientific advice through a wider usage of Operating Model/MSE approaches. We're focused on developing methods that can deal with the most common settings these type of analysis require, and creating the conditions for scientists to develop their own methods. Our expectation is that having a common framework, with clear data structures and workflows, will promote research in this area and make it simpler to implement and share methods.

To achieve these objectives, the Initiative identified a series of tasks, which were or are being carried out, namely:

- define a moderate data stock;
- develop a stock assessment framework;
- develop a forecasting algorithm based on MSE;
- organize training courses for marine scientists.

1.2 The a4a approach to stock assessment and management advice

As stated before, one of the main objectives of `a4a` is to promote a risk type of analysis, so that scientific advice provides policy and decision makers a perspective of the uncertainty existing on stock assessments and its propagation into the scenarios being analyzed.

The sources of uncertainty implemented so far are related to the processes of growth, natural mortality and reproduction (stock-recruitment); and to the estimation of population abundance and fishing mortality by the stock assessment model. In all cases the framework can include sampling error.

The approach is split into 4 steps: (i) converting length data to age data using a growth model, (ii) modeling natural mortality, (iii) assessing the stock, and (iv) MSE.

These steps may be followed in sequence or independently, depending on the user's preferences. All that is needed is to use the objects provided by the previous step and provide the objects required by the next, so that data flows between steps smoothly. One can make the analogy with building with Lego, where for each layer the builder may use the pieces provided by a particular boxset, or make use of pieces from other boxsets. Figure 1.1 shows the process, including the class of the objects that carry the data (in black).

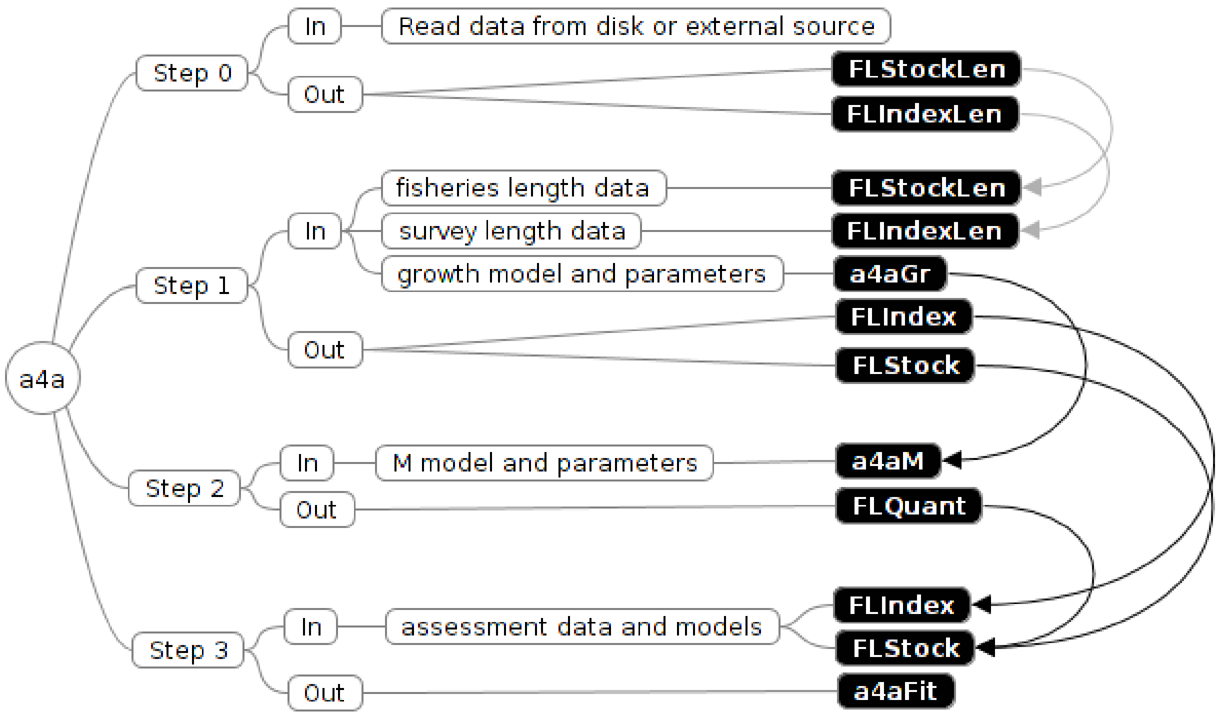

Figure 1.1: In/out process of the `a4a` approach. The boxes in black represent the classes of the objects that carry the information in and out of each step.

Analysis related to projections and biological reference points are dealt with by the `FLR` packages `FLash` and `FLBRP`.

In Steps 1 and 2 there is no fitting of growth models or natural mortality models. The rationale is to provide tools that allow the uncertainty associated with these processes to be carried on into the stock assessment, e.g. through parameter uncertainty. This approach allows the users to pick up the required information from other sources of information such as papers, PhDs, Fishbase, other stocks, etc. If the stock under analysis does not have specific information on the growth or natural mortality processes, generic information about life history invariants may be used such as the generic priors suggested by Bentley, (2014).

Note that an environment like the one distributed by `a4a` promotes the exploration of different models for each process, giving the analyst a lot of flexibility. It also opens the possibility to efficiently include distinct models in the analysis. For example, a stock assessment using two growth, or several models for natural mortality could be performed. Our suggestion to streamline the assessment process is to combine the final outcomes using model averaging (Miller, et. al, 2014). Other solutions may be implemented, like scenario analysis, etc. What is important is to keep the data flowing smoothly and the models clear. R (R Core Team, 2014) and `FLR` (Kell, et.al, 200) provide powerful platforms for this approach.

1.3 How to read this document

The target audience for this document are stock assessment experts. It presents a mixture of text and code that shows how the analysis can be run with R/FLR/FLa4a. The chapters are as independent as possible, so they can be extracted and run individually.

1.4 Software packages - FLR & FLa4a

To run the `FLa4a` methods the reader will need to install the package and its dependencies and load them, together with a couple of other packages. The data sets can be made available upon request.

```
# from CRAN
install.packages(c("copula", "triangle"))
# from FLR
install.packages(c("FLCore", "FLa4a"), repos = "http://flr-project.org/R")
```

To replicate the analysis carried out in this document the user will need the following additional packages:

```
# from CRAN
install.packages(c("plyr", "xtable", "plot3D", "gridExtra", "ggplot2"))
# from FLR
pkgs <- c("FLXSA", "FLAssess", "FLSAM", "FLash", "FLBRP")
install.packages(pkgs, repos = "http://flr-project.org/R")
```

After installing the reader will have to load the packages into one's R session.

```
library(FLa4a)
library(FLBRP)
library(FLXSA)
library(xtable)
library(plyr)
library(plot3D)
library(FLSAM)
library(gridExtra)
source("funs.R")
```

2 Methods

Two major assumptions were considered to support the analysis carried out here,

- that sub-units of a population could be detected by assessing each sub-unit separately and comparing the cumulative results with the aggregated stock;
- that the inflow of individuals into the area of a stock can be detected by an increase in survey catchability which cannot be explained by the stock dynamics.

In the first assumption it is considered that fitting stock assessment models to sub-units of a stock would allow the identification of violations of the closed population assumption. If a sub-unit is not well defined in the sense that migrations of individuals with distinct productivity traits are a major source of the sub-unit productivity, that would affect the stock dynamics and would be reflected in the outcomes of the assessment. In that case, when breaking a larger unit into sub-units, the aggregation of the sub-units abundance and biomass indicators would be very different from the total unit assessment, due to the estimation of the wrong dynamics by the assessment model.

Note that such results alone do not justify breaking one stock into smaller stocks. It simply shows that the sub-units can be treated as parts of the whole, which can be relevant if each sub-unit has different productivities and exploitations, to explore potential local depletion. It also allows projections to be done using the sub-units S/R functions and the relevant fleet's selectivities, which may give very different results from using a multi-fleet projection on a stock with a single dynamics. In fact, the analysis is analogous to a simple spatial analysis, which considers that there is no flow of individuals between areas, or that the flow is not sufficient to have a major impact on assessment results.

With regards to the second assumption, it is considered that the inflow of individuals into the area of a stock can be detected by an increase in survey catchability, that cannot be explained by the stock dynamics. For example, recruitment variability is not able to explain the catches and the population abundance. In this case an assessment without yearly increases in catchability would show trends in the residuals, that could be explained by including a yearly trend in the catchability model.

Note that in both cases the analysis shouldn't rely on the numerical results per se, but have supporting information to consider these particular hypotheses. The stock assessment results should be seen as another piece in the puzzle of the spatial dynamics of the stock, which in case of finding support in the data, can be considered to better manage the stocks or monitor the progress of the populations.

3 North Sea Cod

(This section is supported by two working documents presented to the 2015 ICES benchmark on North Sea stocks, Wright et.al, 2015[1] and Eero et.al, 2015[2]. These documents don't have an online reference.)

Genetic evidence suggests the existence of several subpopulations of cod in the North Sea with high differentiation between the north east and other regions (e.g., Hutchinson et al., 2001; 2003; Heath et al., 2014). The possible implications to fisheries management for not accounting for this population structure have also been considered (e.g., Holmes et al., 2014; Heath et al., 2014).

On the basis of Wright et.al (2015) sub-areas were defined, which represent the current state of knowledge with relation to the distribution areas of the different sub-populations (Fig. 3.1). The defined sub-areas are similar to those used in earlier analyses by Holmes et al. (2014). It is important to note that the exact borders for the defined sub-areas, in terms of representing different sub-populations, are uncertain. Further, there is uncertainty in the extent of mixing of sub-populations across the defined sub-areas.

Eero et.al (2015) provides indications of whether spatial management measures may potentially be needed, and where more focus and research effort should be allocated to improve the data and knowledge base, to potentially be able to take population structure into account in fisheries management in future.

[1]Peter Wright. 2015. Working Document for ICES WKNSEA, 2-6 February 2015, xx pp.

[2]Eero,M.,Holmes,S., Jardim,E., De Oliveira,J., Ulrich,C., Berg,C., Wright,P. 2015. Analyses of stock dynamics and fishing pressure of cod in the North Sea by sub-areas. Working Document for ICES WKNSEA, 2-6 February 2015, 28 pp.

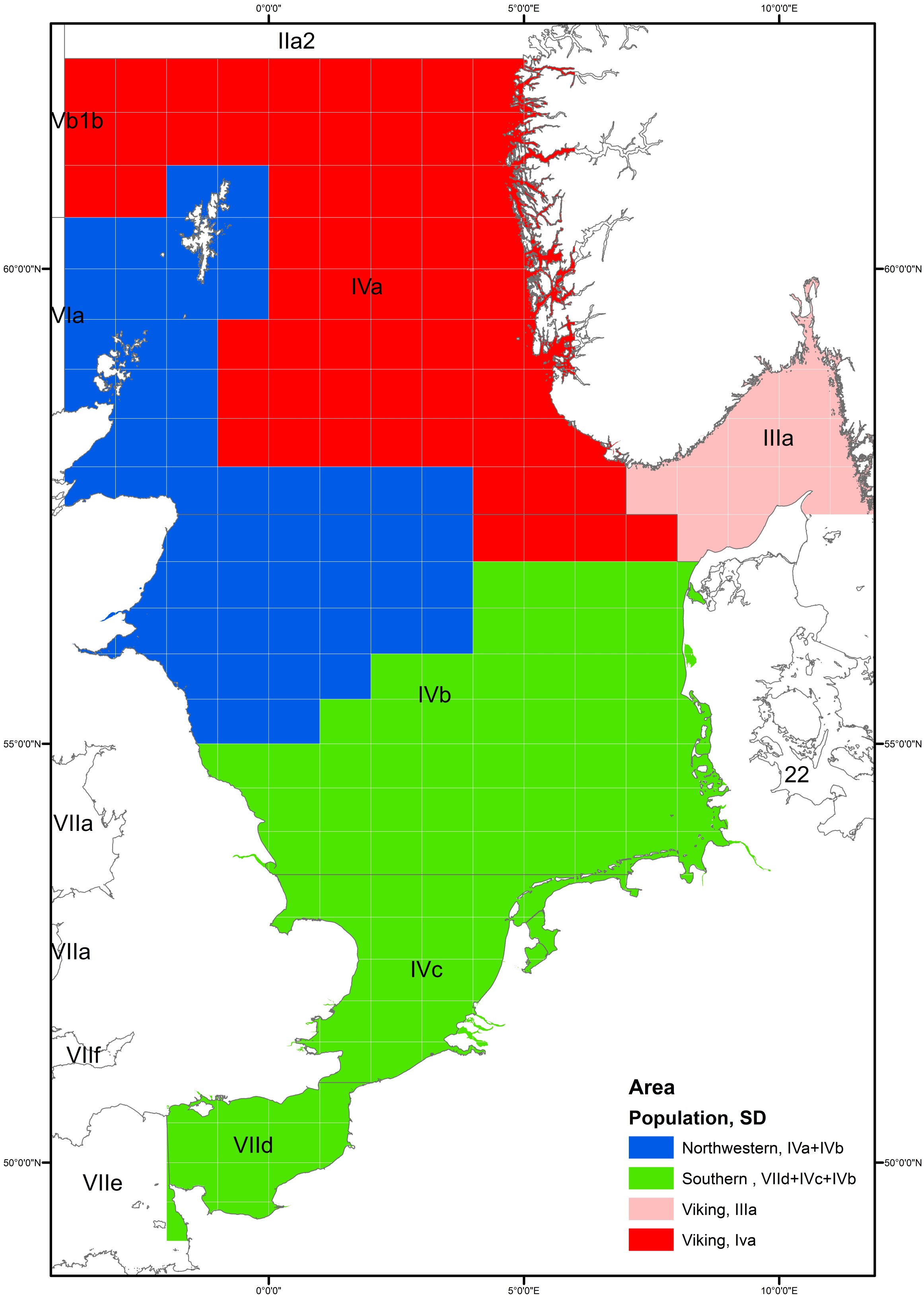

Figure 3.1: The sub-areas used in spatial analyses of North Sea cod defined on the basis of the review of biological knowledge (see Wright et.al, 2015, for further details). In further analyses, the sub-areas are referred to: sk (Skagerrak); vk (Viking); nw (northwest) and so (south), corresponding to pink, red, blue and green colors on the map, respectively.

A first split into 4 subunits (Fig. 3.1) was carried out based on a compilation of different information. Afterwards a second scenario with two subunits was attempted. This scenario became relevant to encompass the migrations between spawning areas and feeding areas, which occurs between the Skagerrak and the Viking grounds, and between the South North Sea and the Northwest NS. Mainly it was an attempt to minimize the violation of the closed population assumption in stock assessment models.

3.1 Data compilation of North Sea cod by sub-areas

3.1.1 Landings

Landings in weight for the different sub-areas came from the STECF database, that includes landing information for EU countries by rectangle. For UK and Denmark, the STECF estimates were supplemented by landings information from national sources. Landings by rectangle from STECF are available for the years 2003-2013. Norwegian landings from the ICES WGNSSK report, were all allocated to the "Viking" sub-area. For Skagerrak area, landings back to 1987 were used, available from national sources and the ICES WKNSSK report.

3.1.2 Landings at age

The age distribution of landings by sub-areas was available from England & Wales and Denmark. In the Skagerrak, Denmark is taking approximately 70% of the landings. Danish age compositions and mean weights-at-age of cod were allocated to the total international landings in this area to estimate numbers-at-age.

In the Viking area, Denmark is taking an average of 23% of landings, and Danish age compositions and mean weights at age in the Viking area were allocated to the total international landings in this area to compute numbers-at-age.

In the Northwestern area there was no age based information available. Thus, the overall North Sea wide age structure of landings and mean weights-at-age (obtained from ICES WGNSSK, 2014) were used to estimate numbers-at-age for the total international landings in the Northwestern area.

In the Southern area, age composition data were available from Denmark and England & Wales, that together take an average of 44% of the total landings in this area. The age information for this particular area was used to derive catch-at-age for these two countries. An average age composition and mean weights-at-age of the two countries was allocated to the remaining landings to compute numbers-at-age.

3.1.3 Discards at age

For the Skagerrak area, discard numbers-at-age from monitoring programs were available from Denmark for the years 2000-2013. An average discard percentage in relation to landings for 2000-2005, was applied to derive discard estimates for 1987-1999. No discards

assumptions were made for other countries fishing in the Skagerrak area. Only Danish discards were added to the international landings to derive catch-at-age.

For the Viking area, discard numbers-at-age from monitoring programs were available from Denmark for the years 2003-2013. The ratio between Danish discard and Danish landing numbers-at-age by year were applied to the total international landings to derive estimates of total discards in the area.

For the Northwestern area discards-at-age were not available. The ratio between total North Sea wide landing and discard numbers-at-age (obtained from ICES WGNSSK, 2014) by year were applied to landings-at-age in the Northwestern area to derive discards.

For the Southern area, discards-at-age estimates from monitoring programs were available for England & Wales and for Denmark for 2003-2013. The ratio between combined landings and discards-at-age from these countries by year was used to derive discard estimates for the rest of the countries fishing cod in the area.

3.1.4 Survey indices

IBTS Q1 and Q3 data were used to derive abundance indices for each sub-unit. A Delta-GAM model approach for fitting numbers-at-age from DATRAS haul-by-haul exchange data was applied (Berg et al.,2013). The indices are obtained by adding filtered model predictions over a spatial grid. The presented model is able to account for changes such as different gears, steep depth gradients, ship/country effects, and spatial coverage. Such effects may be balanced out by the relatively stable survey design over the period considered, but indications of such effects are evident in simple residual plots.

This methodology is the same used to derive abundance indices for the ICES assessment working group (ICES WGNSSK, 2014), but applied to each sub-unit's area.

Mean weights-at-age in the stock for each sub-unit's area were estimated from the IBTS Q1 data. Natural mortality and maturity-at-age were kept the same as the ones used by the ICES WGNSSK (2014)

3.2 Read and process data

This section presents the code to read the datasets into R and process the data, in order to create FLR objects that can be used for the analysis.

The following objects refer to the official ICES assessment carried out with SAM, and already converted into FLR objects.

```
load("datacod/cod347_FLStockObject.RData")
load("datacod/cod347_FLIndexObject_both.RData")
cod1 <- iter(cod, 1)
```

The following sections show how the data assembled for this exercise was imported and processed to create the FLR objects required to run stock assessments.

3.2.1 Four subunits option

The Northwestern sub-unit (nw)

```
codnw.stk <- readFLStock("datacod/NW/files.ind", name = "NSCOD-NW",
    no.discards = TRUE, harvest.units = "f")
catch(codnw.stk) <- computeCatch(codnw.stk)
landings(codnw.stk) <- computeLandings(codnw.stk)
discards(codnw.stk) <- computeDiscards(codnw.stk)
harvest.spwn(codnw.stk) <- 0
m.spwn(codnw.stk) <- 0
codnw.stk <- setPlusGroup(codnw.stk, 7)

## [1] "maxfbar has been changed to accomodate new plusgroup"

range(codnw.stk)[c("minfbar", "maxfbar")] <- c(2, 4)
codnw.ids <- readFLIndices("datacod/NW/survey.dat")
```

The Skagerrak sub-unit (sk)

```
codsk.stk <- readFLStock("datacod/Skagerrak/files.ind", name = "NSCOD-SK",
    no.discards = TRUE, harvest.units = "f")
catch(codsk.stk) <- computeCatch(codsk.stk)
landings(codsk.stk) <- computeLandings(codsk.stk)
discards(codsk.stk) <- computeDiscards(codsk.stk)
harvest.spwn(codsk.stk) <- 0
m.spwn(codsk.stk) <- 0
codsk.stk <- setPlusGroup(codsk.stk, 7)

## [1] "maxfbar has been changed to accomodate new plusgroup"

range(codsk.stk)[c("minfbar", "maxfbar")] <- c(2, 4)
codsk.ids <- readFLIndices("datacod/Skagerrak/survey.dat")
```

The Southern sub-unit (so)

```
codso.stk <- readFLStock("datacod/South/files.ind", name = "NSCOD-SO",
    no.discards = TRUE, harvest.units = "f")
catch(codso.stk) <- computeCatch(codso.stk)
landings(codso.stk) <- computeLandings(codso.stk)
discards(codso.stk) <- computeDiscards(codso.stk)
harvest.spwn(codso.stk) <- 0
m.spwn(codso.stk) <- 0
codso.stk <- setPlusGroup(codso.stk, 7)
```

```
## [1] "maxfbar has been changed to accomodate new plusgroup"

range(codso.stk)[c("minfbar", "maxfbar")] <- c(2, 4)
codso.ids <- readFLIndices("datacod/South/survey.dat")
```

The Viking sub-unit (vk)

```
codvk.stk <- readFLStock("datacod/Viking/files.ind", name = "NSCOD-VK",
    no.discards = TRUE, harvest.units = "f")
catch(codvk.stk) <- computeCatch(codvk.stk)
landings(codvk.stk) <- computeLandings(codvk.stk)
discards(codvk.stk) <- computeDiscards(codvk.stk)
harvest.spwn(codvk.stk) <- 0
m.spwn(codvk.stk) <- 0
codvk.stk <- setPlusGroup(codvk.stk, 7)

## [1] "maxfbar has been changed to accomodate new plusgroup"

range(codvk.stk)[c("minfbar", "maxfbar")] <- c(2, 4)
codvk.ids <- readFLIndices("datacod/Viking/survey.dat")
```

3.2.2 Two subunits option

The South + Northwest sub-unit (nwso)

```
# NW + SO

codnwso.stk <- readFLStock("datacod/NWSO/files.ind", name = "NSCOD-NWSO",
    no.discards = TRUE, harvest.units = "f")
catch(codnwso.stk) <- computeCatch(codnwso.stk)
landings(codnwso.stk) <- computeLandings(codnwso.stk)
discards(codnwso.stk) <- computeDiscards(codnwso.stk)
harvest.spwn(codnwso.stk) <- 0
m.spwn(codnwso.stk) <- 0
codnwso.stk <- setPlusGroup(codnwso.stk, 7)

## [1] "maxfbar has been changed to accomodate new plusgroup"

range(codnwso.stk)[c("minfbar", "maxfbar")] <- c(2, 4)
codnwso.ids <- readFLIndices("datacod/NWSO/survey.dat")

codnwso.stk <- window(codnwso.stk, start = 2003, end = 2013)
codnwso.ids <- window(codnwso.ids, start = 2003, end = 2013)
```

The Skagerrak + Viking sub-unit (skvk)

```
# SK + VK
codskvk.stk <- readFLStock("datacod/SKVK/files.ind", name = "NSCOD-SKVK",
    no.discards = TRUE, harvest.units = "f")
catch(codskvk.stk) <- computeCatch(codskvk.stk)
landings(codskvk.stk) <- computeLandings(codskvk.stk)
discards(codskvk.stk) <- computeDiscards(codskvk.stk)
harvest.spwn(codskvk.stk) <- 0
m.spwn(codskvk.stk) <- 0
codskvk.stk <- setPlusGroup(codskvk.stk, 7)

## [1] "maxfbar has been changed to accomodate new plusgroup"

range(codskvk.stk)[c("minfbar", "maxfbar")] <- c(2, 4)
codskvk.ids <- readFLIndices("datacod/SKVK/survey.dat")

codskvk.stk <- window(codskvk.stk, start = 2003, end = 2013)
codskvk.ids <- window(codskvk.ids, start = 2003, end = 2013)
```

3.3 Model fits

The process to fit models to the sub-units' datasets was initiated by fitting the default model settings and afterwards trying to adjust the sub-models to get better fits. The diagnostics were largely based on visual analysis of the residuals.

3.3.1 Quick and dirty - the default method

```
cod.fit0 <- sca(window(cod1, end = 2013), window(cod.tun, end = 2013))
plot(window(cod1, end = 2013) + cod.fit0)
```

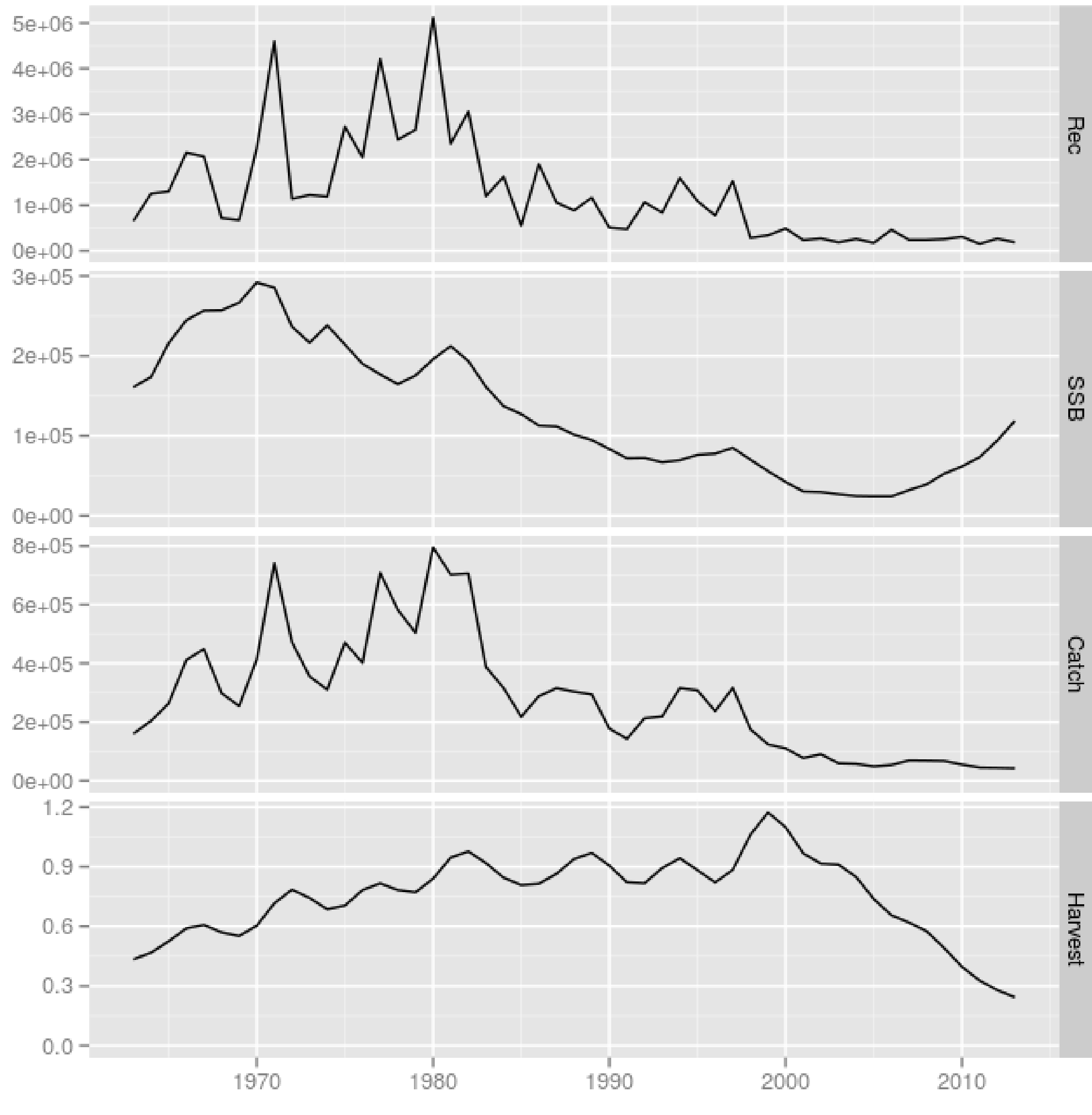

Figure 3.2: Cod in the North Sea - a4a default assessment

```
stk <- window(codnw.stk, start = 2003, end = 2013)
ids <- window(codnw.ids, start = 2003, end = 2013)
codnw.fit0 <- sca(stk, ids)
plot(stk + codnw.fit0)
```

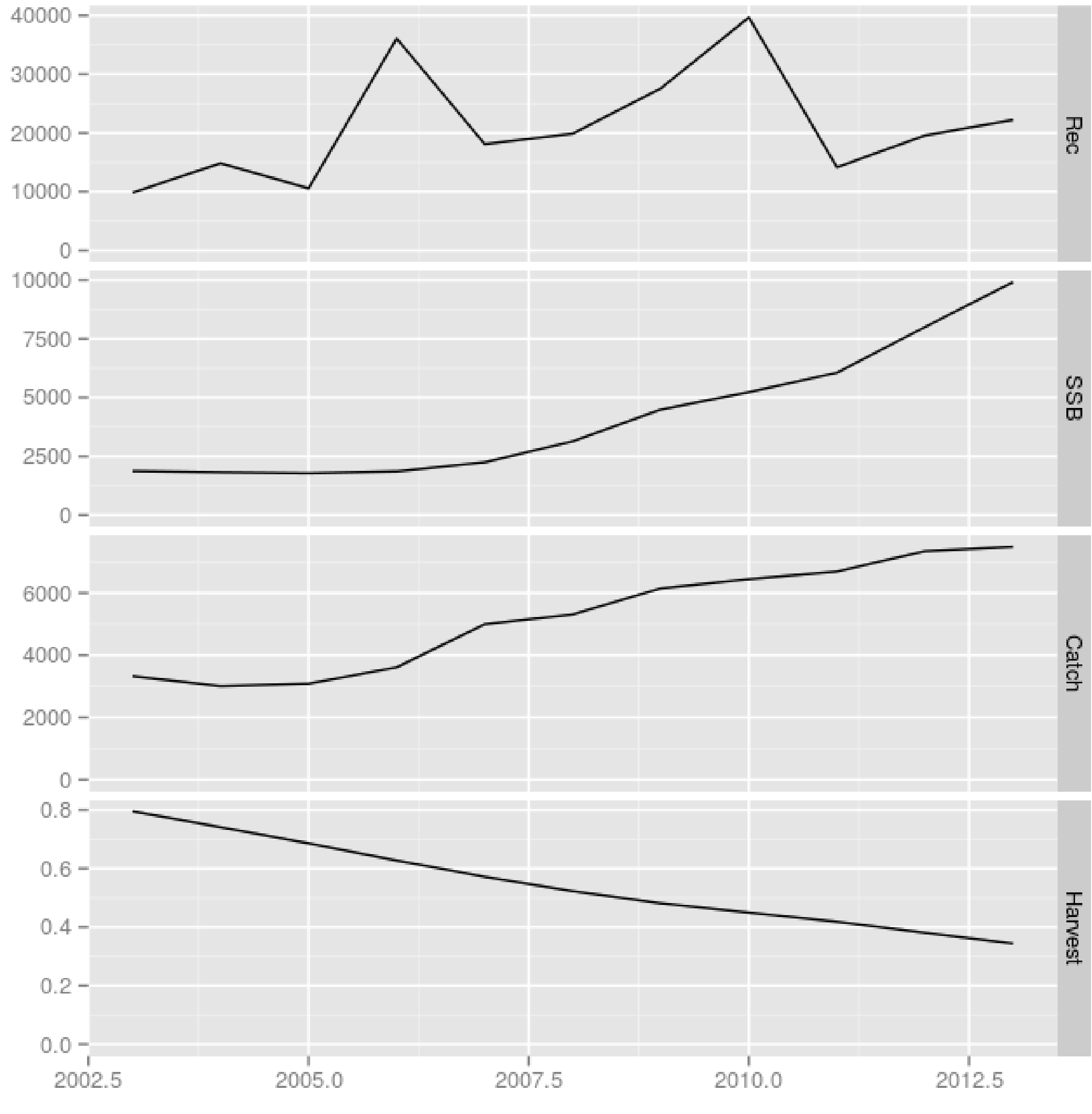

Figure 3.3: Cod in the Northwest North Sea sub-unit - a4a default assessment

```
stk <- window(codsk.stk, start = 2003, end = 2013)
ids <- window(codsk.ids, start = 2003, end = 2013)
codsk.fit0 <- sca(stk, ids)
plot(stk + codsk.fit0)
```

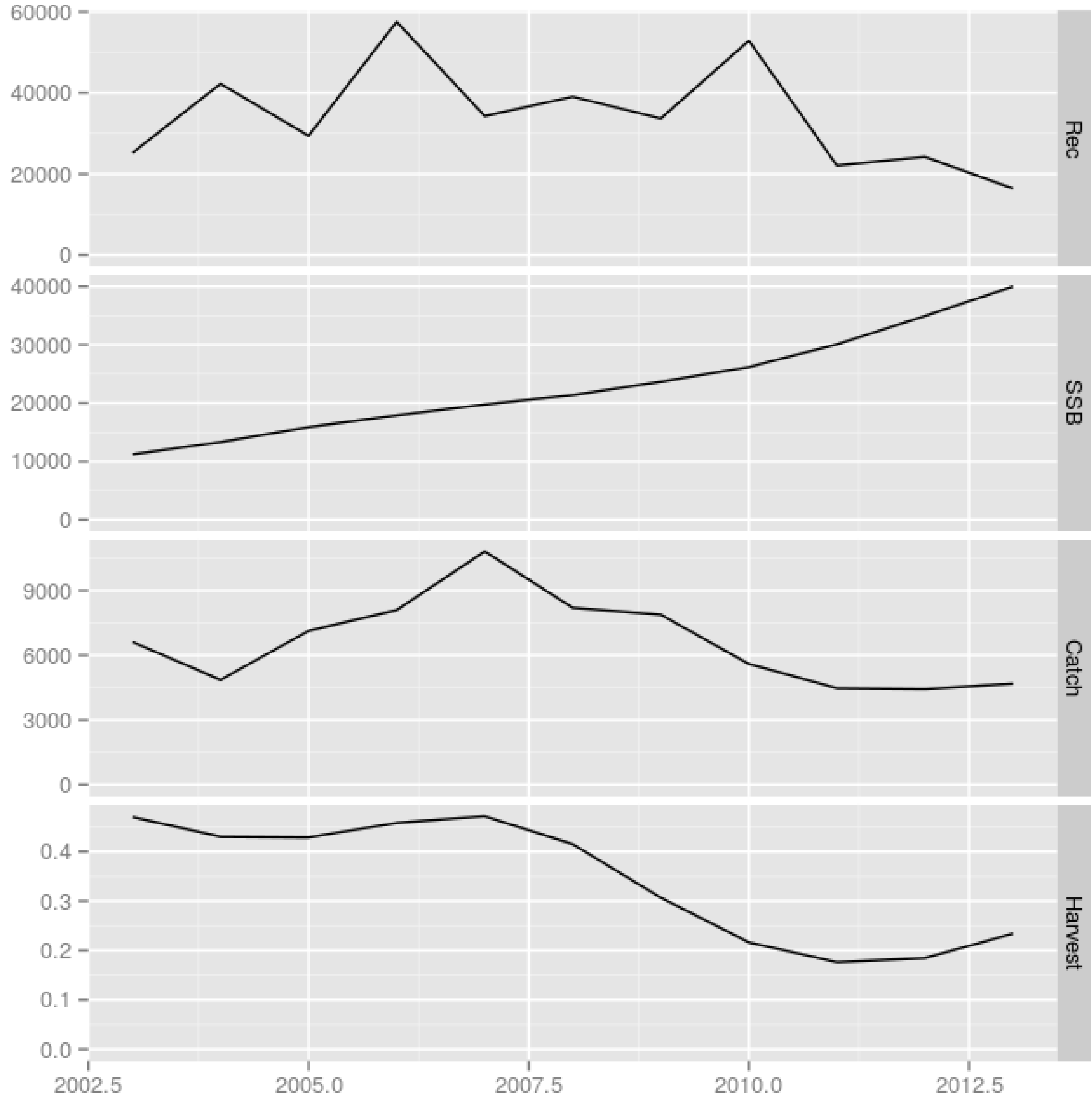

Figure 3.4: Cod in the Skagerrak sub-unit - a4a default assessment

```r
stk <- window(codso.stk, start = 2003, end = 2013)
ids <- window(codso.ids, start = 2003, end = 2013)
codso.fit0 <- sca(stk, ids)
plot(stk + codso.fit0)
```

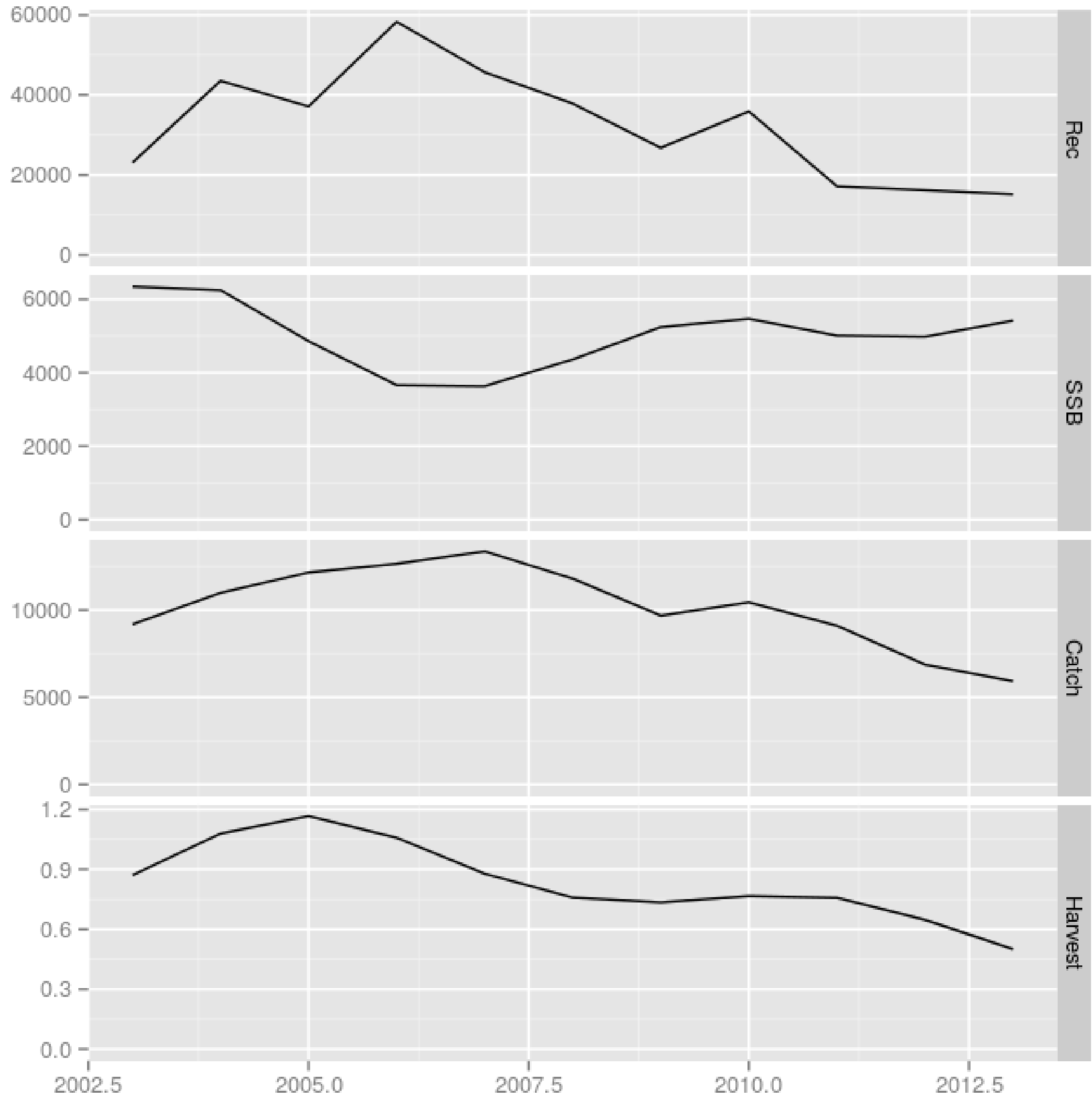

Figure 3.5: Cod in the South North Sea sub-unit - a4a default assessment

```r
stk <- window(codvk.stk, start = 2003, end = 2013)
ids <- window(codvk.ids, start = 2003, end = 2013)
codvk.fit0 <- sca(stk, ids)
plot(stk + codvk.fit0)
```

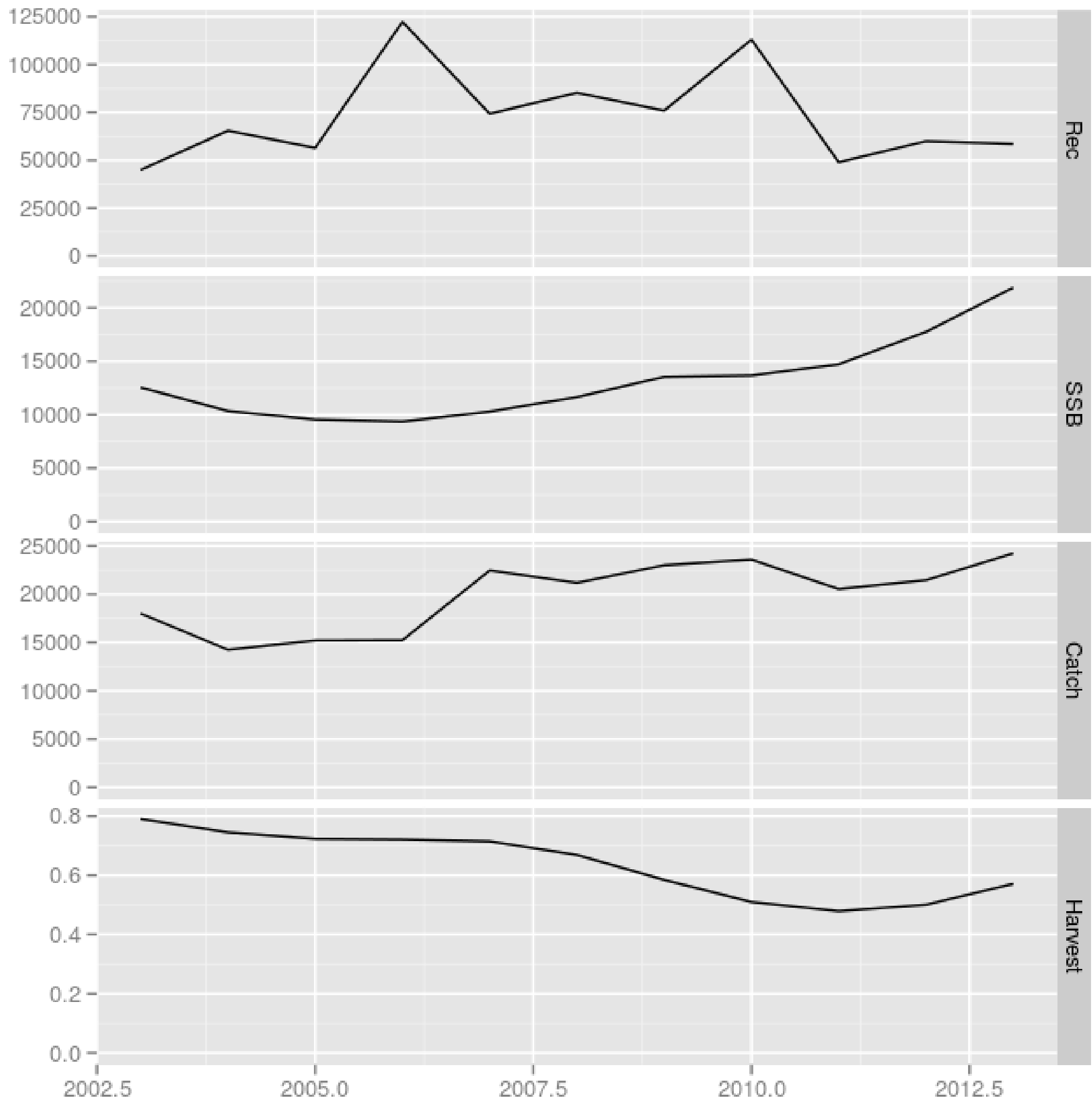

Figure 3.6: Cod in the Viking sub-unit - a4a default assessment

```
codnwso.fit0 <- sca(codnwso.stk, codnwso.ids)
plot(codnwso.stk + codnwso.fit0)
```

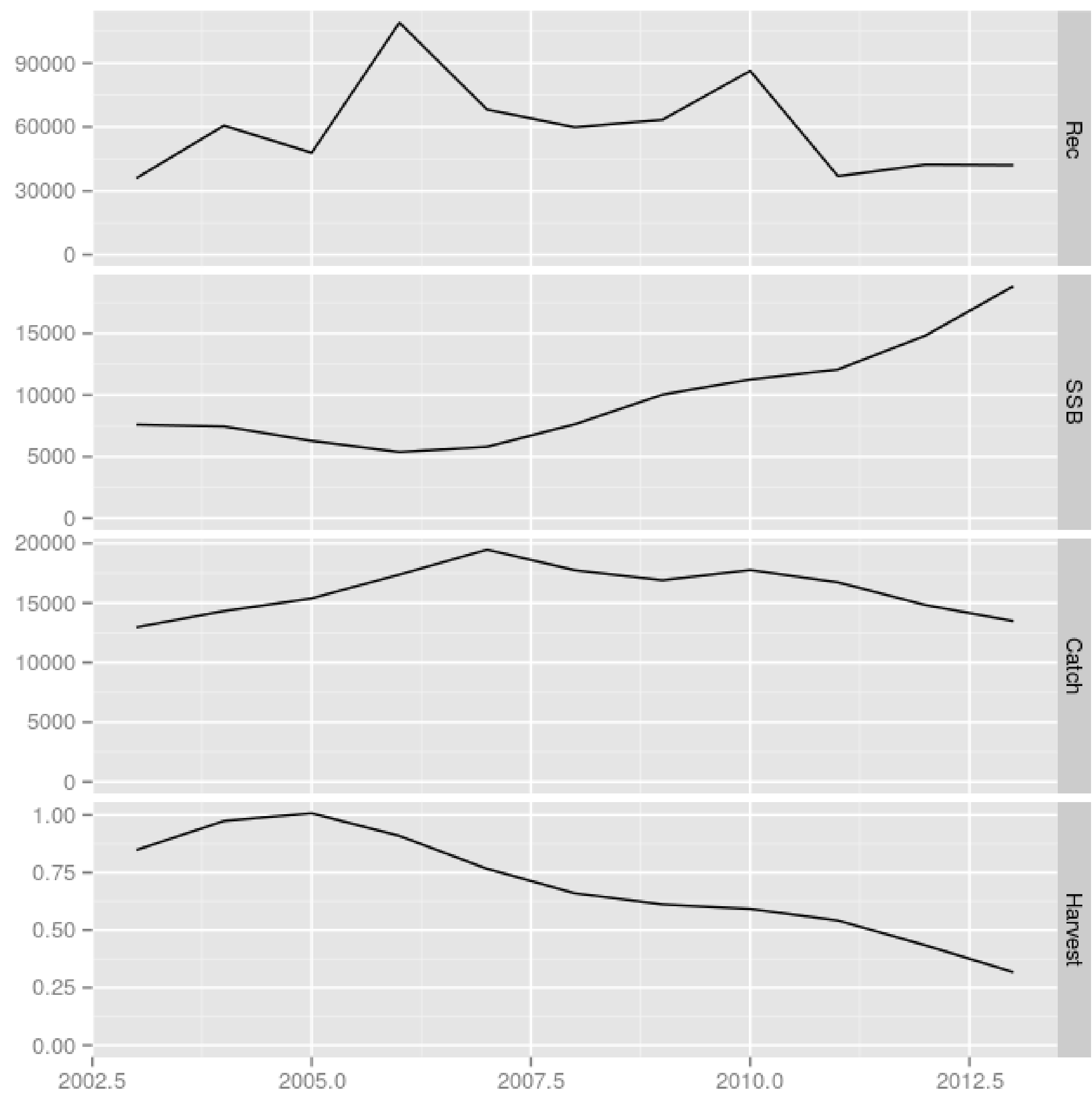

Figure 3.7: Cod in the South + Northwest sub-unit - a4a default assessment

```
codskvk.fit0 <- sca(codskvk.stk, codskvk.ids)
plot(codskvk.stk + codskvk.fit0)
```

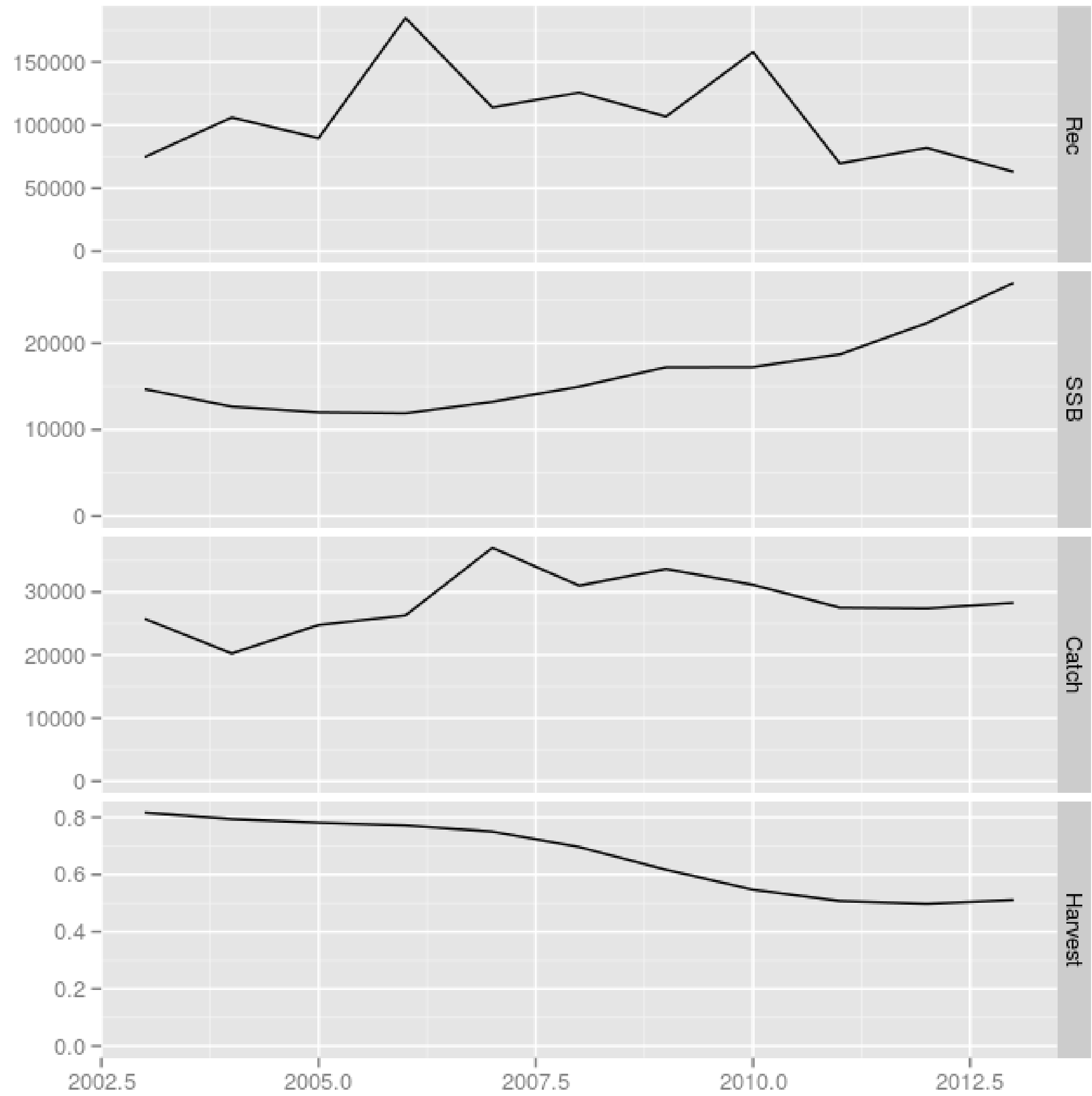

Figure 3.8: Cod in the Skagerrak + Viking sub-unit - a4a default assessment

3.3.2 Improving the fits

The North Sea stock

Two attempts were carried out, one using the first quarter IBTS survey, which would mimic the official assessment, and a second one using both the first and the third quarter IBTS survey.

```r
# IBTS Q1
stk <- cod1
ids <- window(cod.tun[1], end = 2013)
fmod <- ~te(age, year, k = c(4, 20)) + s(year, k = 3, by = as.numeric(age ==
    1))
qmod <- list(~s(age, k = 4))
fit <- sca(stk, ids, fmodel = fmod, qmodel = qmod, fit = "assessment")
```

```r
res <- residuals(fit, stk, ids)
plot(res)
```

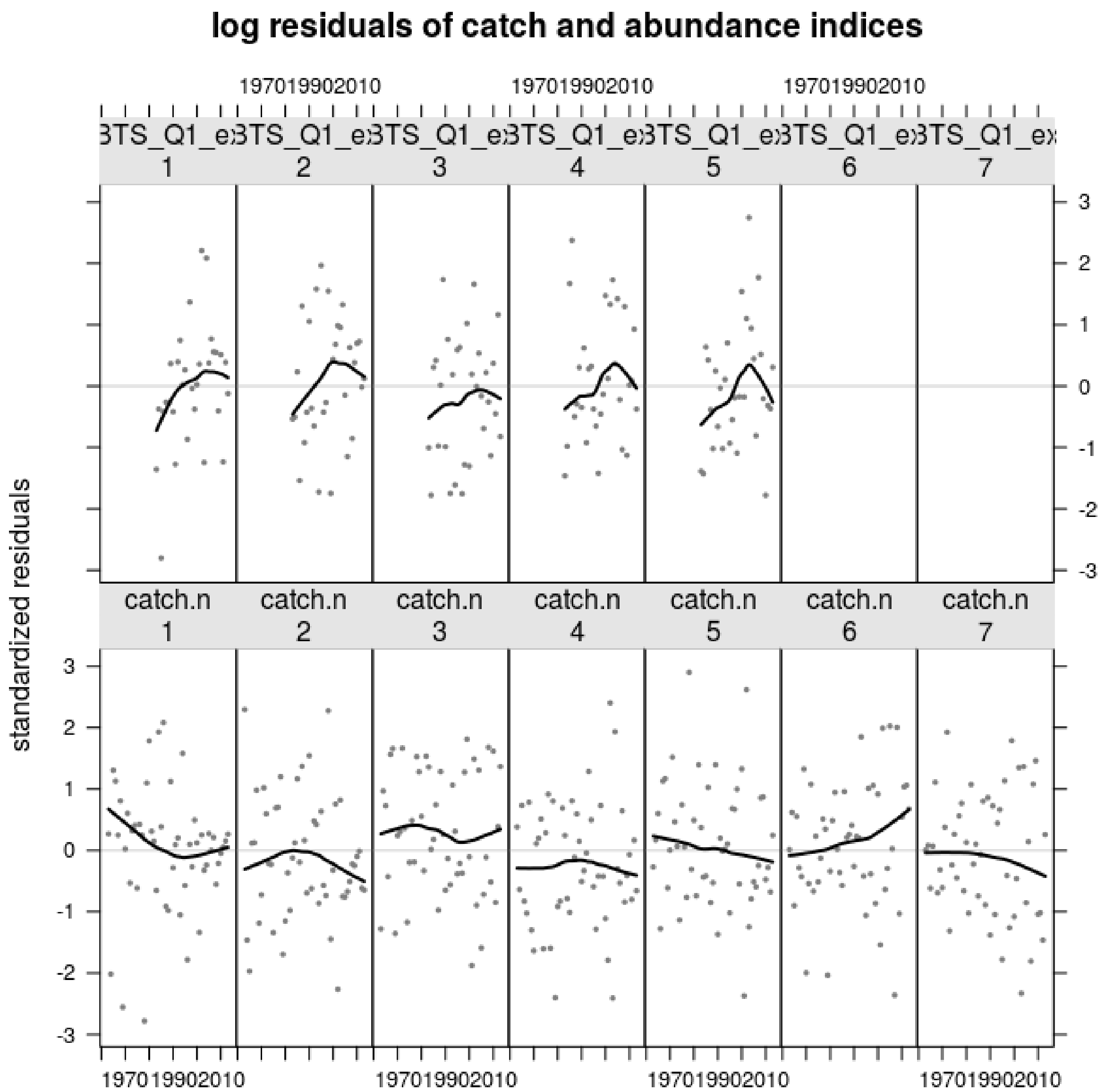

Figure 3.9: NSCod with IBTS Q1 assessment residuals

```
wireframe(data ~ year + age, data = harvest(fit))
```

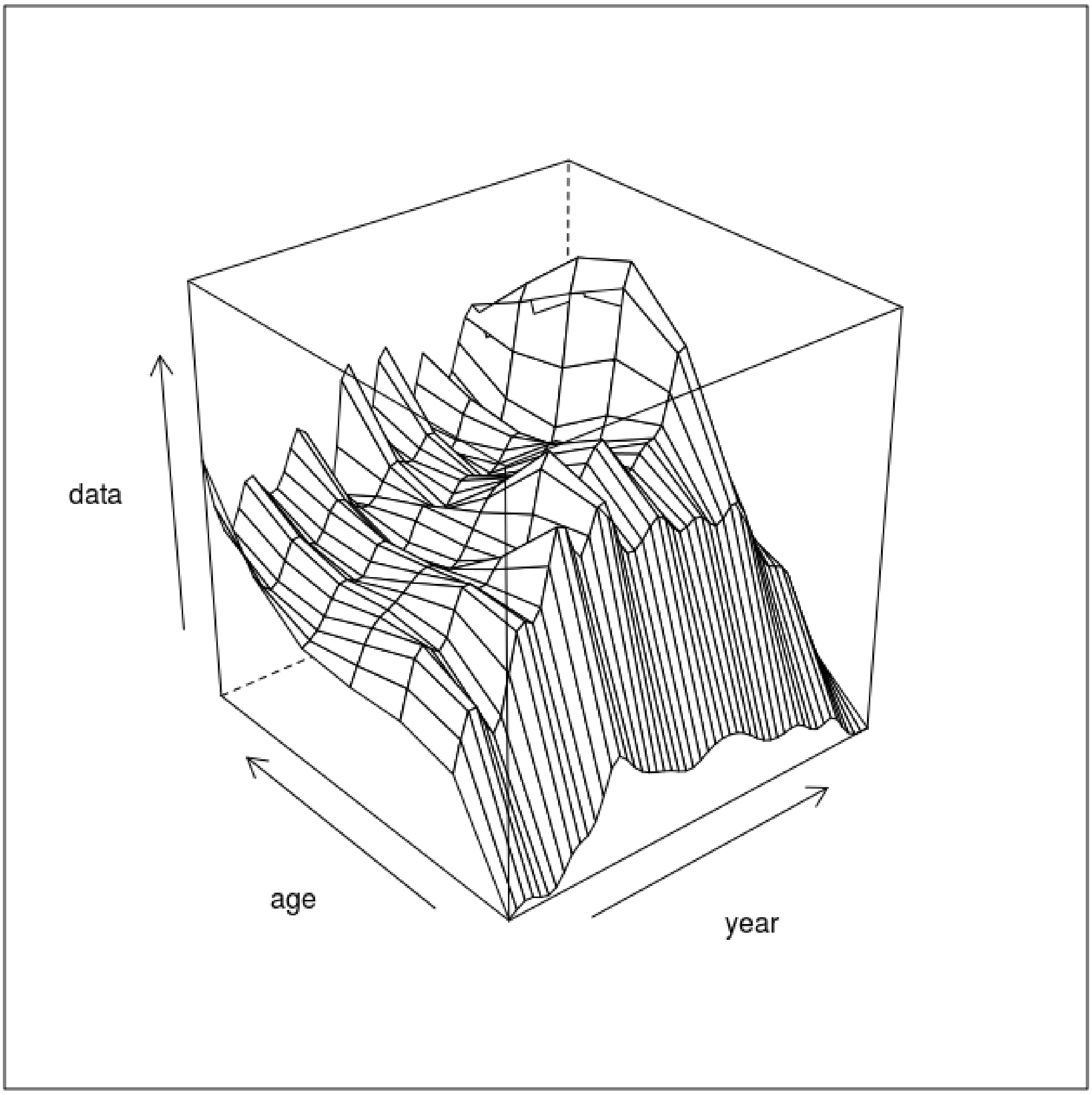

Figure 3.10: NSCod with IBTS Q1 assessment F-at-age surface

```
cod.fstks <- stk + simulate(fit, 1000)
plot(cod.fstks)
```

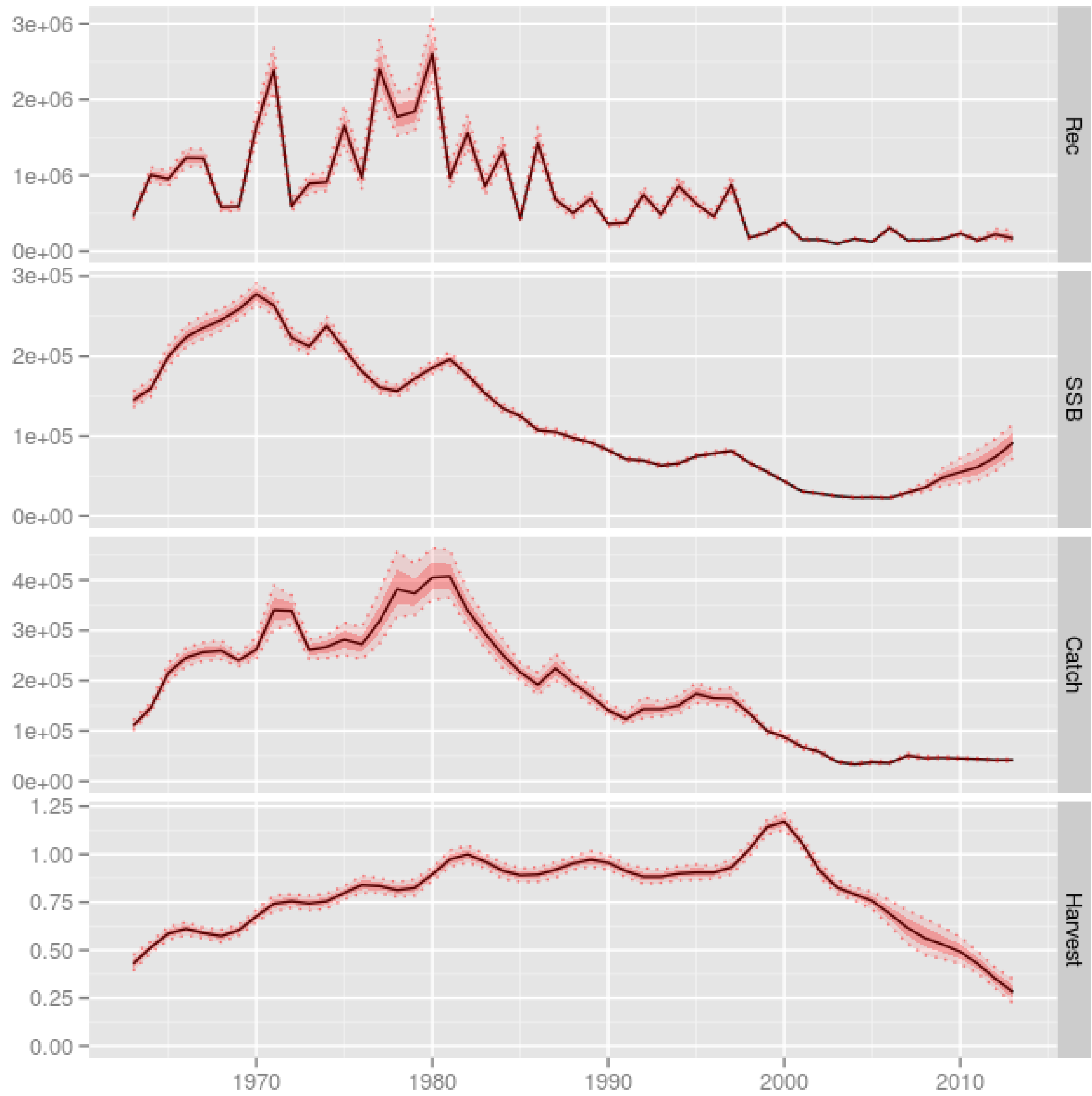

Figure 3.11: NSCod with IBTS Q1 assessment summary

```
cod.fit <- fit
cod.fstk <- stk + fit
plot(FLStocks(a4a = cod.fstk, sam = cod1))
```

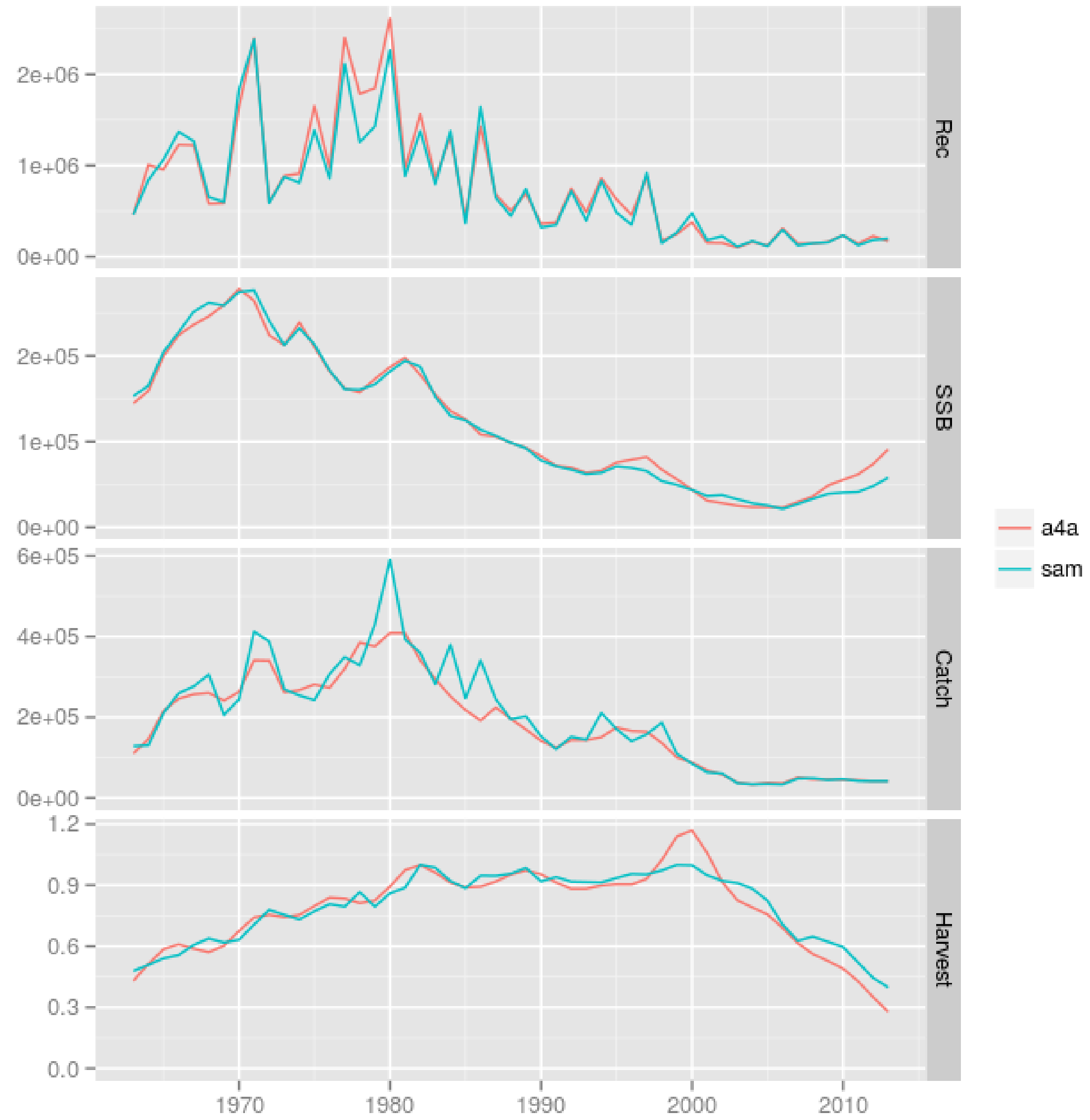

Figure 3.12: NSCod with IBTS Q1 assessment comparison with official

```
cod.sr <- fmle(as.FLSR(cod.fstk, model = "bevholt"), control = list(trace = 0))
plot(cod.sr)
```

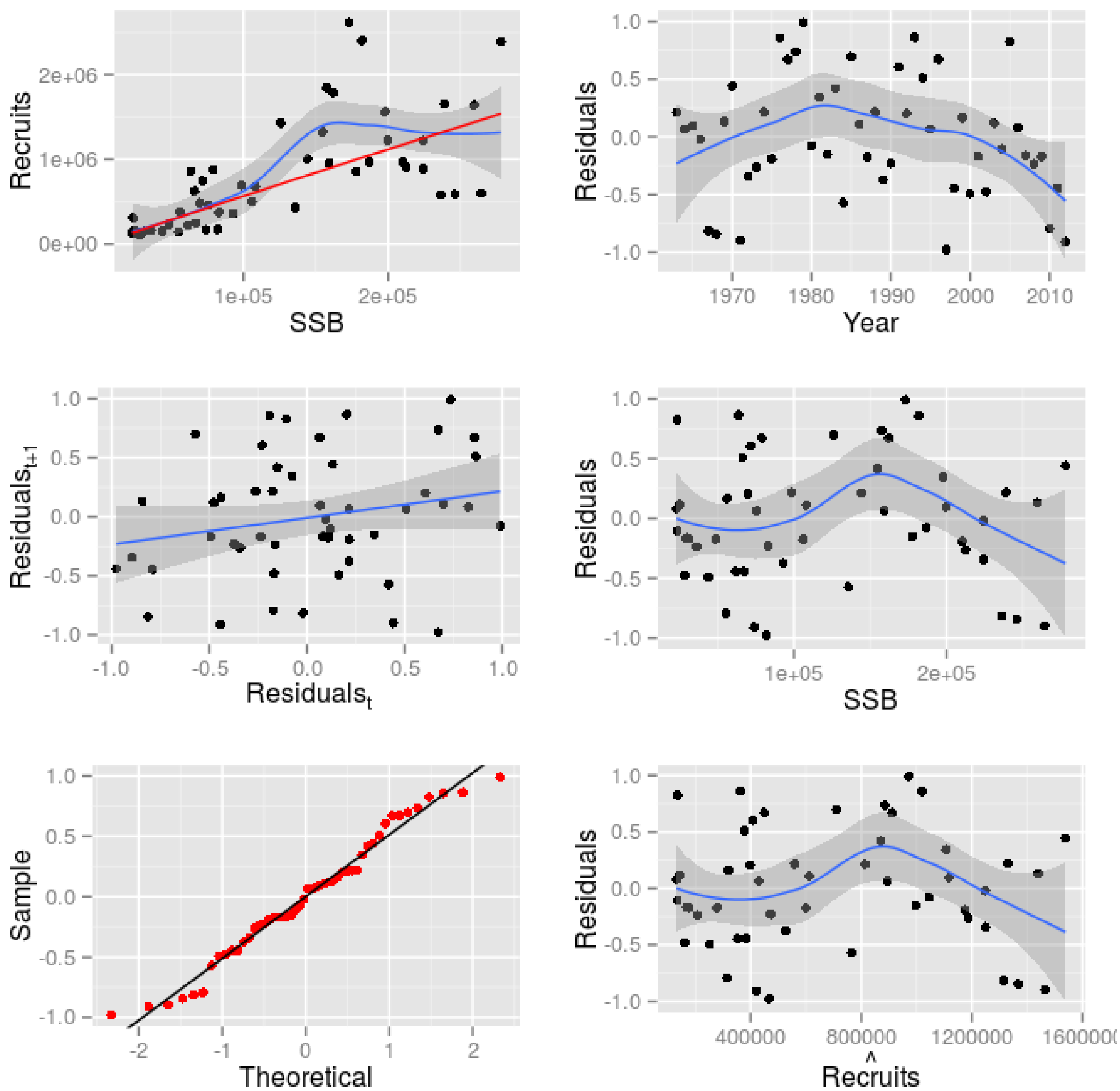

Figure 3.13: NSCod with IBTS Q1 stock-recruitment

```
# IBTS Q1 + Q3
ids <- window(cod.tun, end = 2013)
# fmod <- ~ s(age, k=5, by=breakpts(year, 1982)) + s(year,
# k=15, by=breakpts(age, c(1.5:6))) fmod <- ~ te(age, year,
# k=c(5, 15)) + s(year-age, k=3)
fmod <- ~te(age, year, k = c(4, 20)) + s(year, k = 3, by = as.numeric(age ==
    1))
qmod <- list(~s(age, k = 4), ~s(age, k = 4) + s(year, k = 3))
fit <- sca(stk, ids, fmodel = fmod, qmodel = qmod, fit = "assessment")
```

```r
res <- residuals(fit, stk, ids)
plot(res)
```

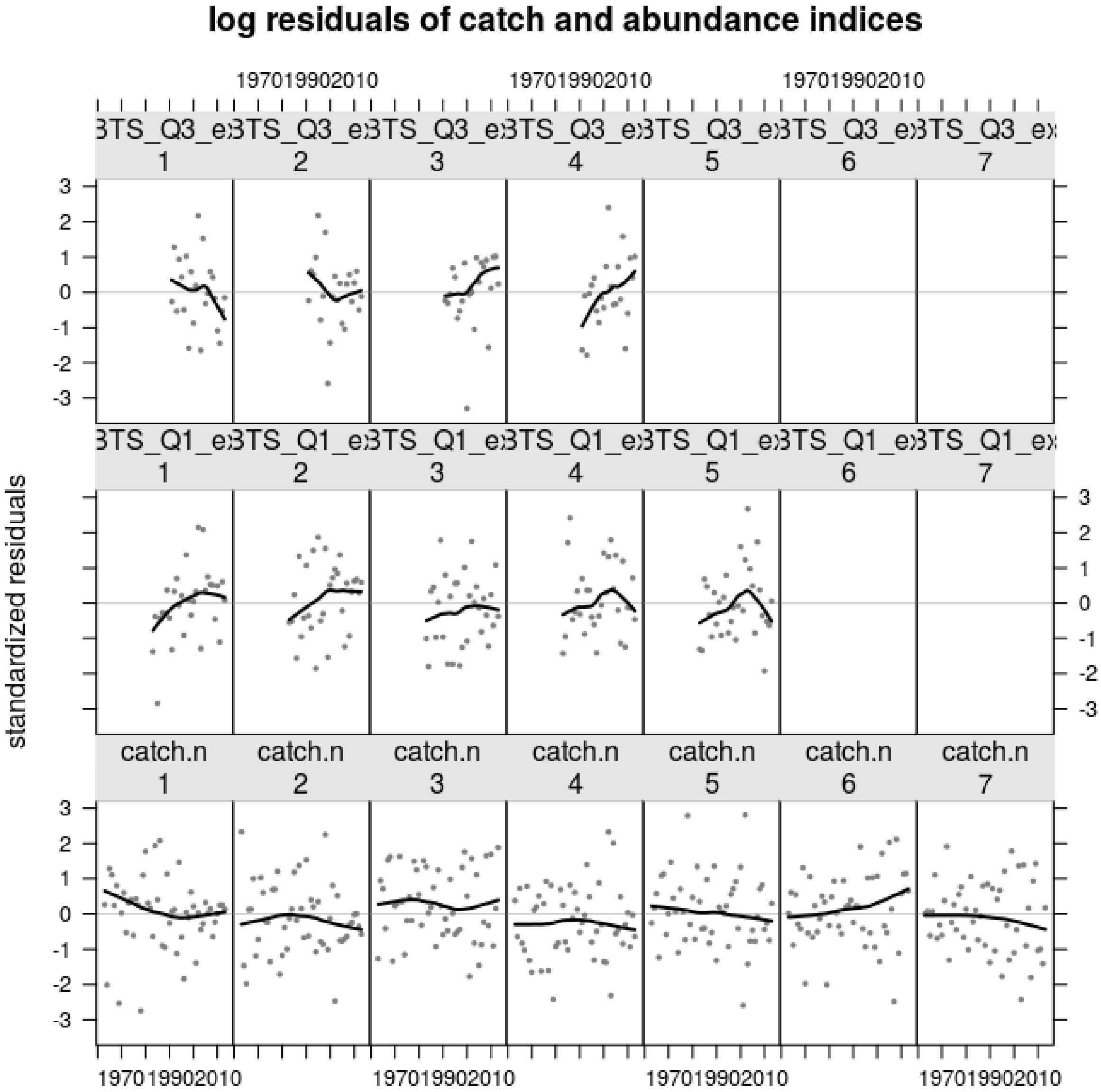

Figure 3.14: NSCod with IBTS Q1+Q3 assessment residuals

```r
wireframe(data ~ year + age, data = harvest(fit))
```

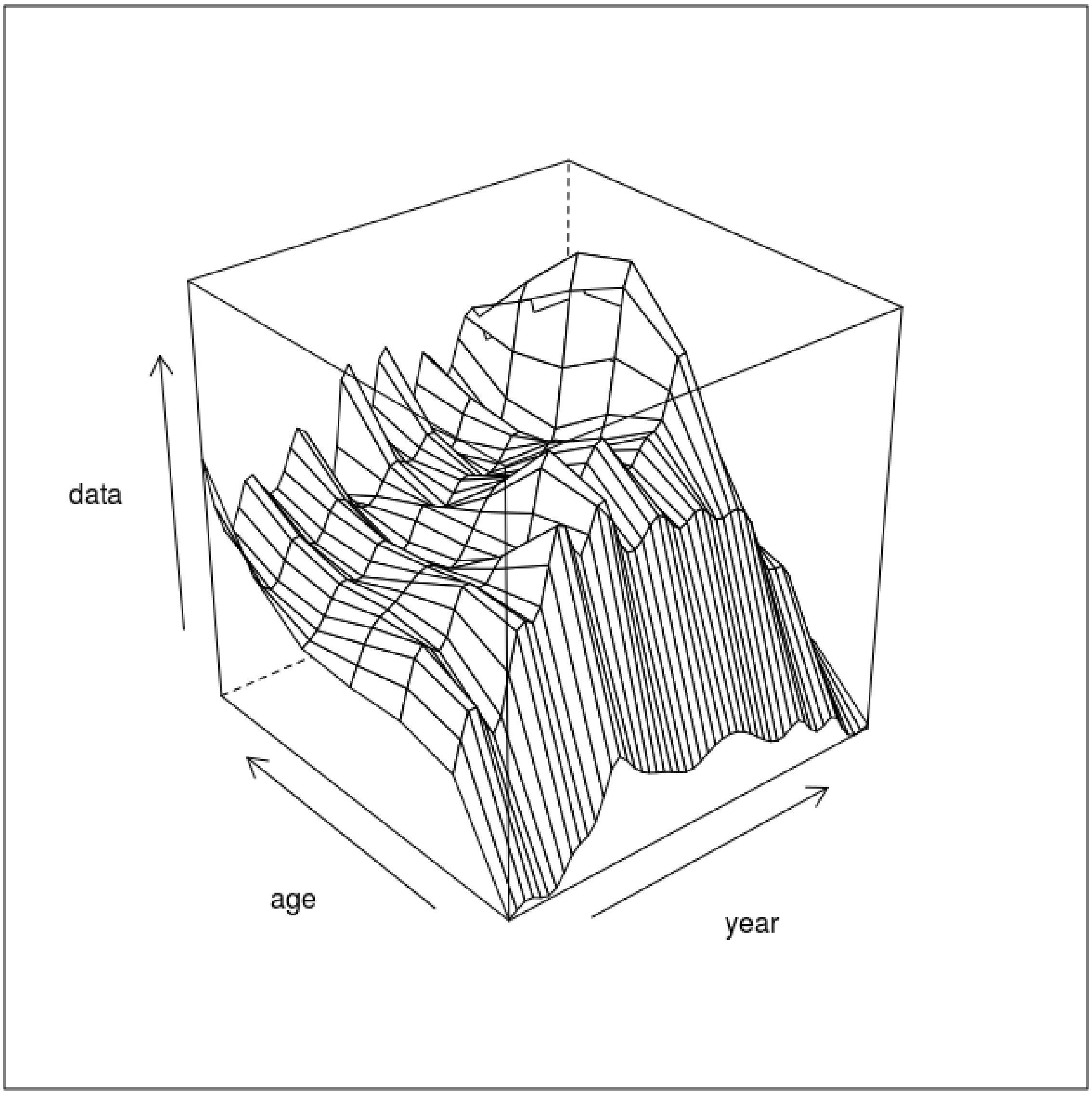

Figure 3.15: NSCod with IBTS Q1+Q3 assessment F-at-age surface

```r
cod.fstks <- stk + simulate(fit, 1000)
plot(cod.fstks)
```

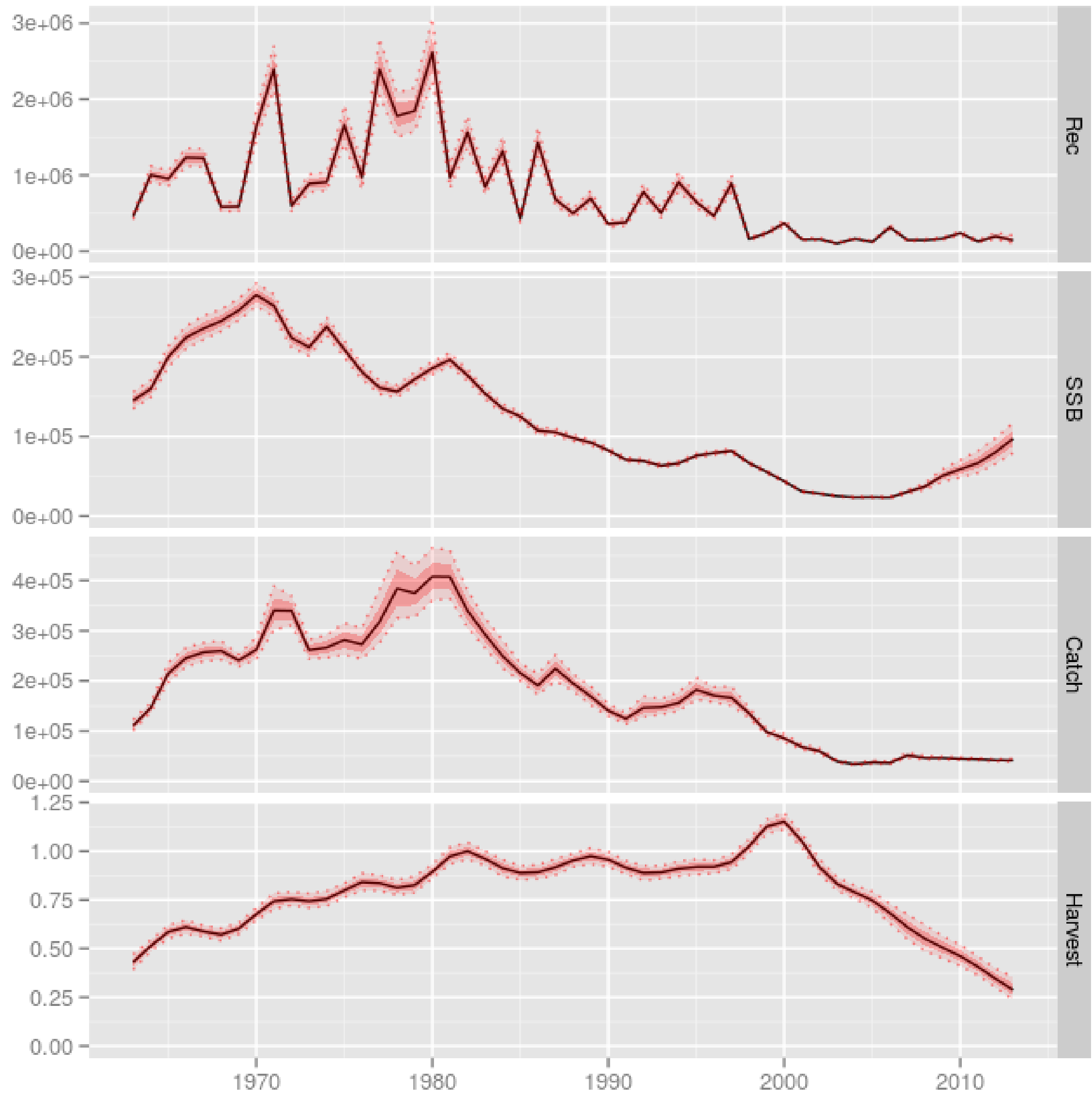

Figure 3.16: NSCod with IBTS Q1+Q3 assessment summary

```
cod.fit <- fit
cod.fstk <- stk + fit
plot(FLStocks(a4a = cod.fstk, sam = cod1))
```

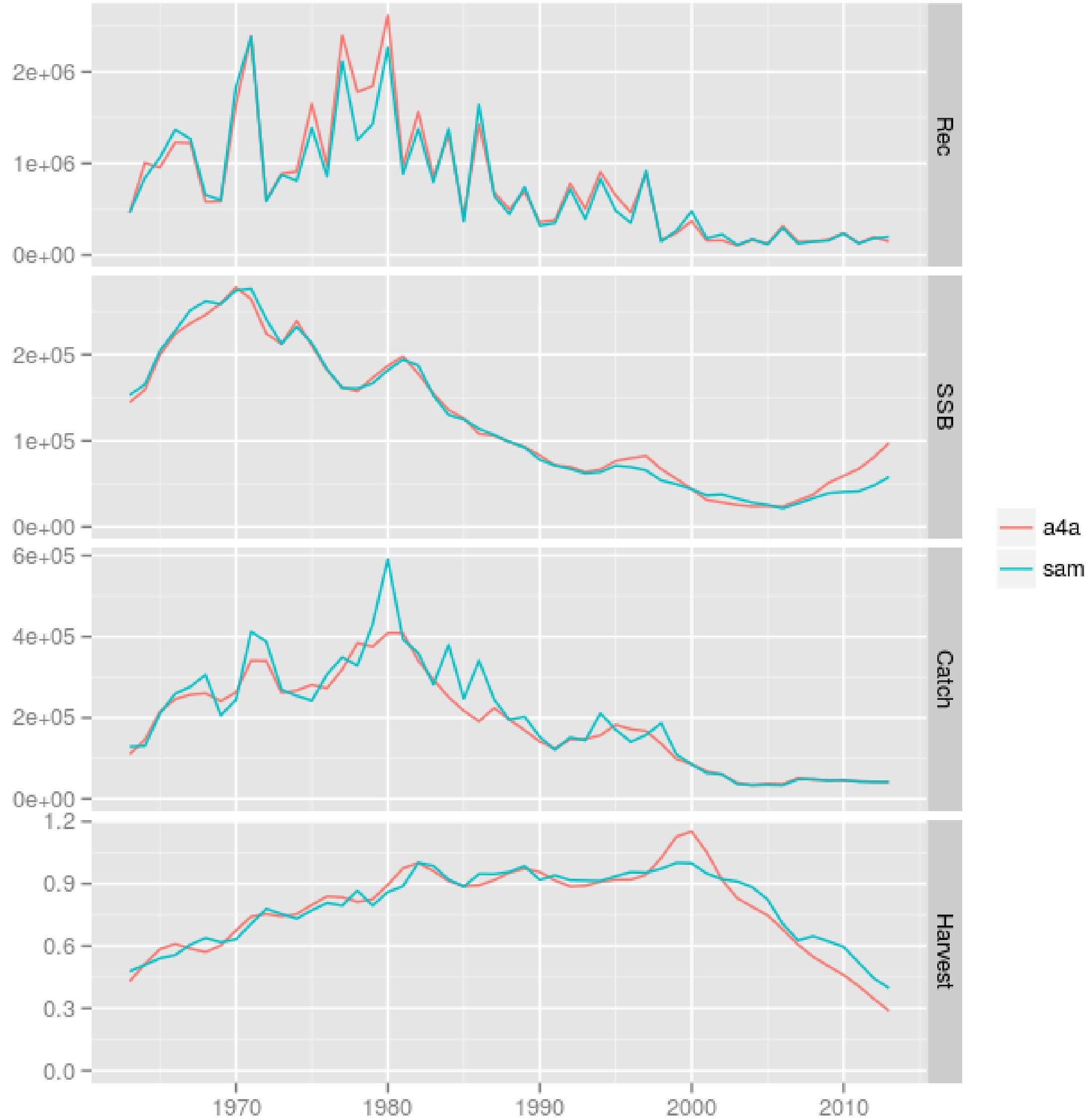

Figure 3.17: NSCod with IBTS Q1+Q3 assessment comparison with official

```
cod.sr <- fmle(as.FLSR(cod.fstk, model = "bevholt"), control = list(trace = 0))
plot(cod.sr)
```

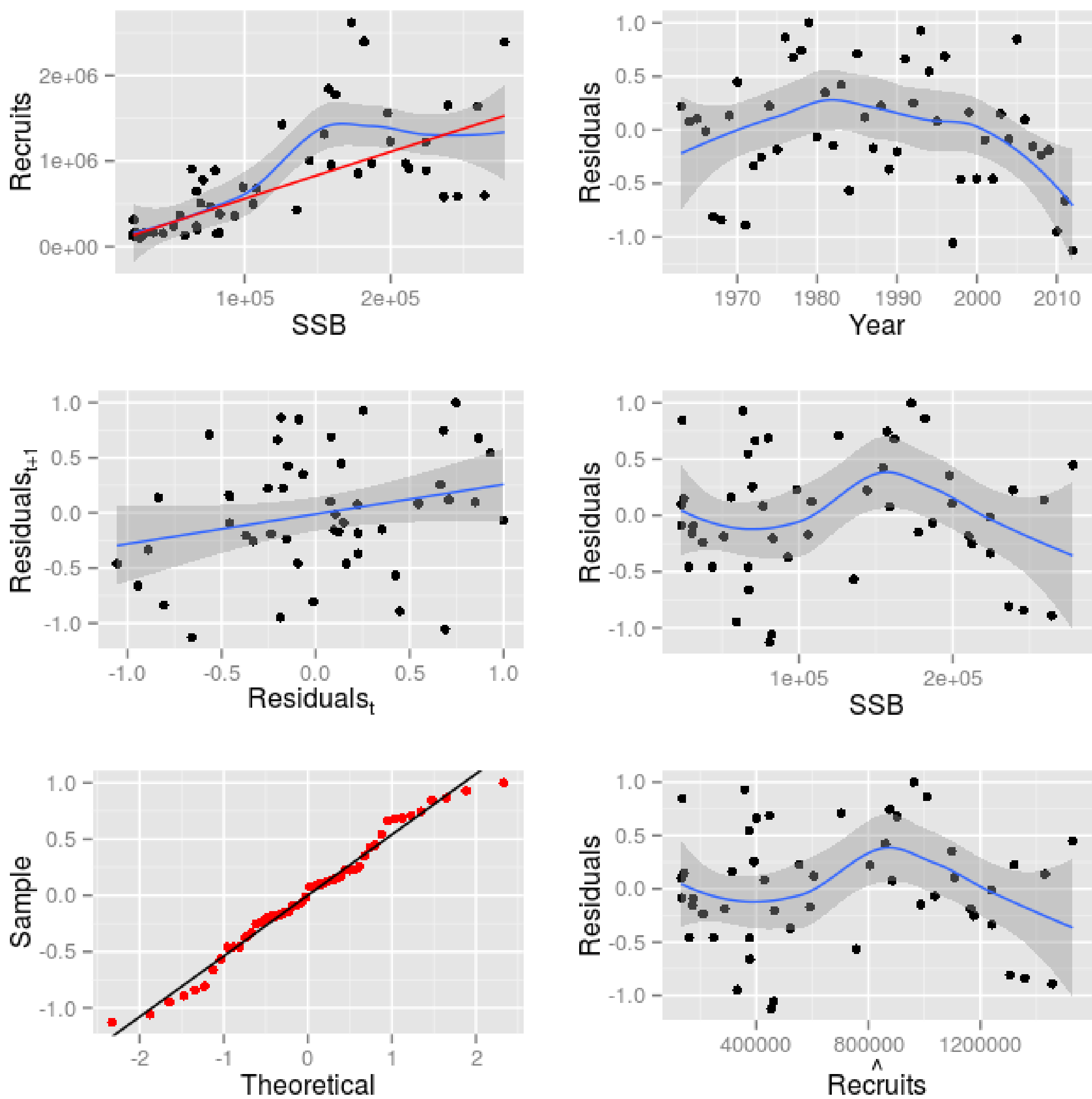

Figure 3.18: NSCod with IBTS Q1+Q3 stock-recruitment

The outcomes are similar to the official assessment, although in the last years the a4a model tends to estimate lower Fs and larger SSBs than SAM. The importance to replicate other stock assessment models is quite important in the case of MSE analysis, where the management procedure should replicate the real process as much as possible.

The Northwestern sub-unit (nw)

```
stk <- window(codnw.stk, start = 2003, end = 2013)
ids <- window(codnw.ids, start = 2003, end = 2013)
```

```
fmod <- ~s(age, k = 6) + s(year, k = 8, by = breakpts(age, c(1.5:5)))
qmod <- list(~s(age, k = 4) + s(year, k = 3, by = as.numeric(age ==
    6)), ~s(age, k = 4))
fit <- sca(stk, ids, fmodel = fmod, qmodel = qmod, fit = "assessment")
```

```
res <- residuals(fit, stk, ids)
plot(res)
```

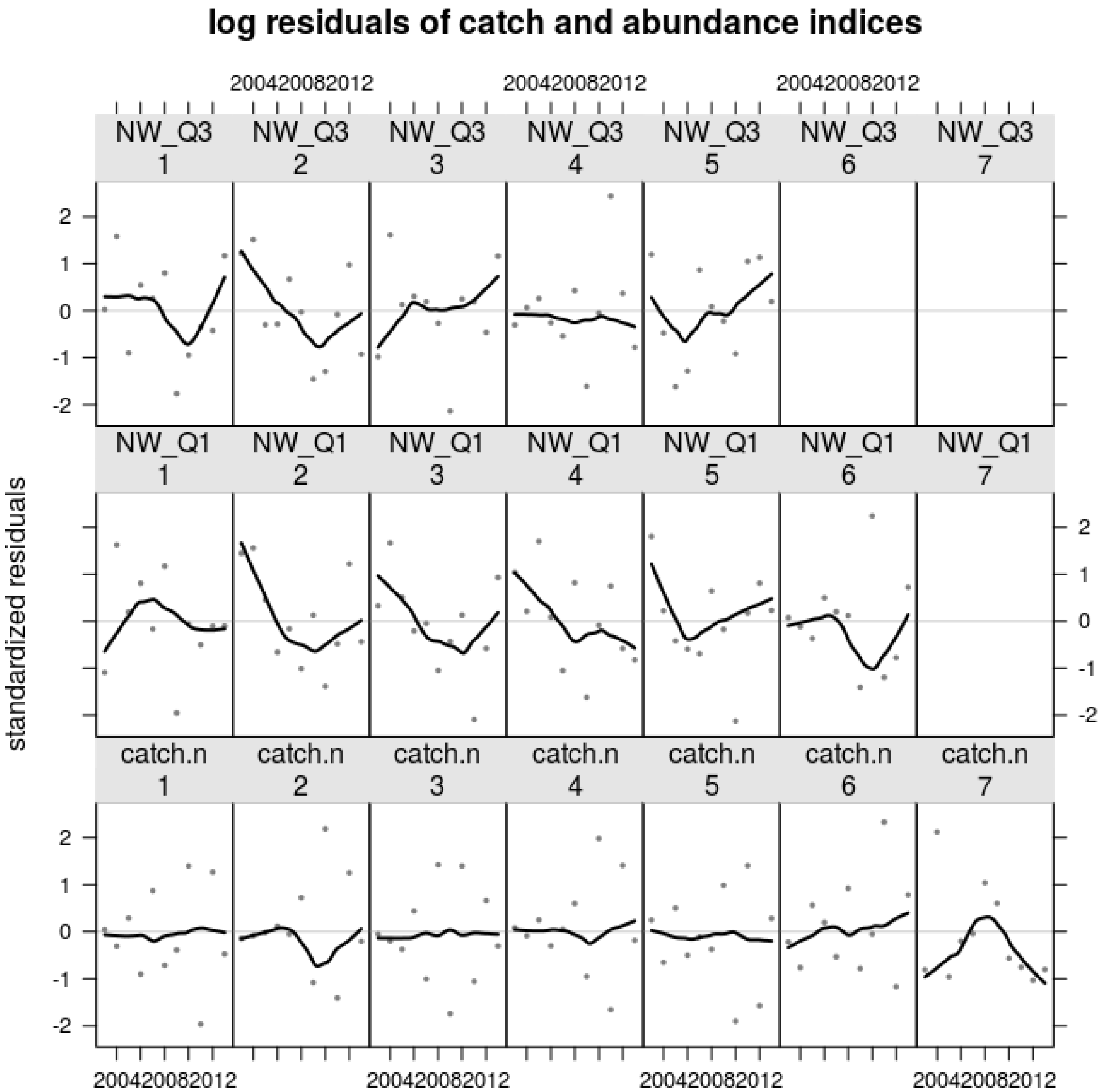

Figure 3.19: Cod-nw with IBTS Q1+Q3 assessment residuals

```r
qqmath(res)
```

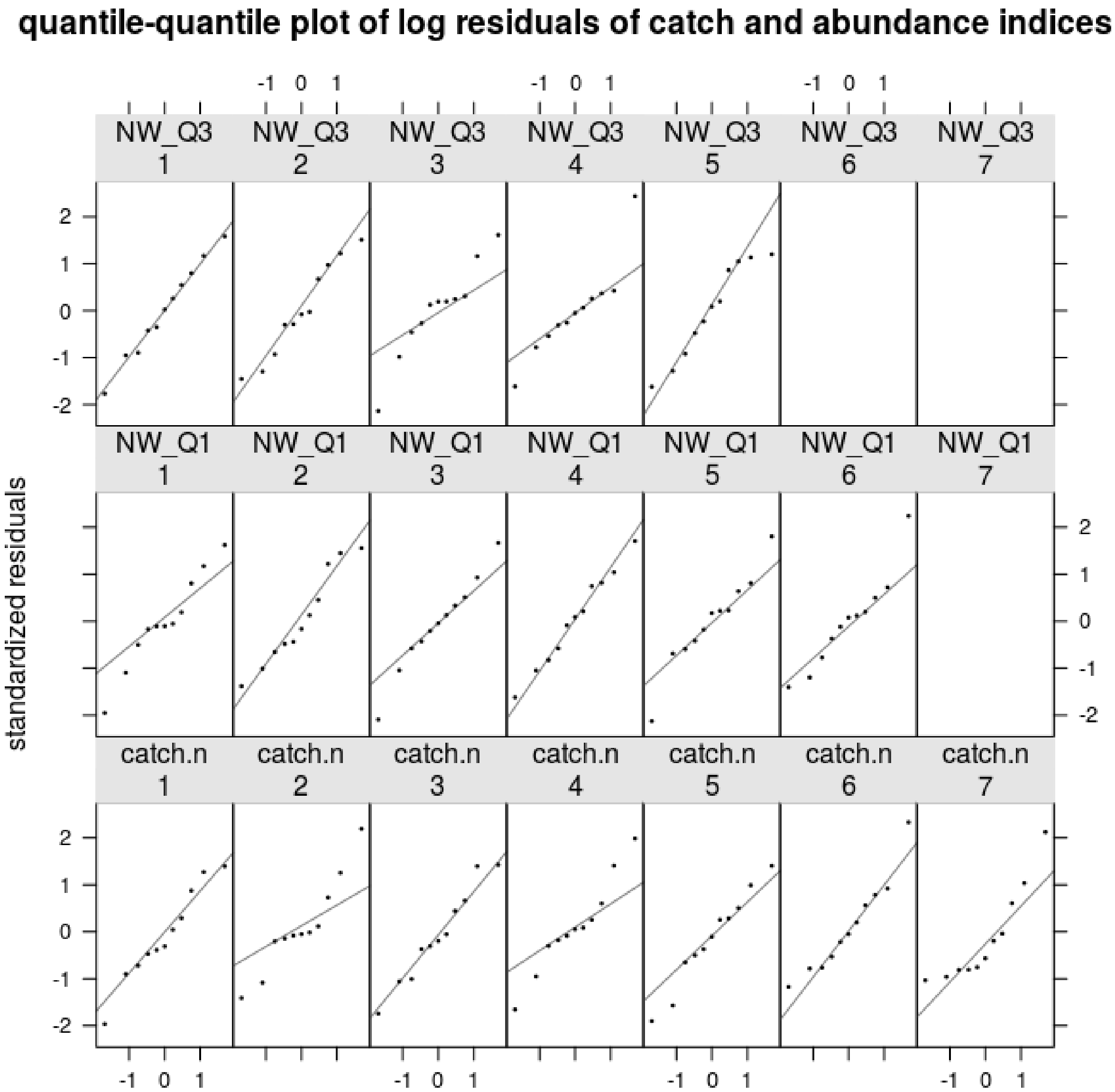

Figure 3.20: Cod-nw with IBTS Q1+Q3 assessment residuals

```r
bubbles(res)
```

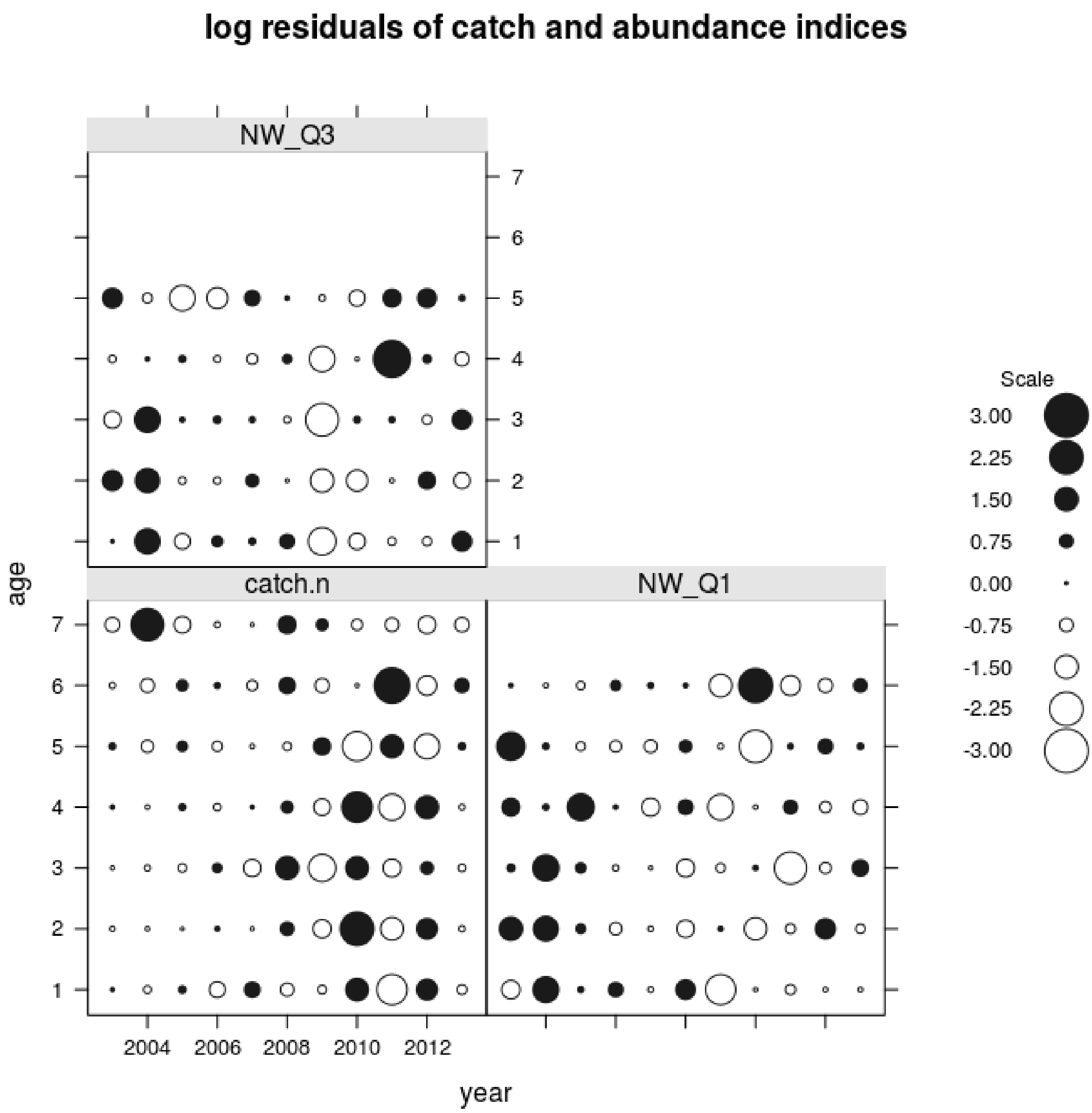

Figure 3.21: Cod-nw with IBTS Q1+Q3 assessment residuals

```r
plot(fit, stk)
```

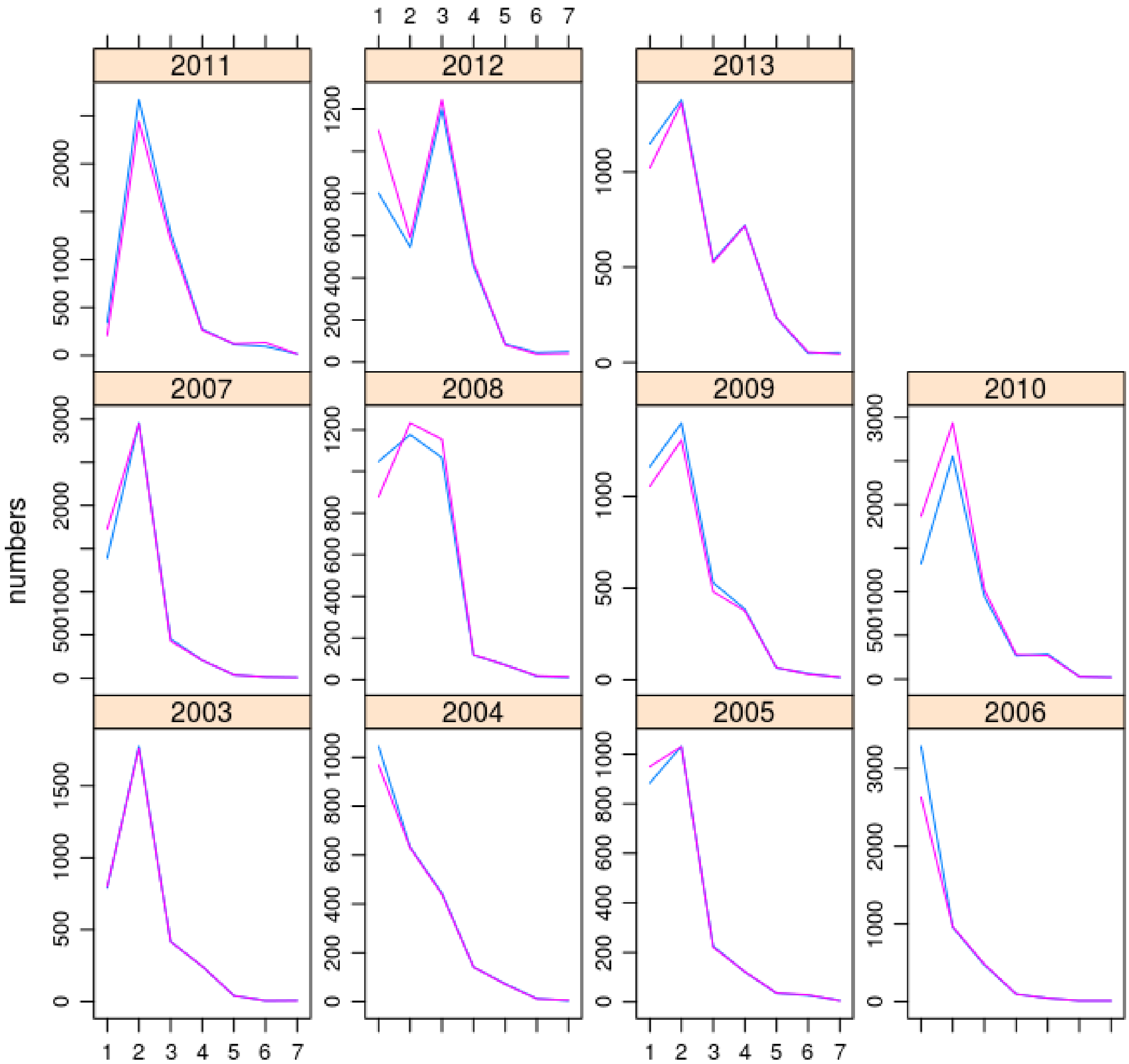

Figure 3.22: Cod-nw with IBTS Q1+Q3 catch observed VS predictions

```
plot(fit, ids[1])
```

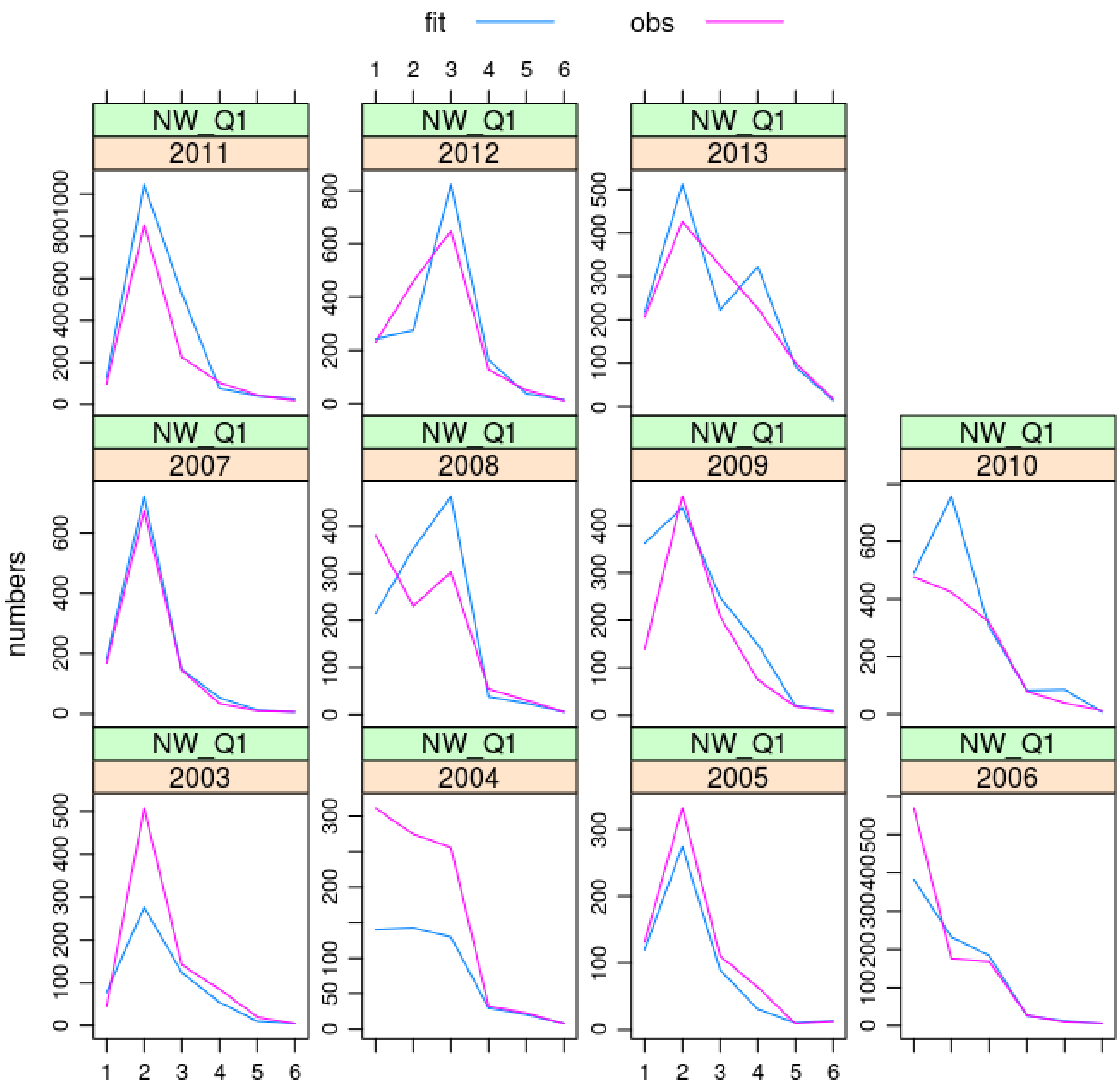

Figure 3.23: Cod-nw with IBTS Q1+Q3 index observed VS predictions

```r
plot(fit, ids[2])
```

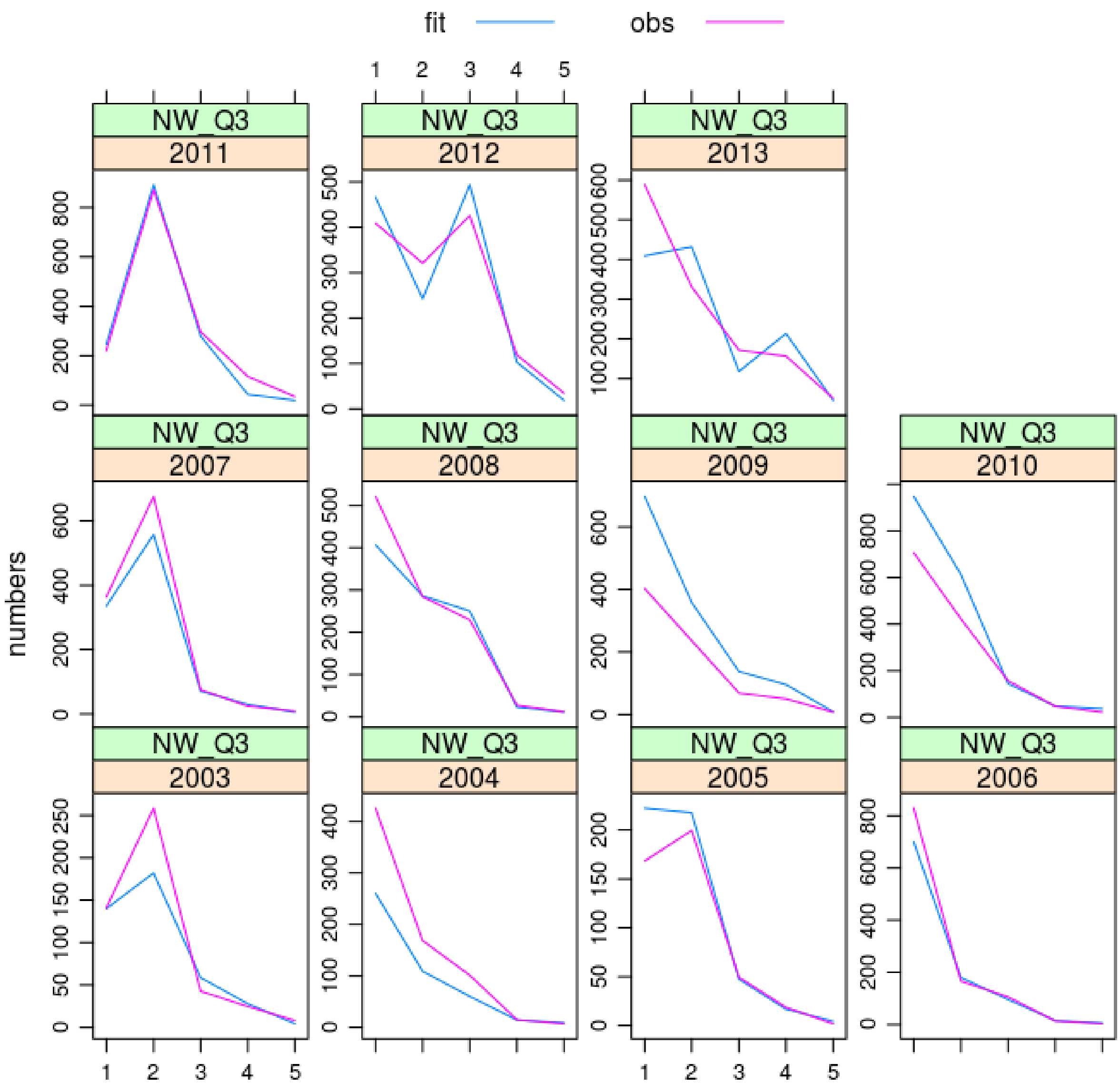

Figure 3.24: Cod-nw with IBTS Q1+Q3 index observed VS predictions

```
wireframe(data ~ year + age, data = harvest(fit))
```

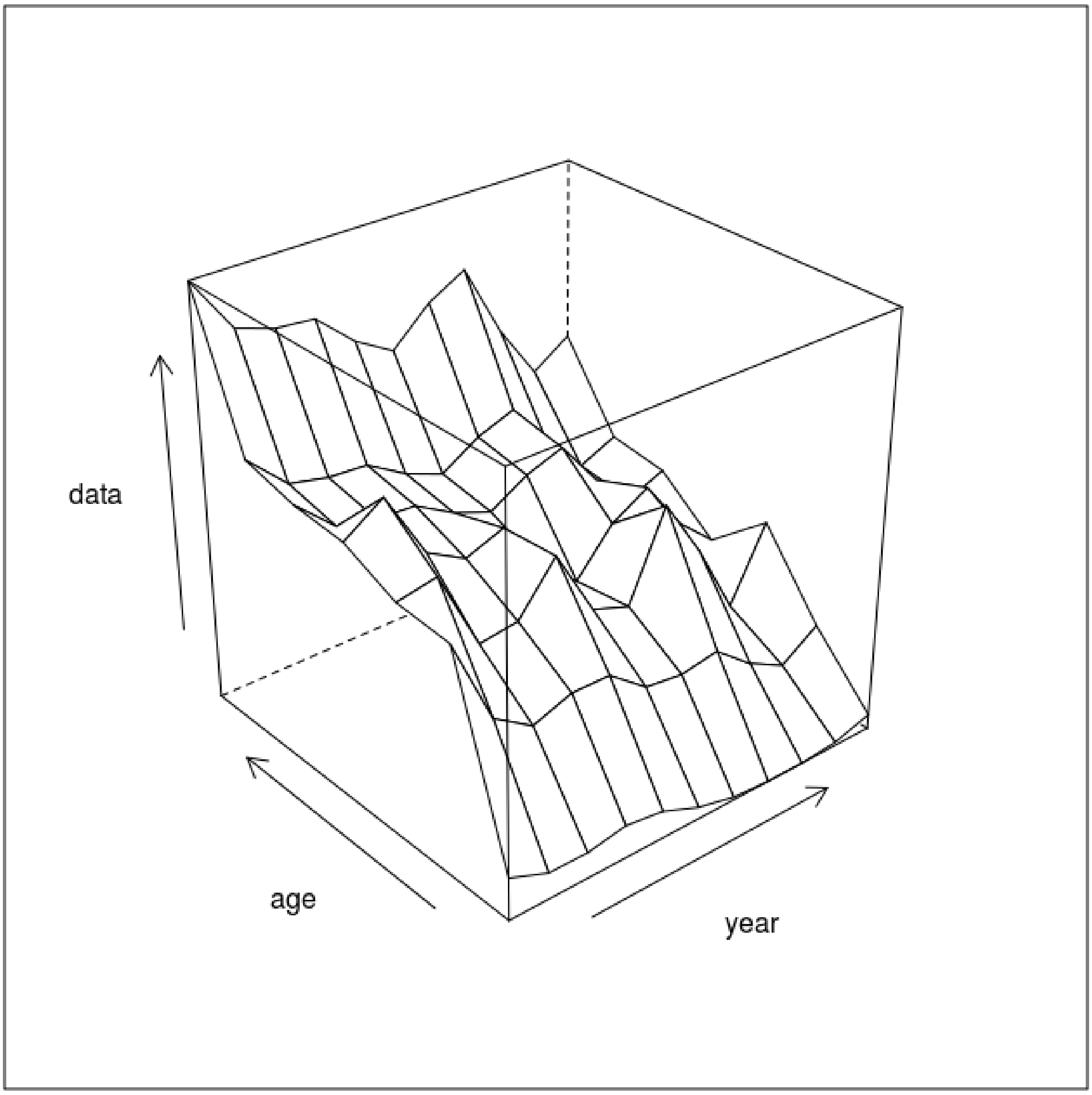

Figure 3.25: Cod-nw with IBTS Q1+Q3 assessment F-at-age surface

```r
codnw.fstks <- stk + simulate(fit, 1000)
plot(codnw.fstks)
```

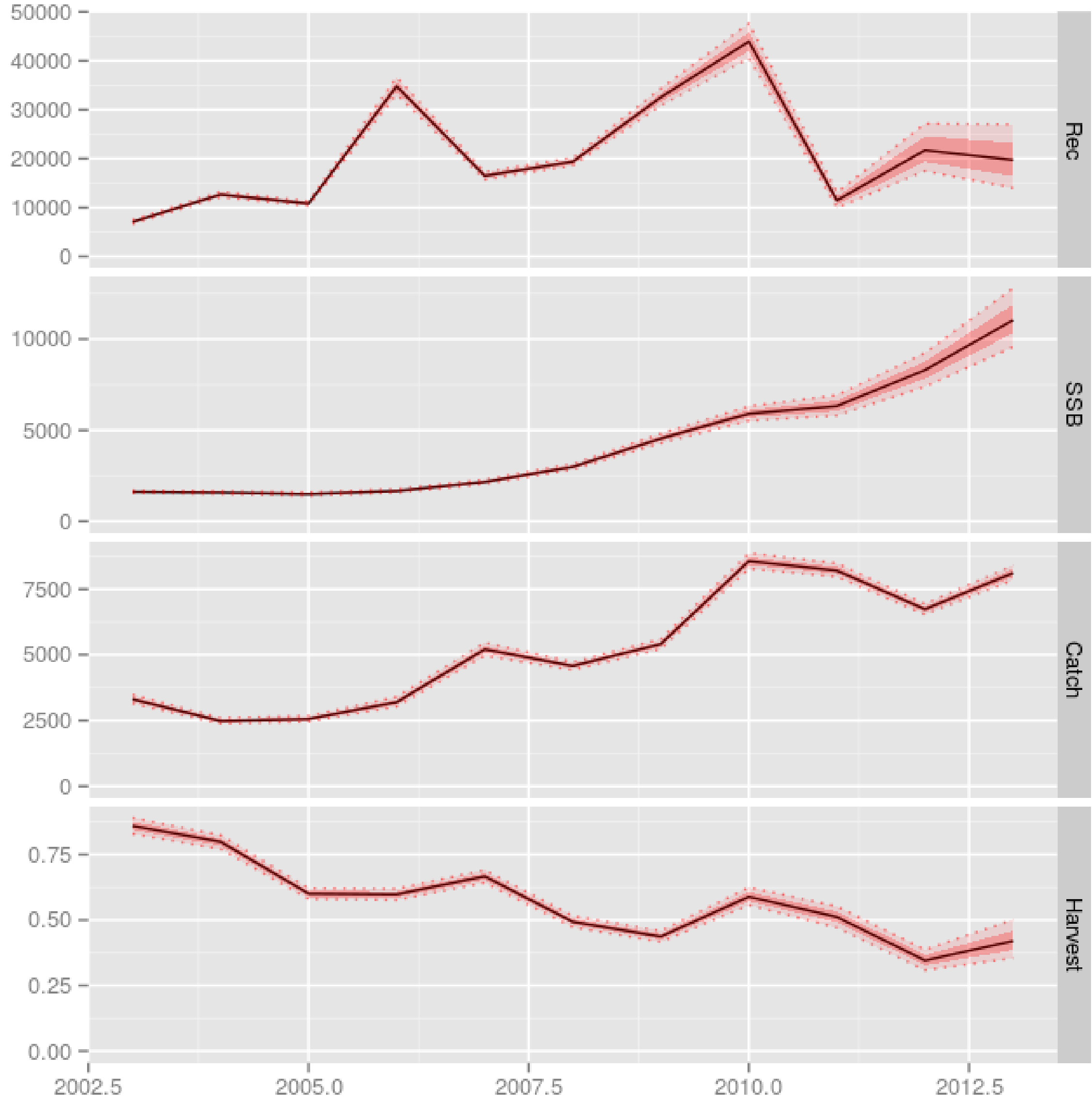

Figure 3.26: Cod-nw with IBTS Q1+Q3 assessment summary

```
codnw.fit <- fit
codnw.fstk <- stk + fit
codnw.sr <- fmle(as.FLSR(codnw.fstk, model = "bevholt"), control = list(trace = 0))
plot(codnw.sr)
```

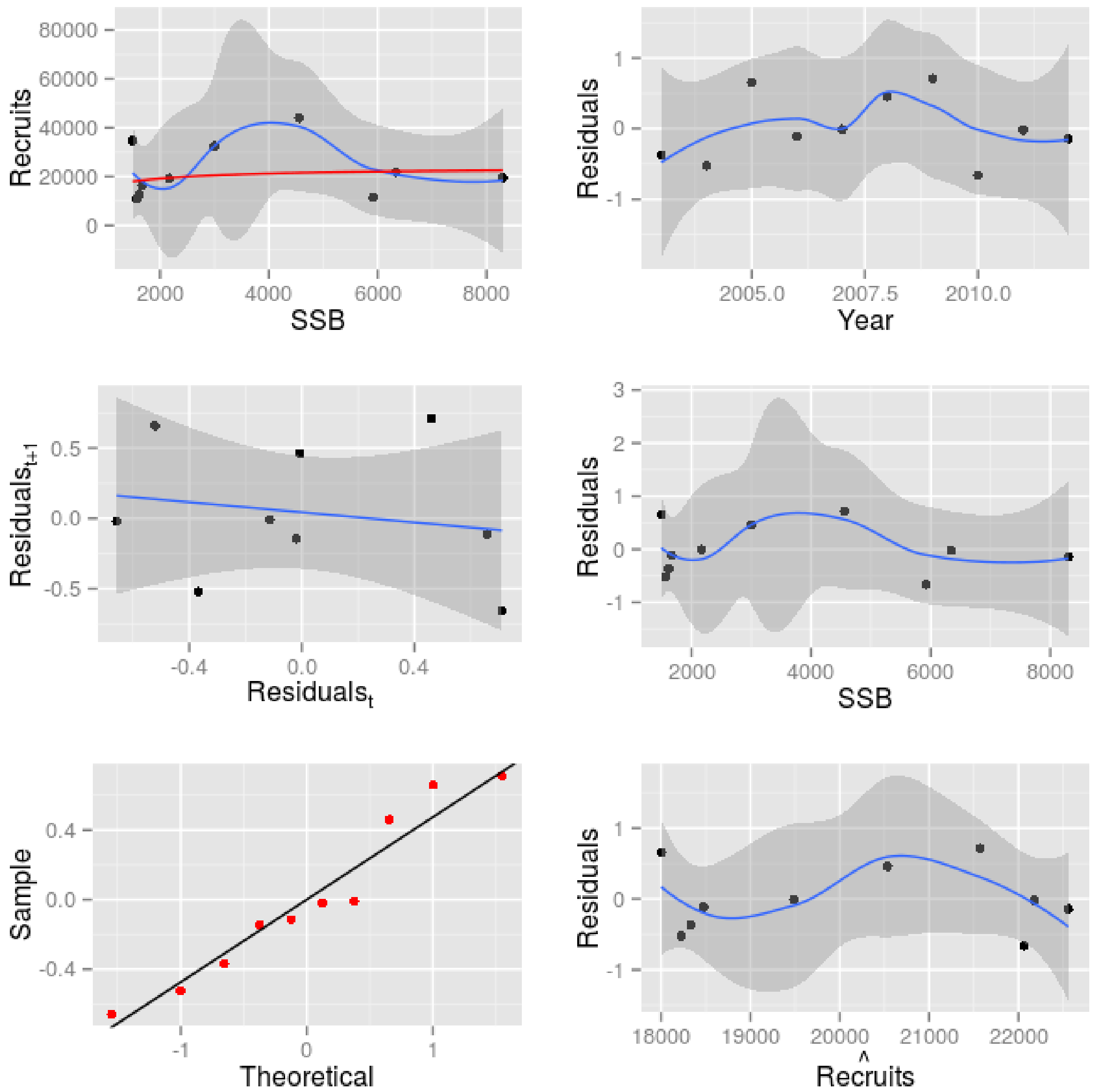

Figure 3.27: Cod-nw with IBTS Q1+Q3 stock-recruitment

The Skagerrak sub-unit (sk)

```
stk <- window(codsk.stk, start = 2003, end = 2013)
ids <- window(codsk.ids, start = 2003, end = 2013)
fmod <- ~s(age, k = 6) + s(year, k = 6, by = breakpts(age, 1.1:5.1))
qmod <- list(~s(age, k = 4), ~s(age, k = 4) + s(year, k = 3))
fit <- sca(stk, ids, fmodel = fmod, qmodel = qmod, fit = "assessment")
```

```r
res <- residuals(fit, stk, ids)
plot(res)
```

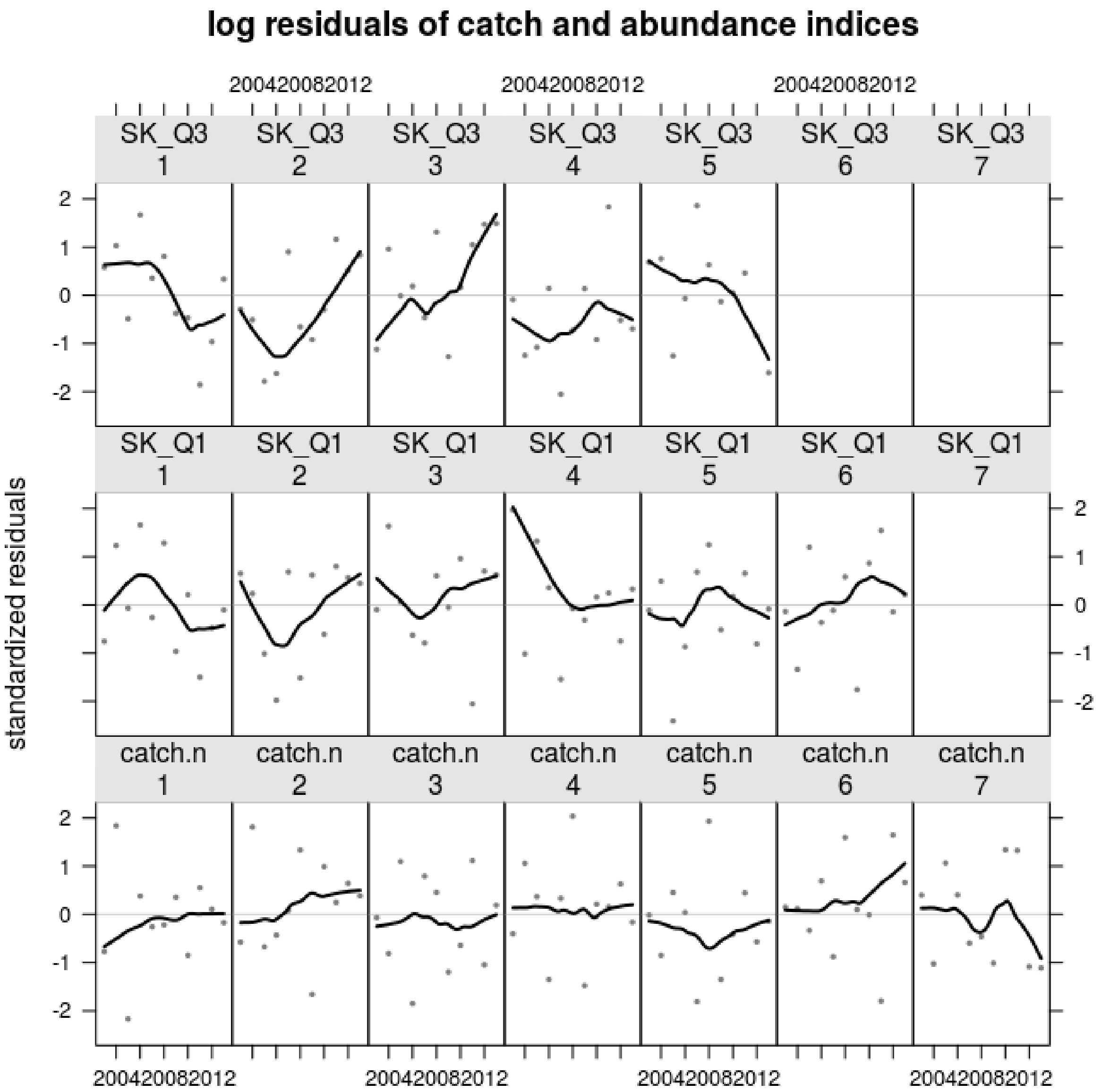

Figure 3.28: Cod-sk with IBTS Q1+Q3 assessment residuals

```
qqmath(res)
```

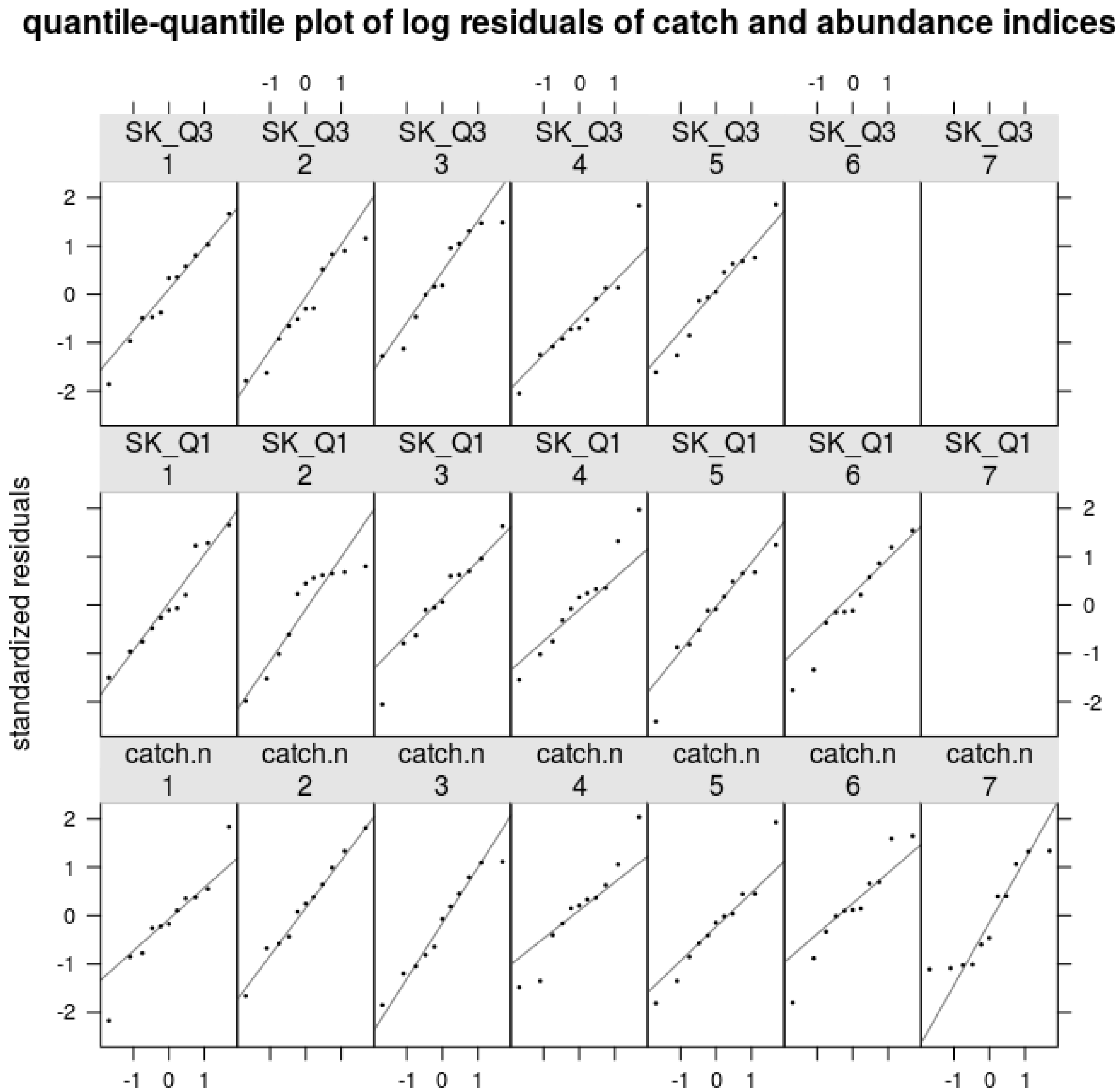

Figure 3.29: Cod-sk with IBTS Q1+Q3 assessment residuals

```
bubbles(res)
```

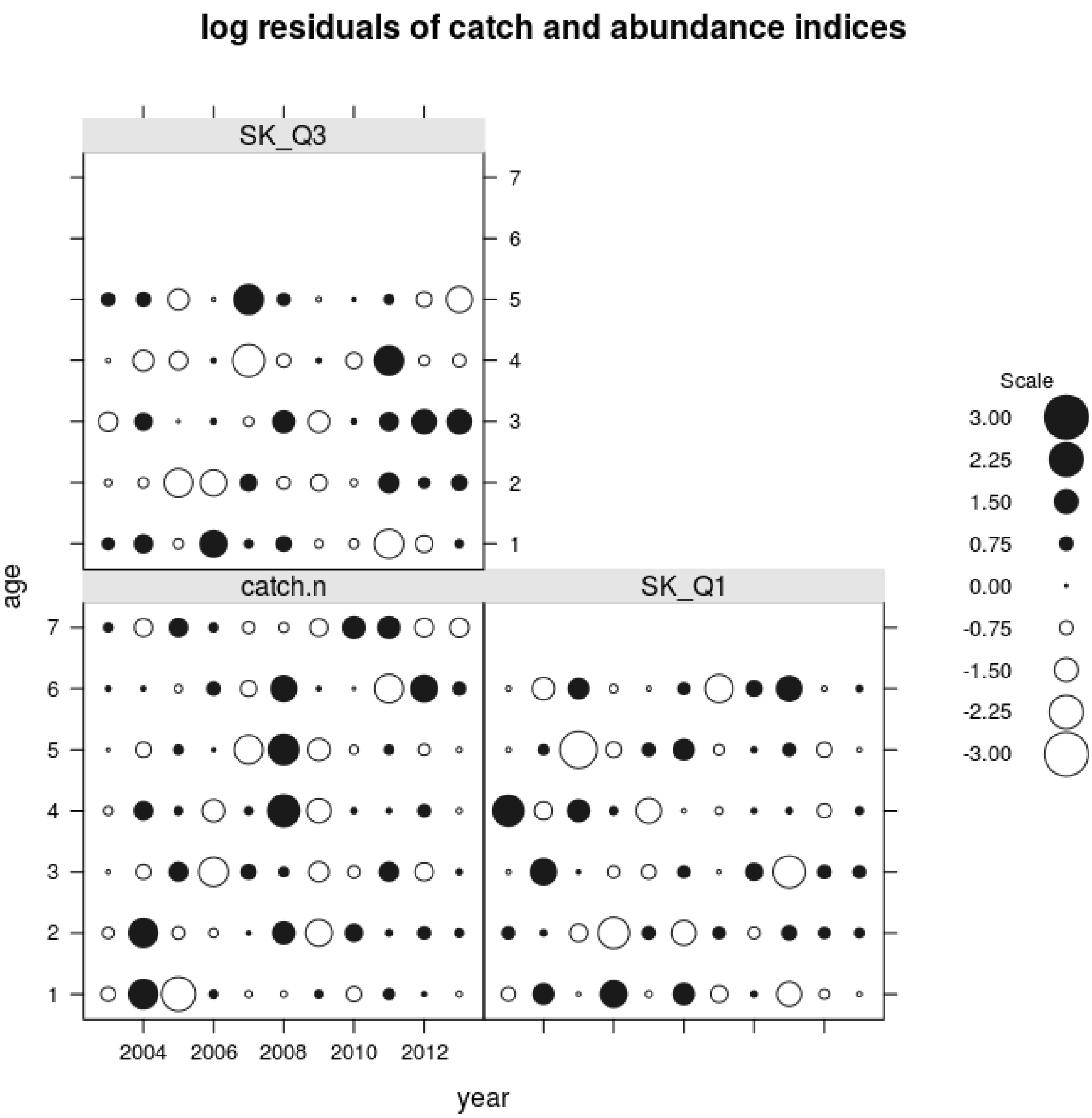

Figure 3.30: Cod-sk with IBTS Q1+Q3 assessment residuals

```r
plot(fit, stk)
```

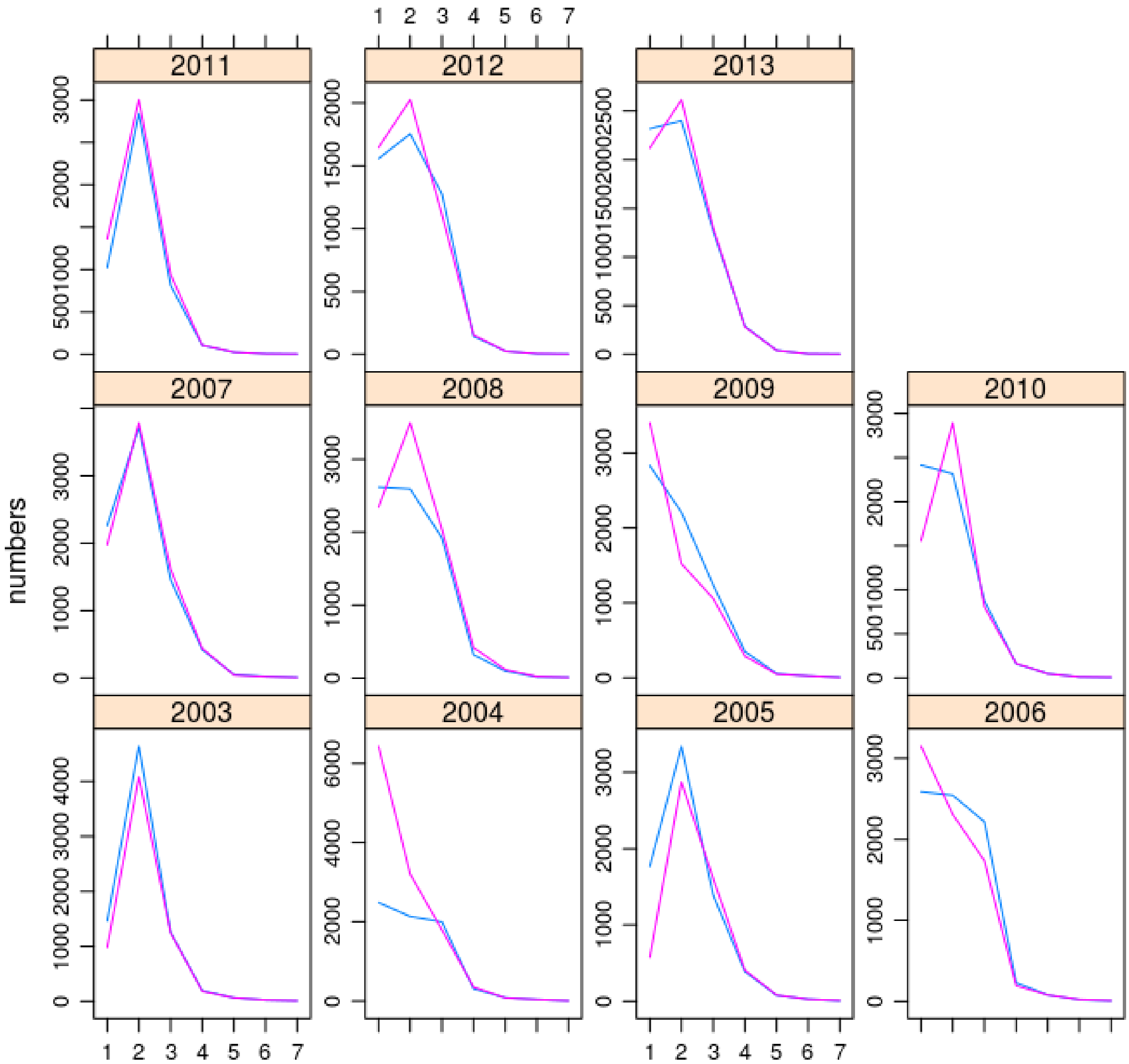

Figure 3.31: Cod-sk with IBTS Q1+Q3 catch observed VS predictions

```
plot(fit, ids[1])
```

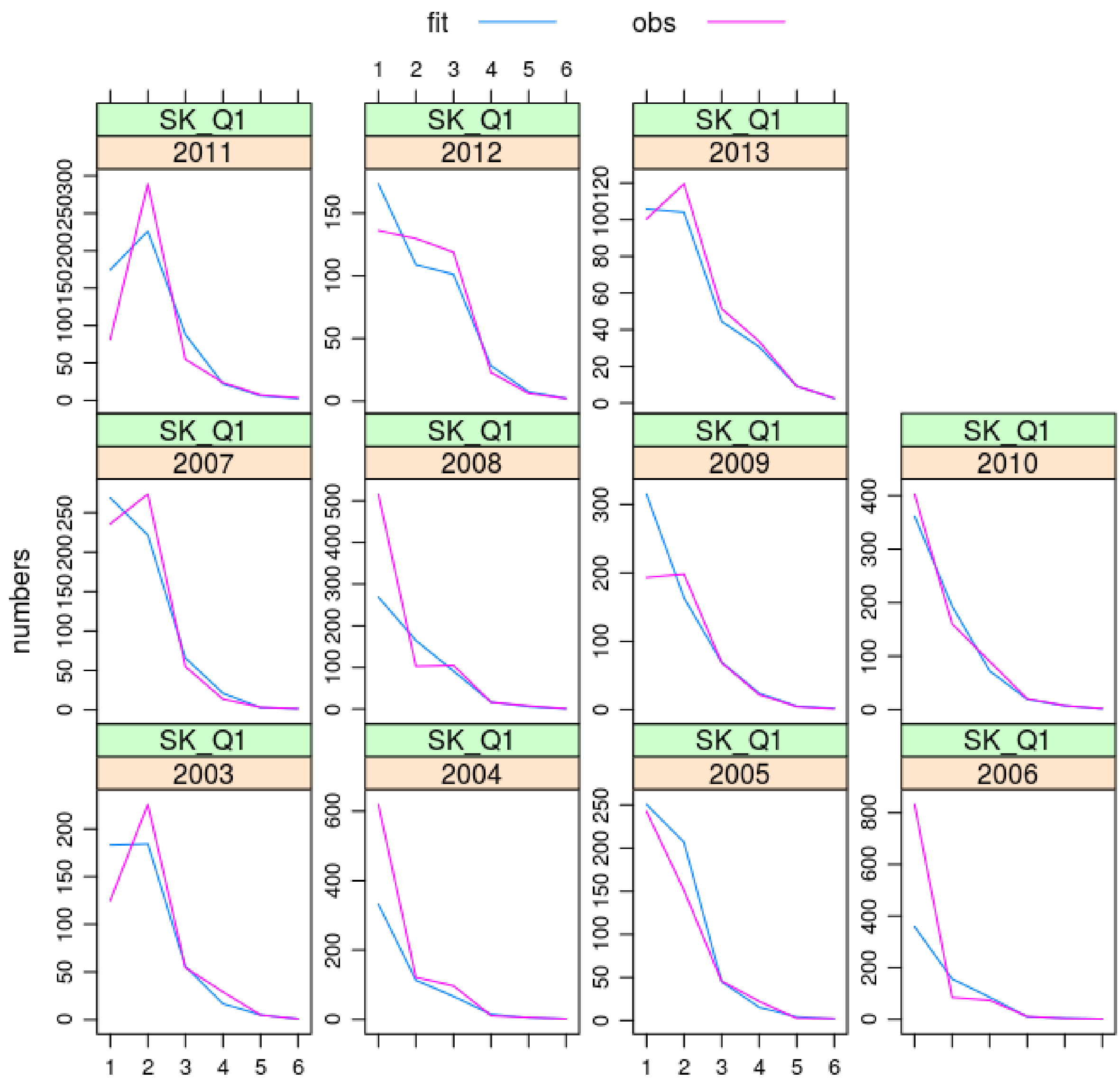

Figure 3.32: Cod-sk with IBTS Q1+Q3 index observed VS predictions

```
plot(fit, ids[2])
```

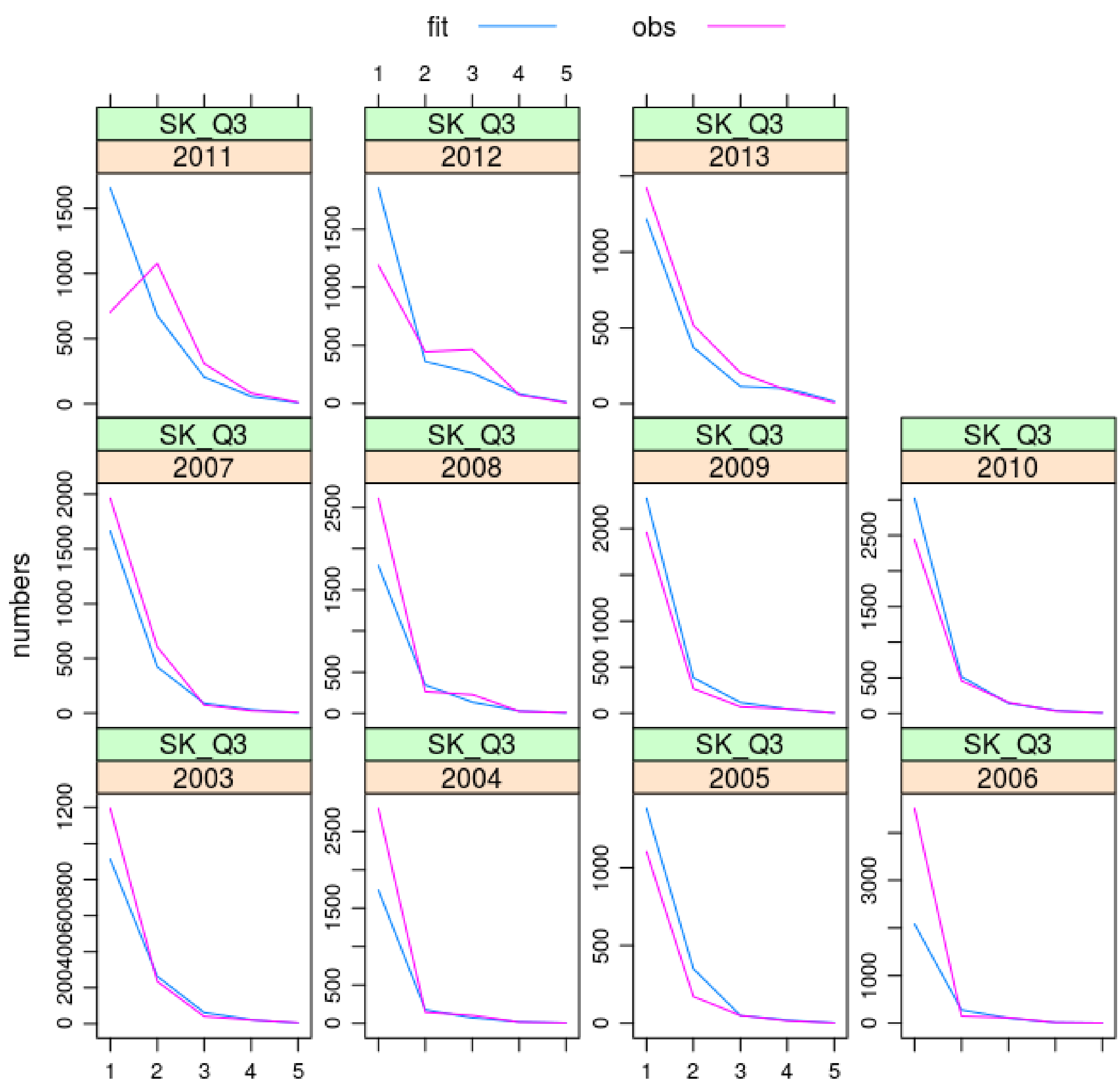

Figure 3.33: Cod-sk with IBTS Q1+Q3 index observed VS predictions

```r
wireframe(data ~ year + age, data = harvest(fit))
```

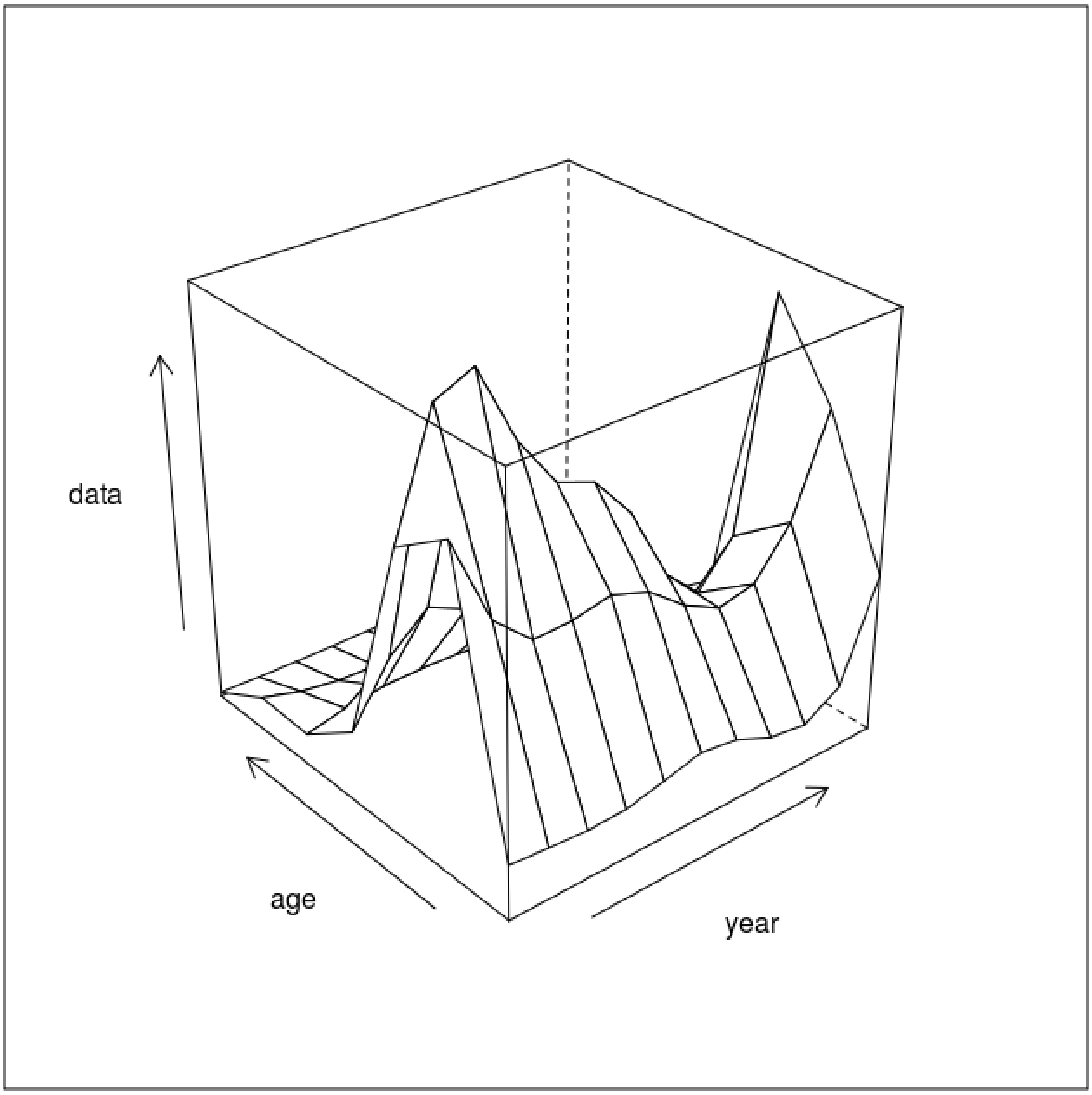

Figure 3.34: Cod-sk with IBTS Q1+Q3 assessment F-at-age surface

```
codsk.fstks <- stk + simulate(fit, 1000)
plot(codsk.fstks)
```

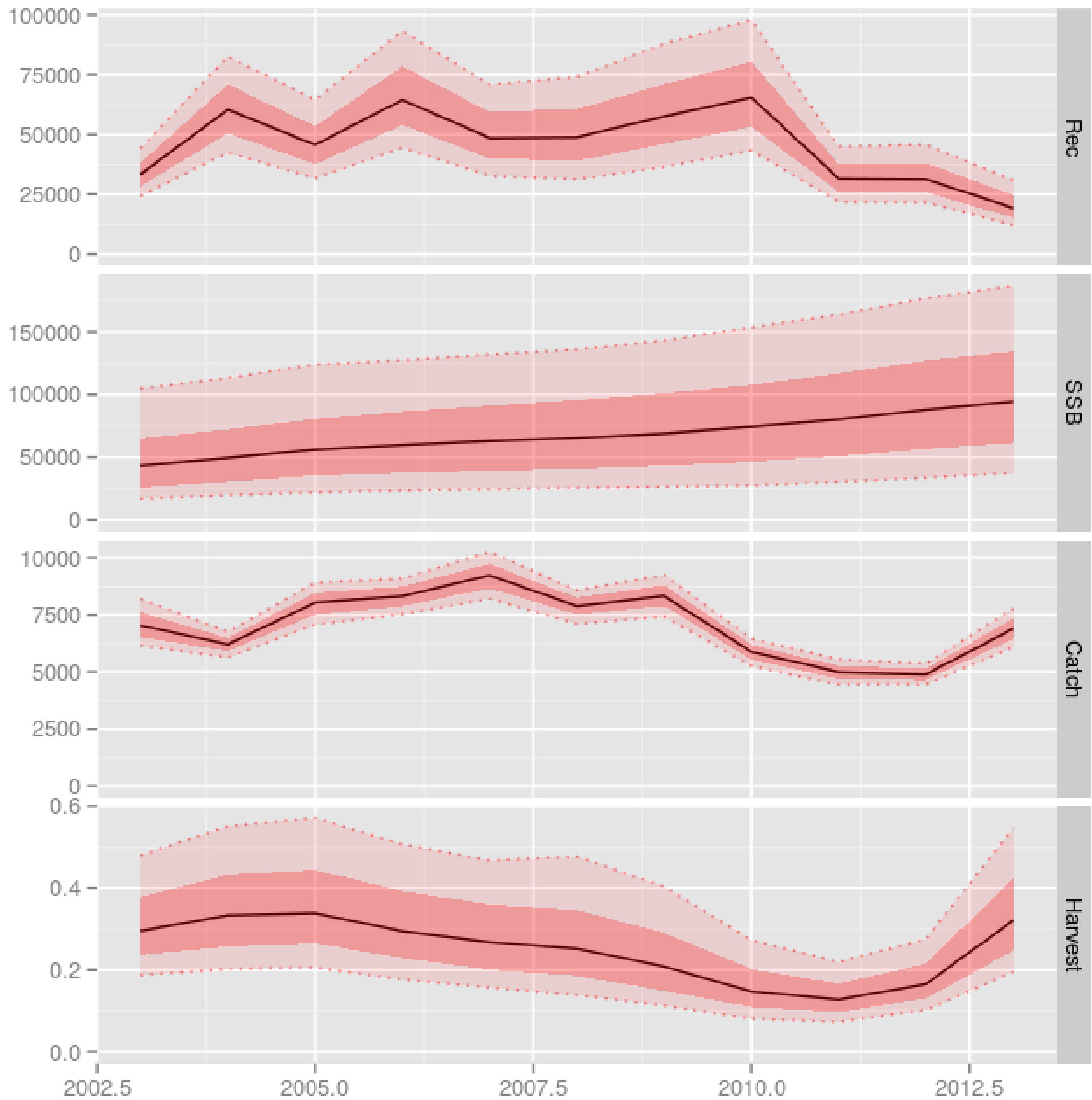

Figure 3.35: Cod-sk with IBTS Q1+Q3 assessment summary

```
codsk.fit <- fit
codsk.fstk <- stk + fit
codsk.sr <- fmle(as.FLSR(codsk.fstk, model = "bevholt"), control = list(trace = 0))
plot(codsk.sr)
```

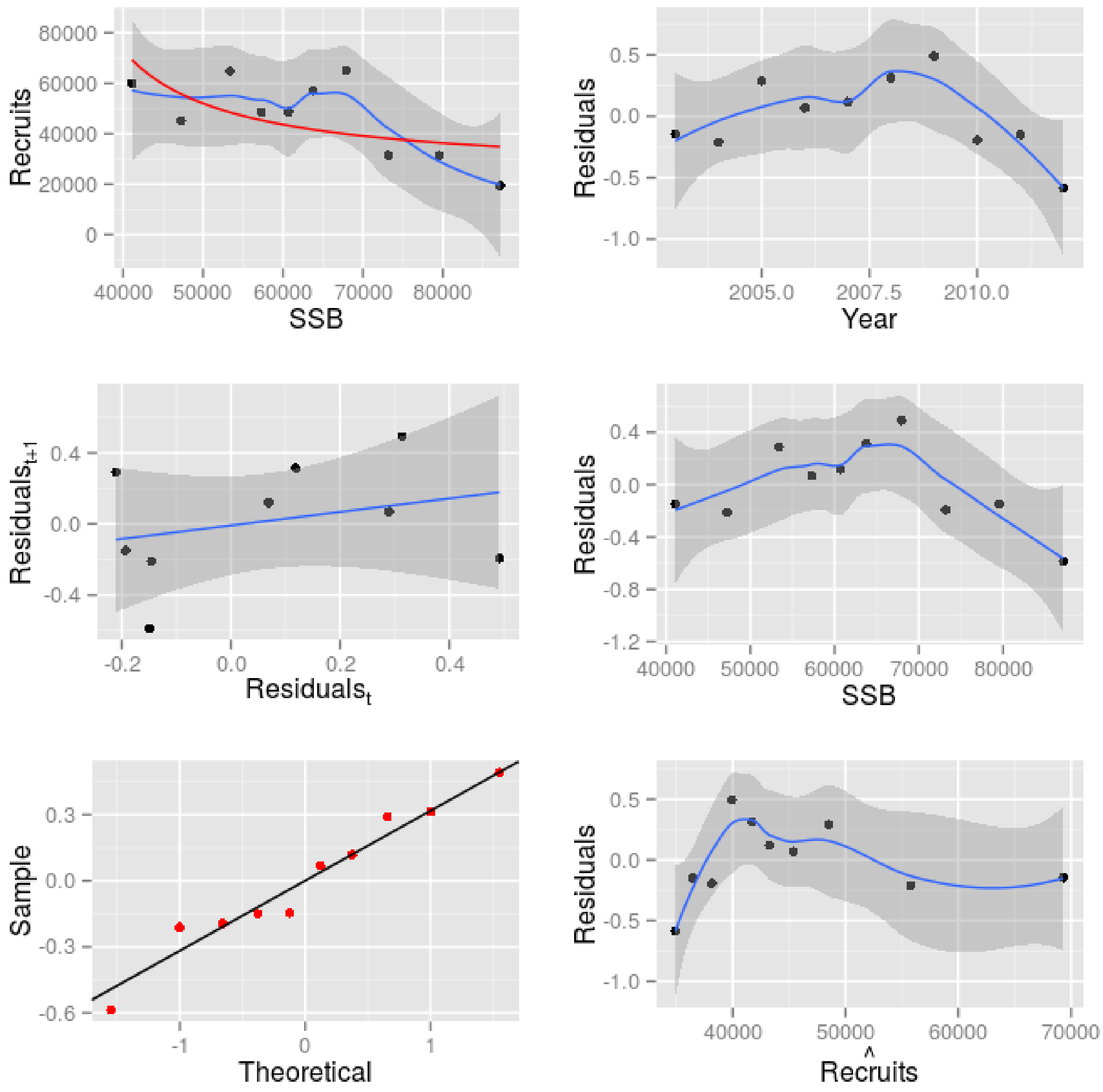

Figure 3.36: Cod-sk with IBTS Q1+Q3 stock-recruitment

The Southern sub-unit (so)

```
stk <- window(codso.stk, start = 2003, end = 2013)
ids <- window(codso.ids, start = 2003, end = 2013)
fmod <- ~s(age, k = 6) + s(year, k = 6)  #, by = breakpts(age, 1.1:5.1))
fmod <- ~te(age, year, k = c(5, 5), bs = "tp")
qmod <- list(~s(age, k = 4), ~s(age, k = 4) + s(year, k = 3))
```

```
fit <- sca(stk, ids, fmodel = fmod, qmodel = qmod, fit = "assessment")
```

```
res <- residuals(fit, stk, ids)
plot(res)
```

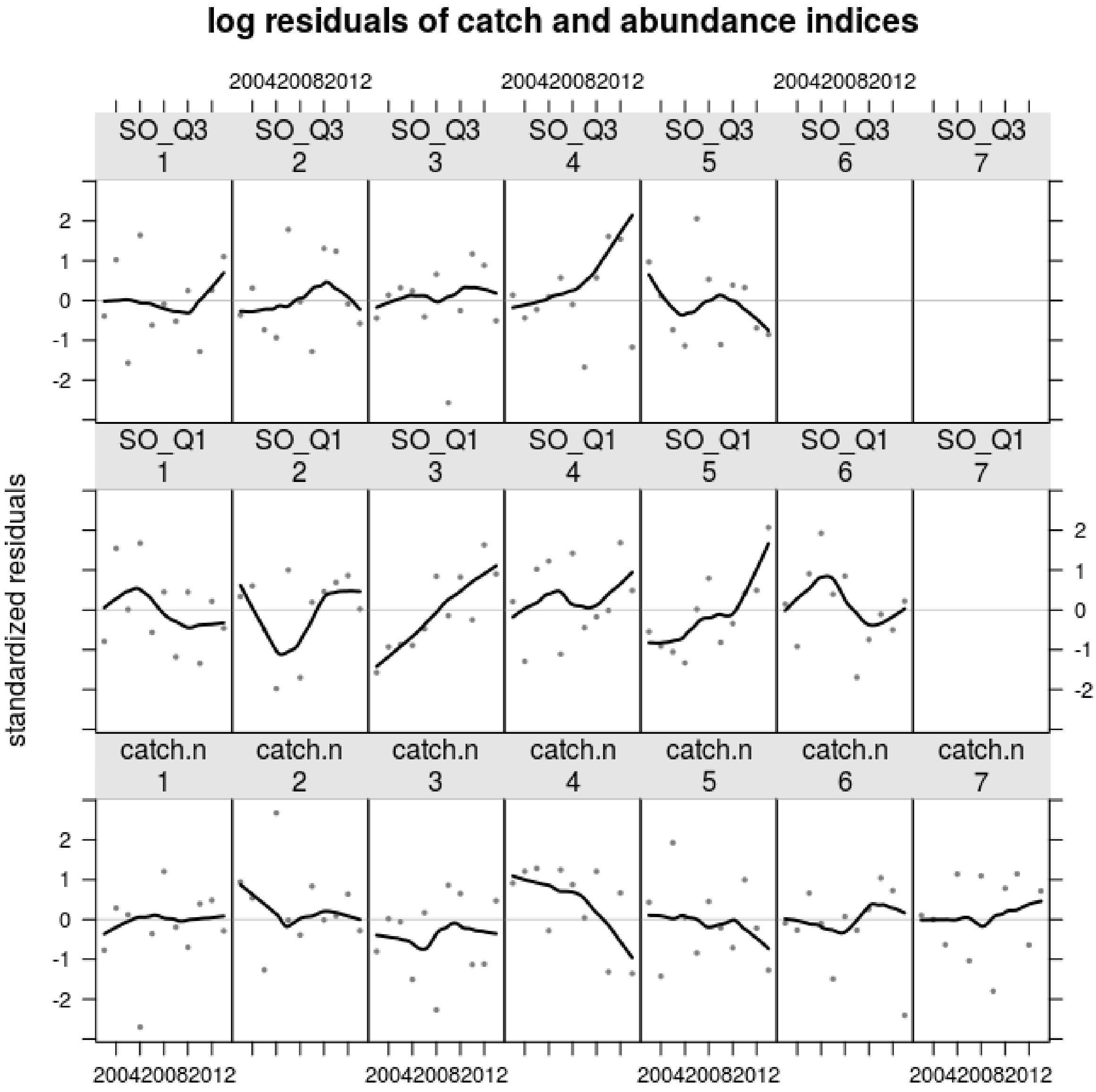

Figure 3.37: Cod-so with IBTS Q1+Q3 assessment residuals

```
qqmath(res)
```

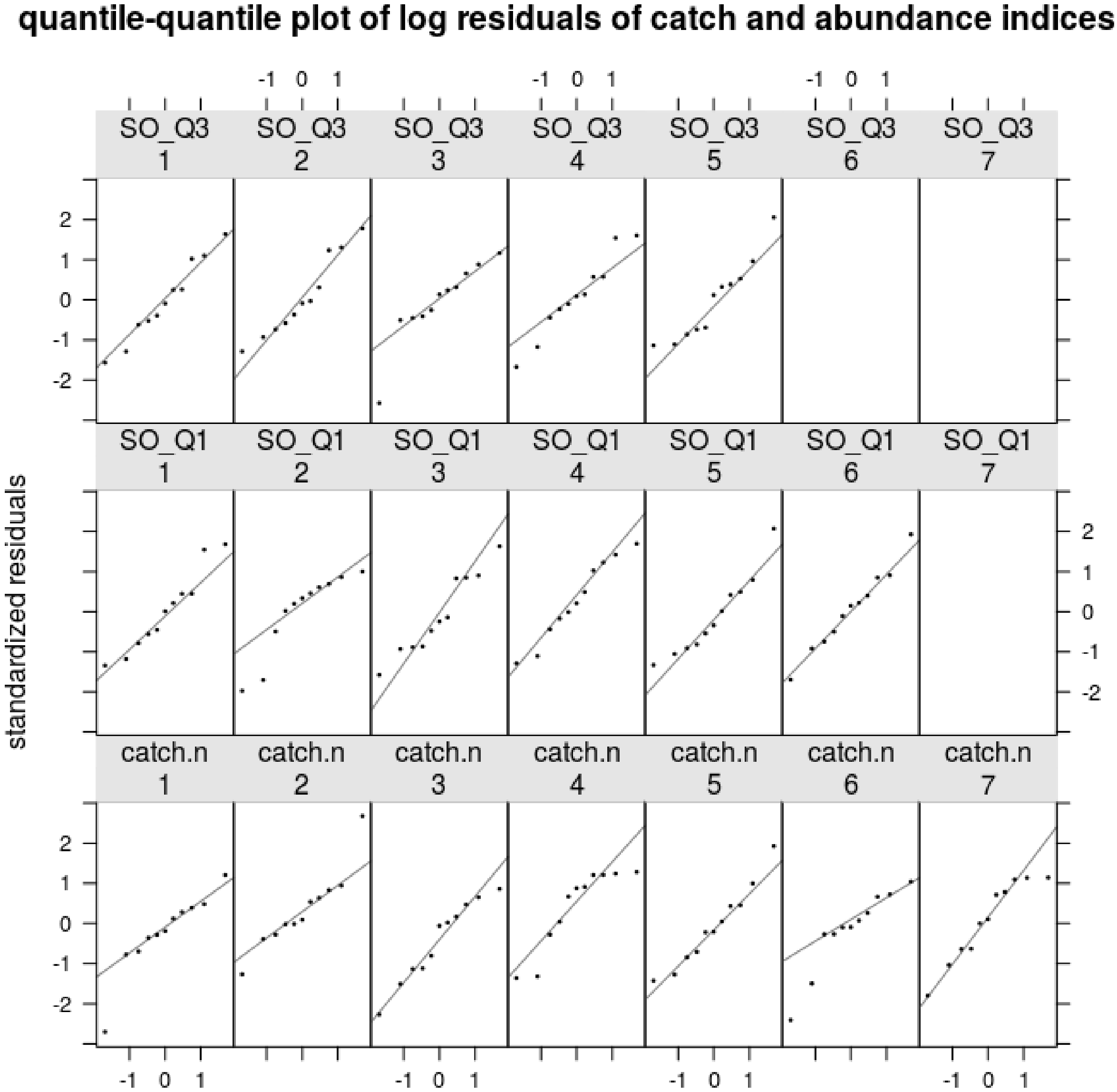

Figure 3.38: Cod-so with IBTS Q1+Q3 assessment residuals

```
bubbles(res)
```

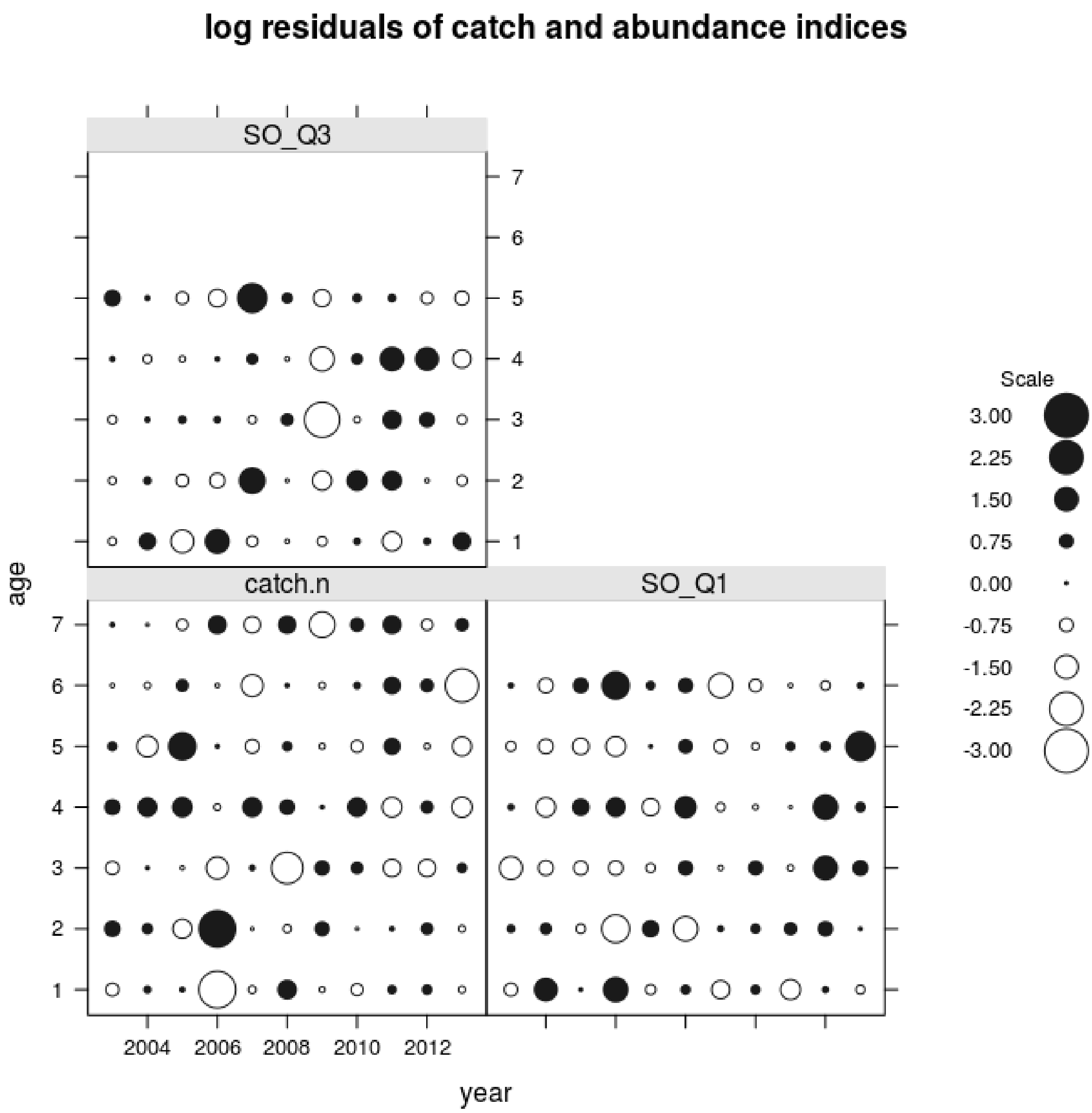

Figure 3.39: Cod-so with IBTS Q1+Q3 assessment residuals

```r
plot(fit, stk)
```

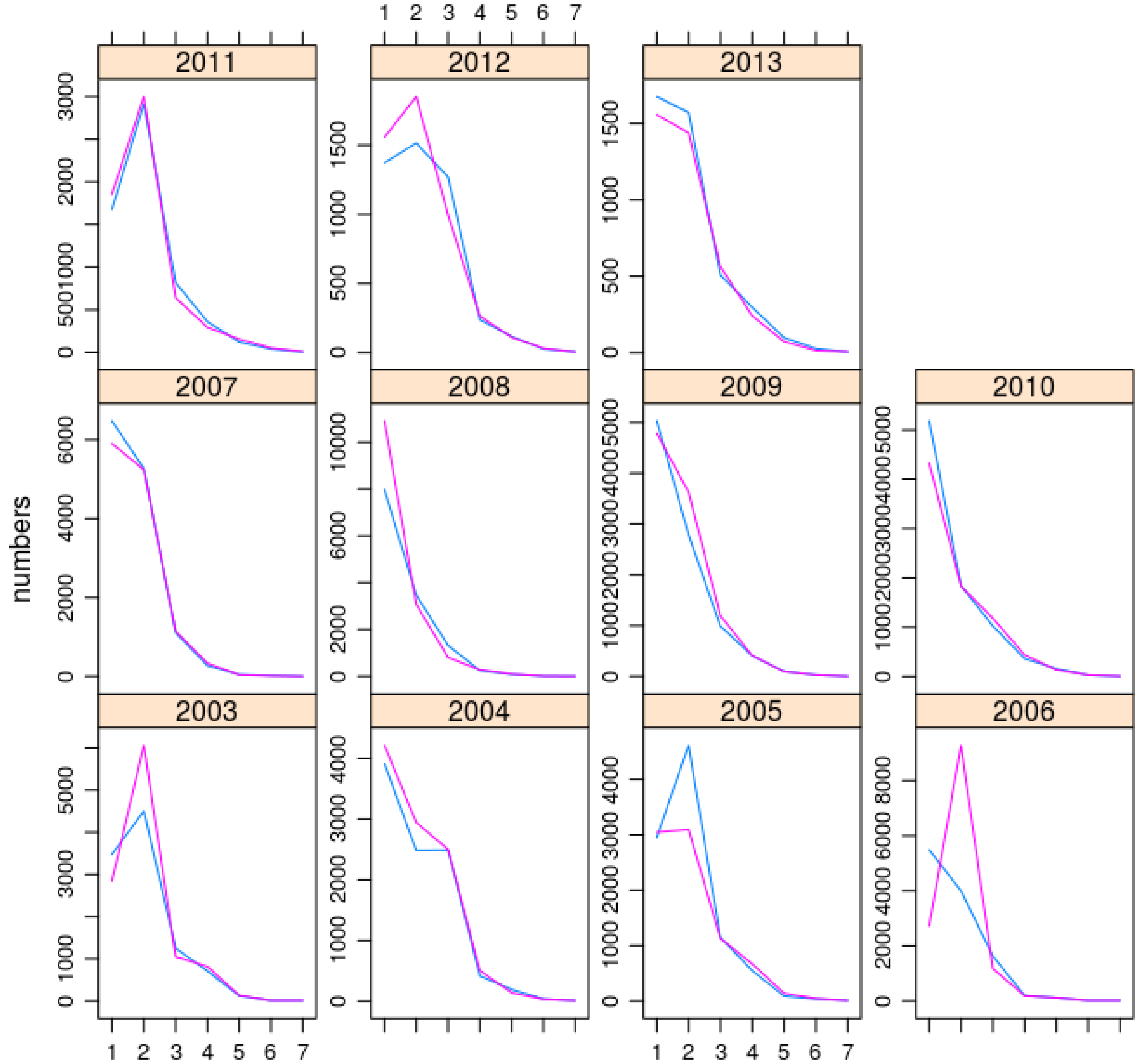

Figure 3.40: Cod-so with IBTS Q1+Q3 catch observed VS predictions

```
plot(fit, ids[1])
```

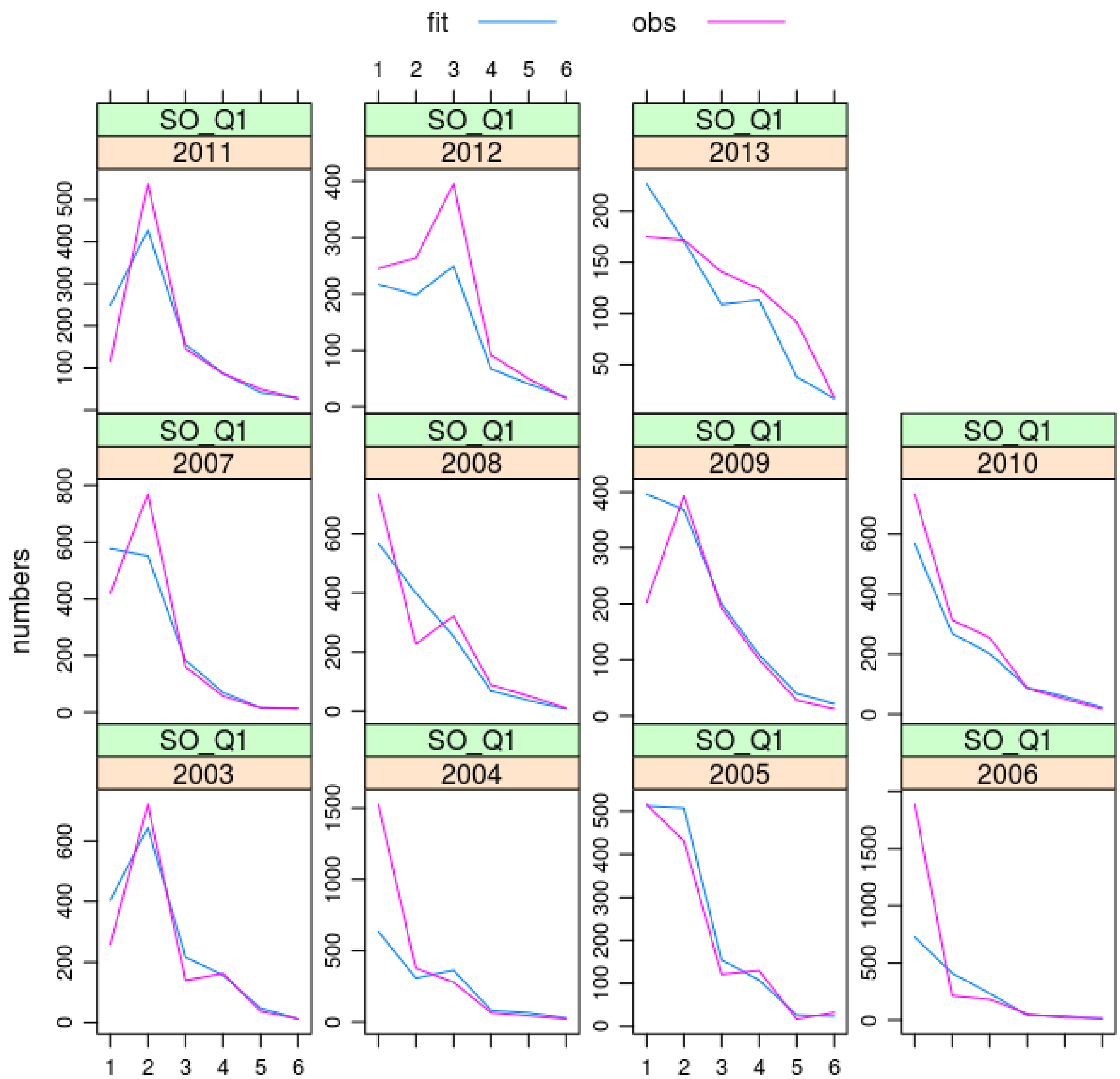

Figure 3.41: Cod-so with IBTS Q1+Q3 index observed VS predictions

```r
plot(fit, ids[2])
```

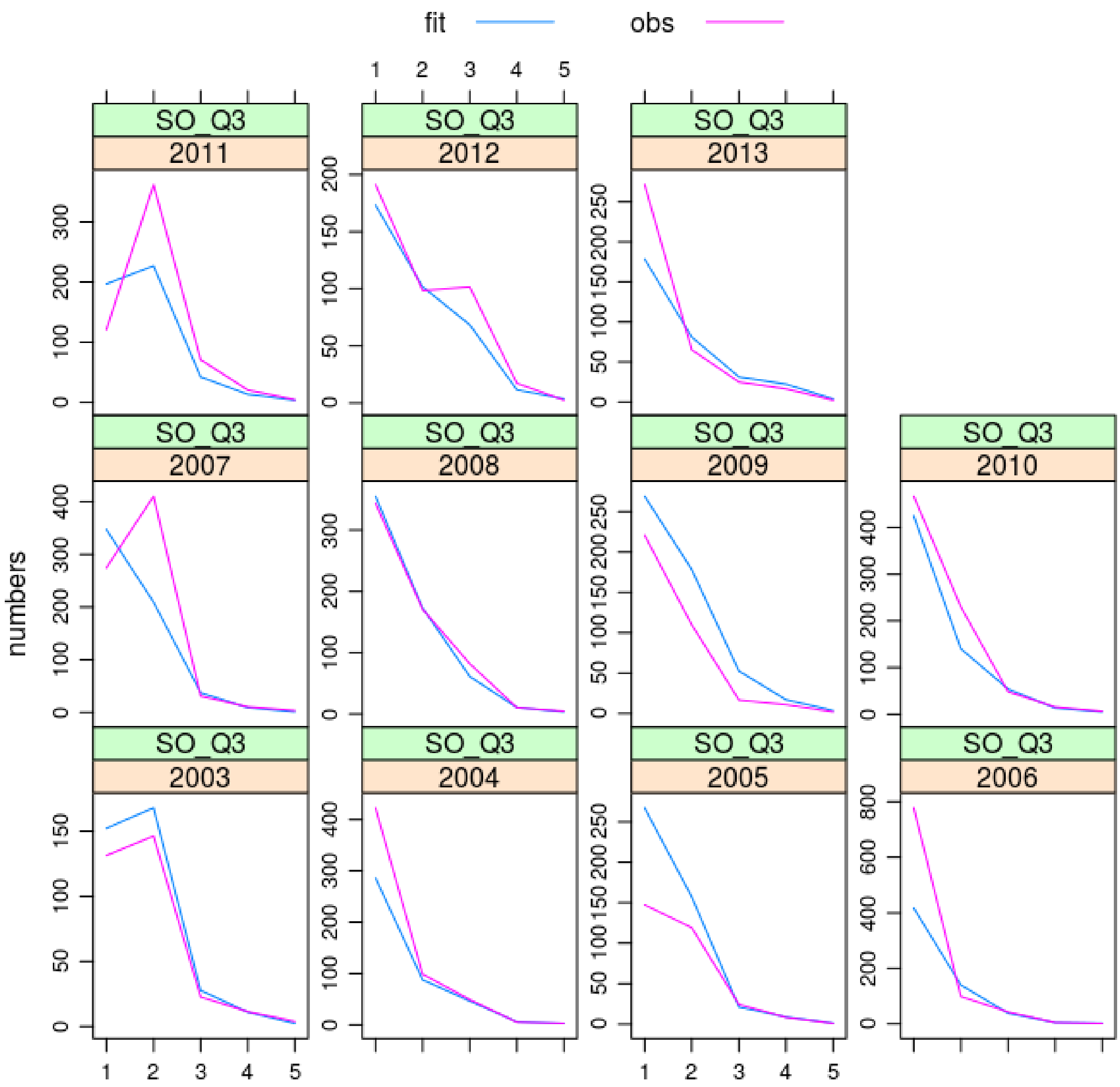

Figure 3.42: Cod-so with IBTS Q1+Q3 index observed VS predictions

```
wireframe(data ~ year + age, data = harvest(fit))
```

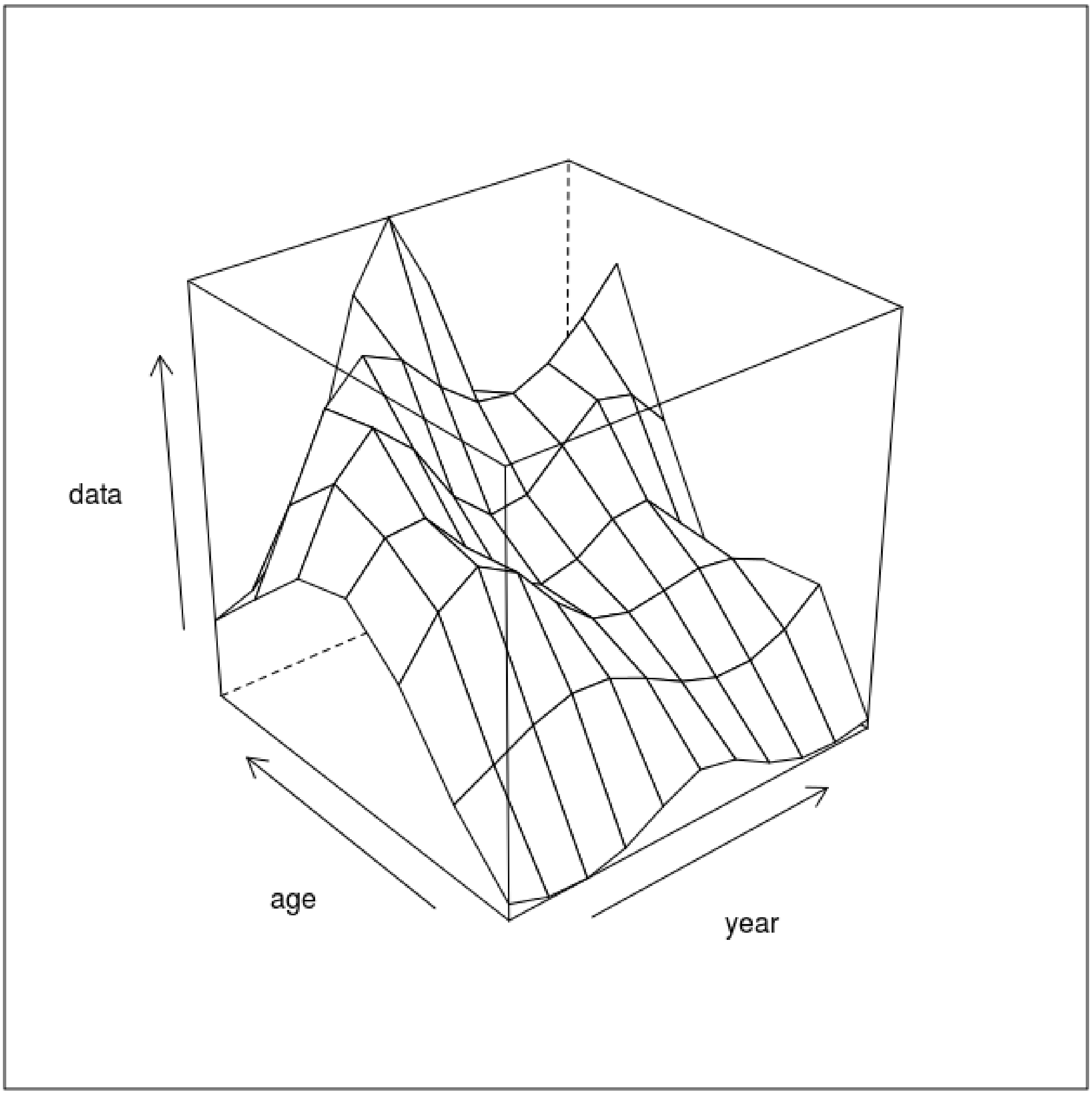

Figure 3.43: Cod-so with IBTS Q1+Q3 assessment F-at-age surface

```
codso.fstks <- stk + simulate(fit, 1000)
plot(codso.fstks)
```

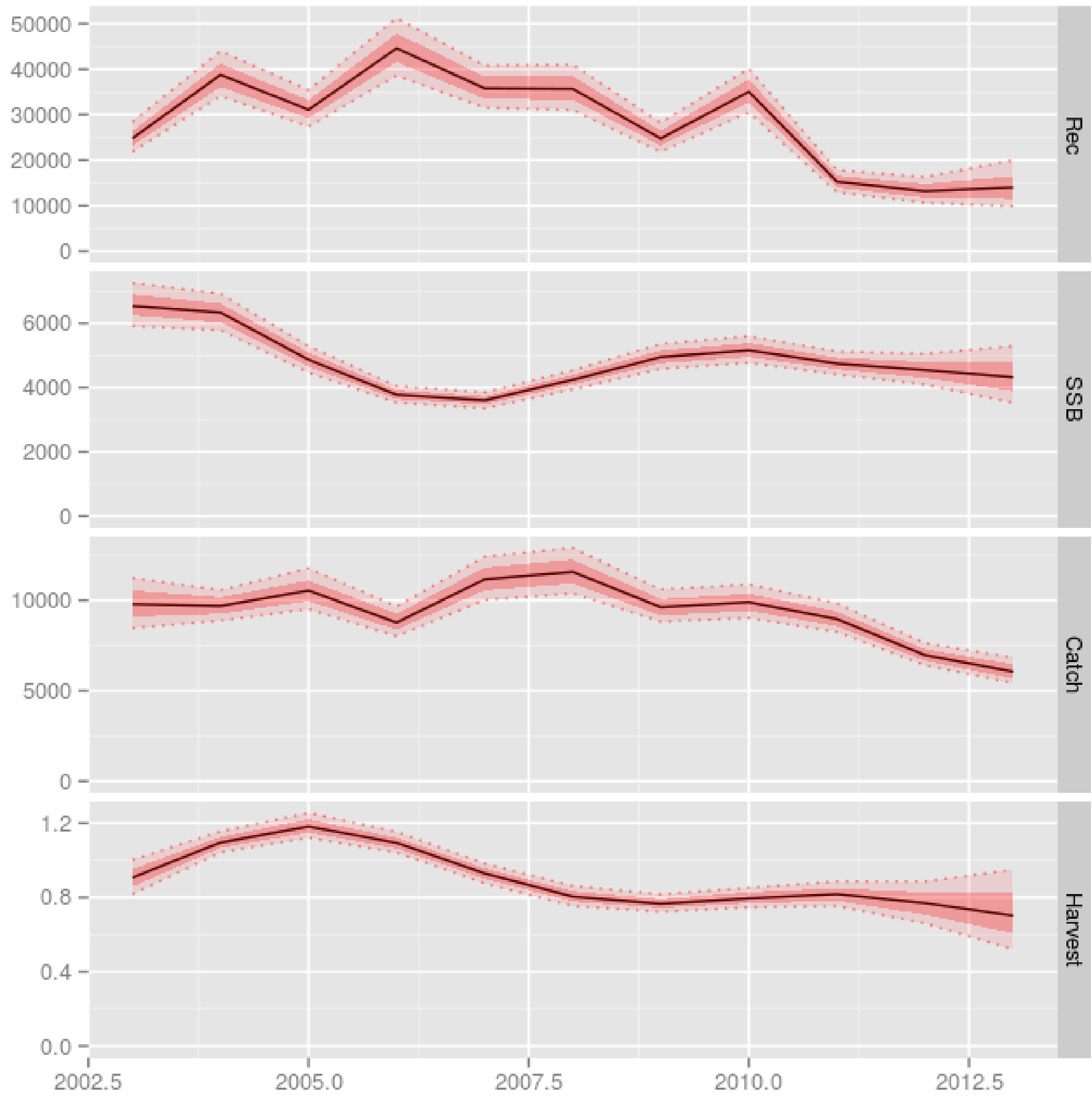

Figure 3.44: Cod-so with IBTS Q1+Q3 assessment summary

```
codso.fit <- fit
codso.fstk <- stk + fit
codso.sr <- fmle(as.FLSR(codso.fstk, model = "bevholt"), control = list(trace = 0))
plot(codso.sr)
```

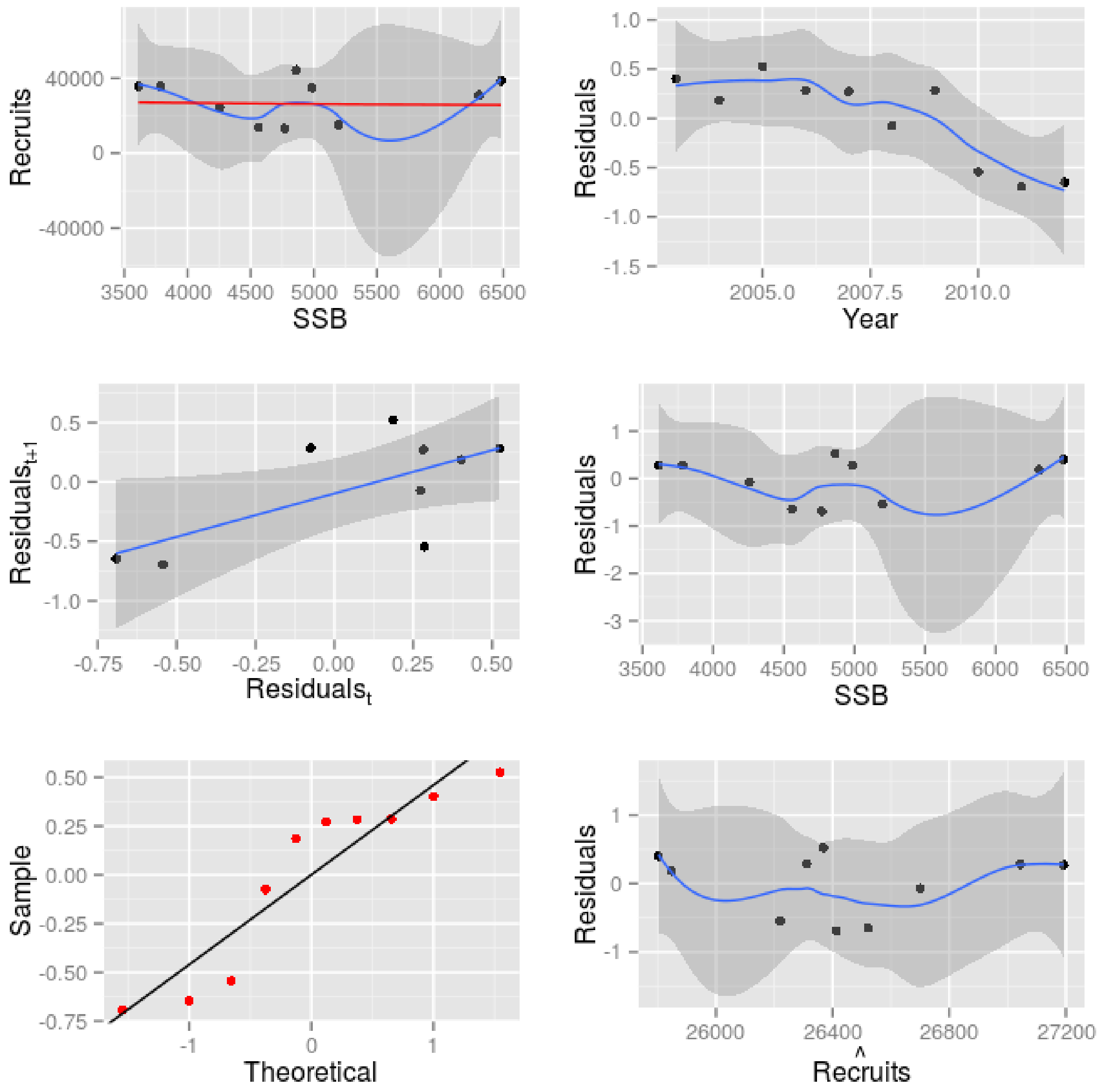

Figure 3.45: Cod-so with IBTS Q1+Q3 stock-recruitment

The Viking sub-unit (vk)

```
stk <- window(codvk.stk, start = 2003, end = 2013)
ids <- window(codvk.ids, start = 2003, end = 2013)
fmod <- ~s(age, k = 5) + s(year, k = 5, by = breakpts(age, 1.1:5.1))
qmod <- list(~s(age, k = 6), ~s(age, k = 4) + s(year, k = 3))
fit <- sca(stk, ids, fmodel = fmod, qmodel = qmod, fit = "assessment")
```

```r
res <- residuals(fit, stk, ids)
plot(res)
```

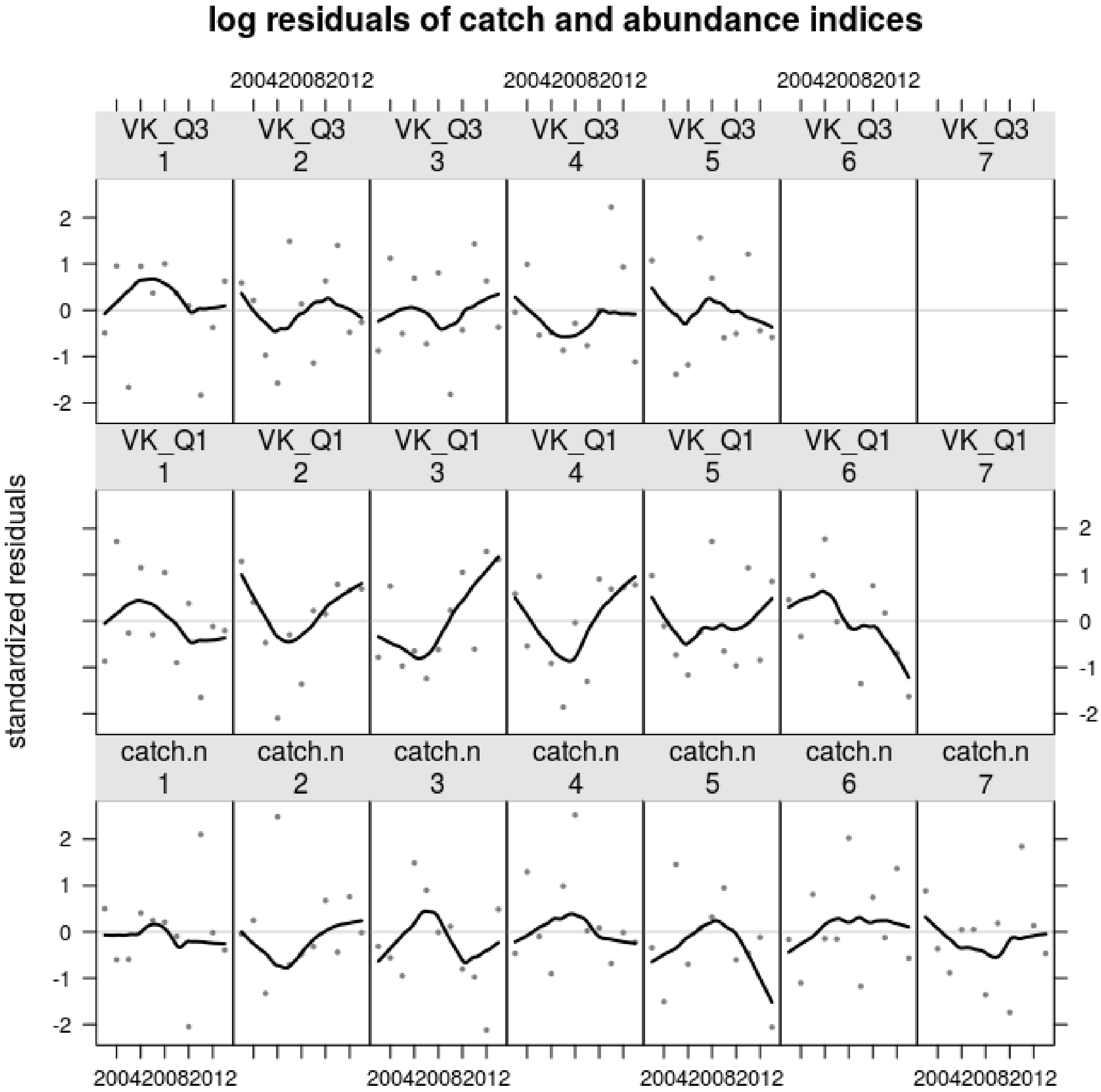

Figure 3.46: Cod-vk with IBTS Q1+Q3 assessment residuals

```r
qqmath(res)
```

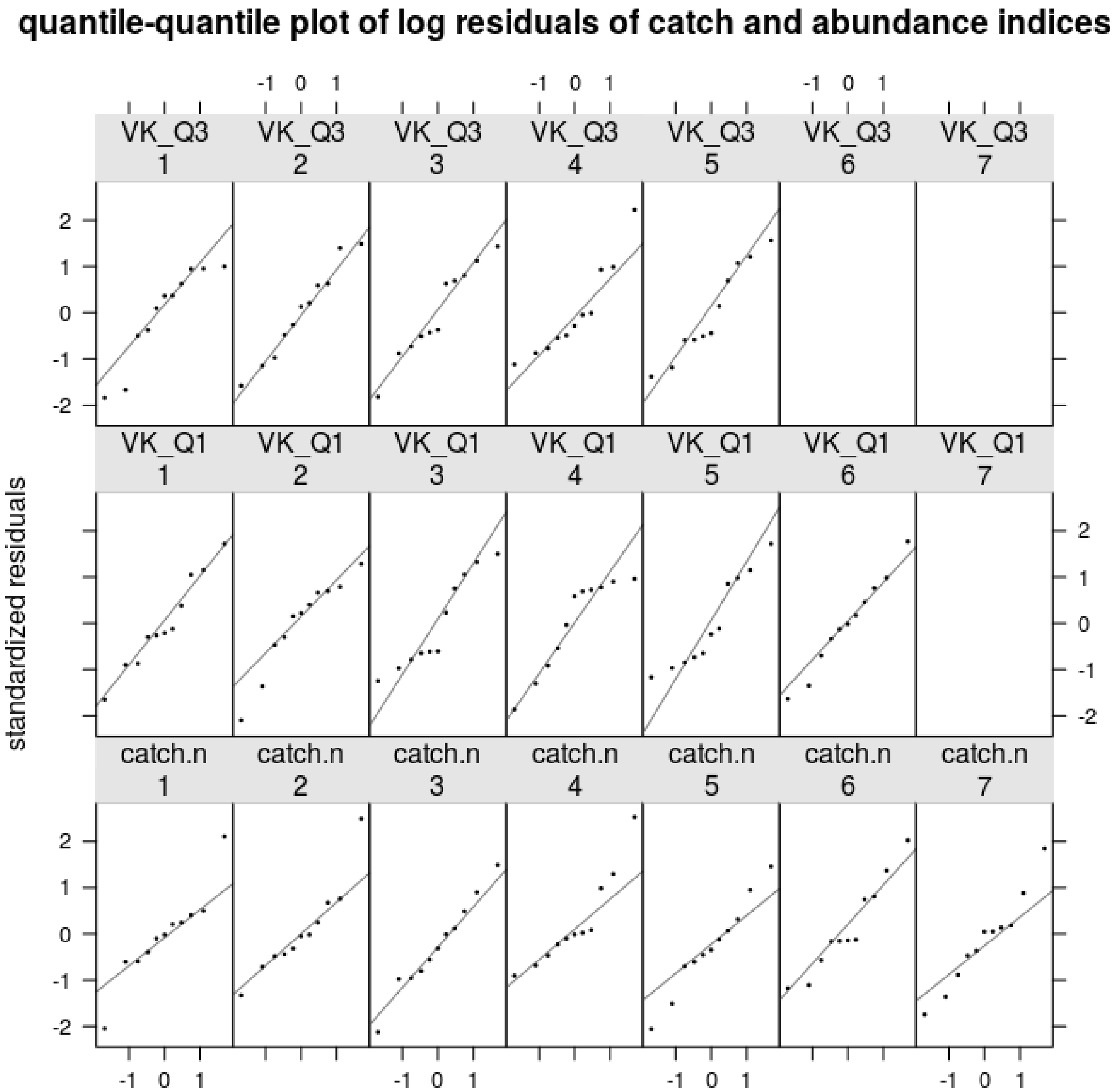

Figure 3.47: Cod-vk with IBTS Q1+Q3 assessment residuals

```
bubbles(res)
```

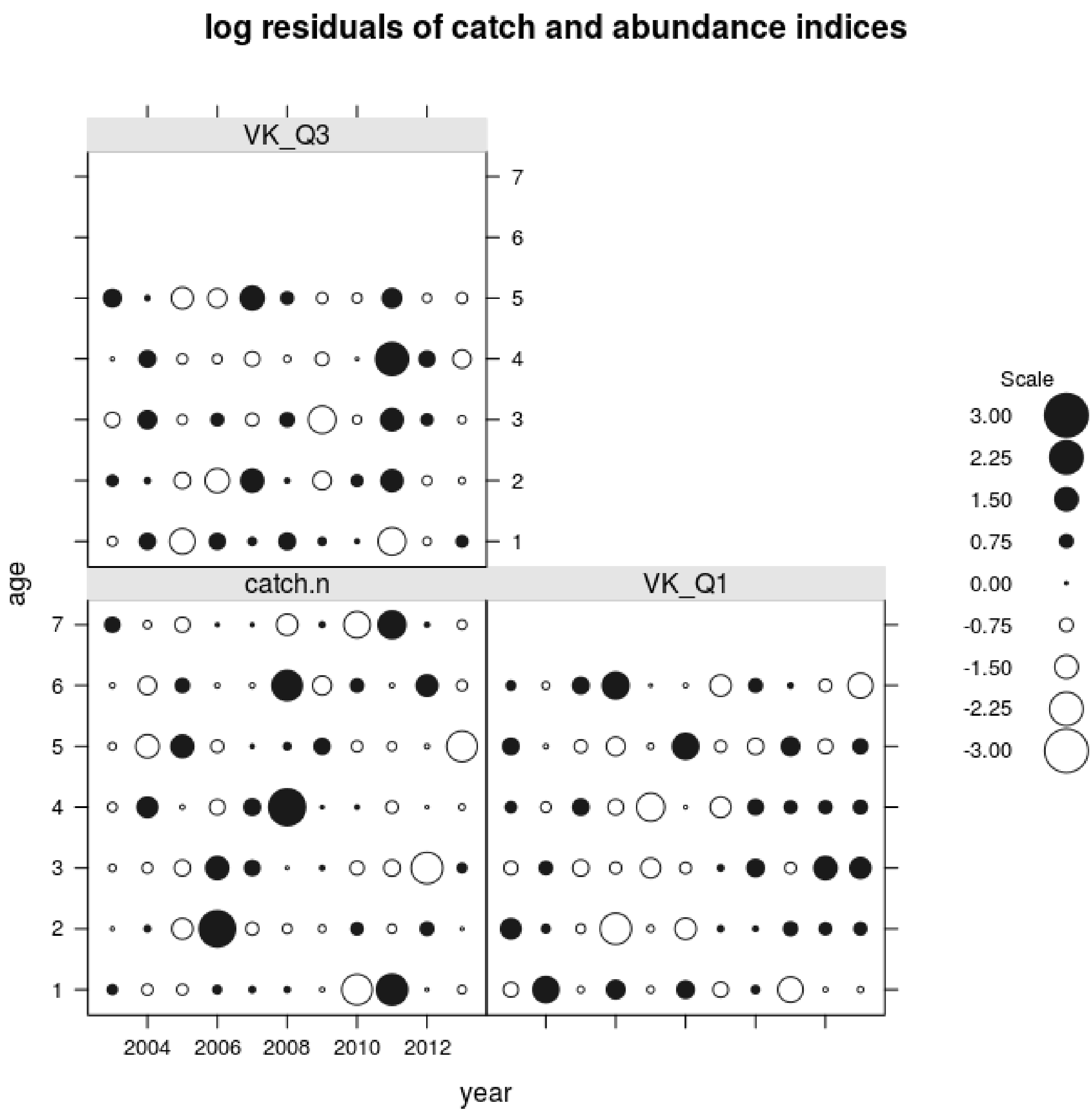

Figure 3.48: Cod-vk with IBTS Q1+Q3 assessment residuals

```r
plot(fit, stk)
```

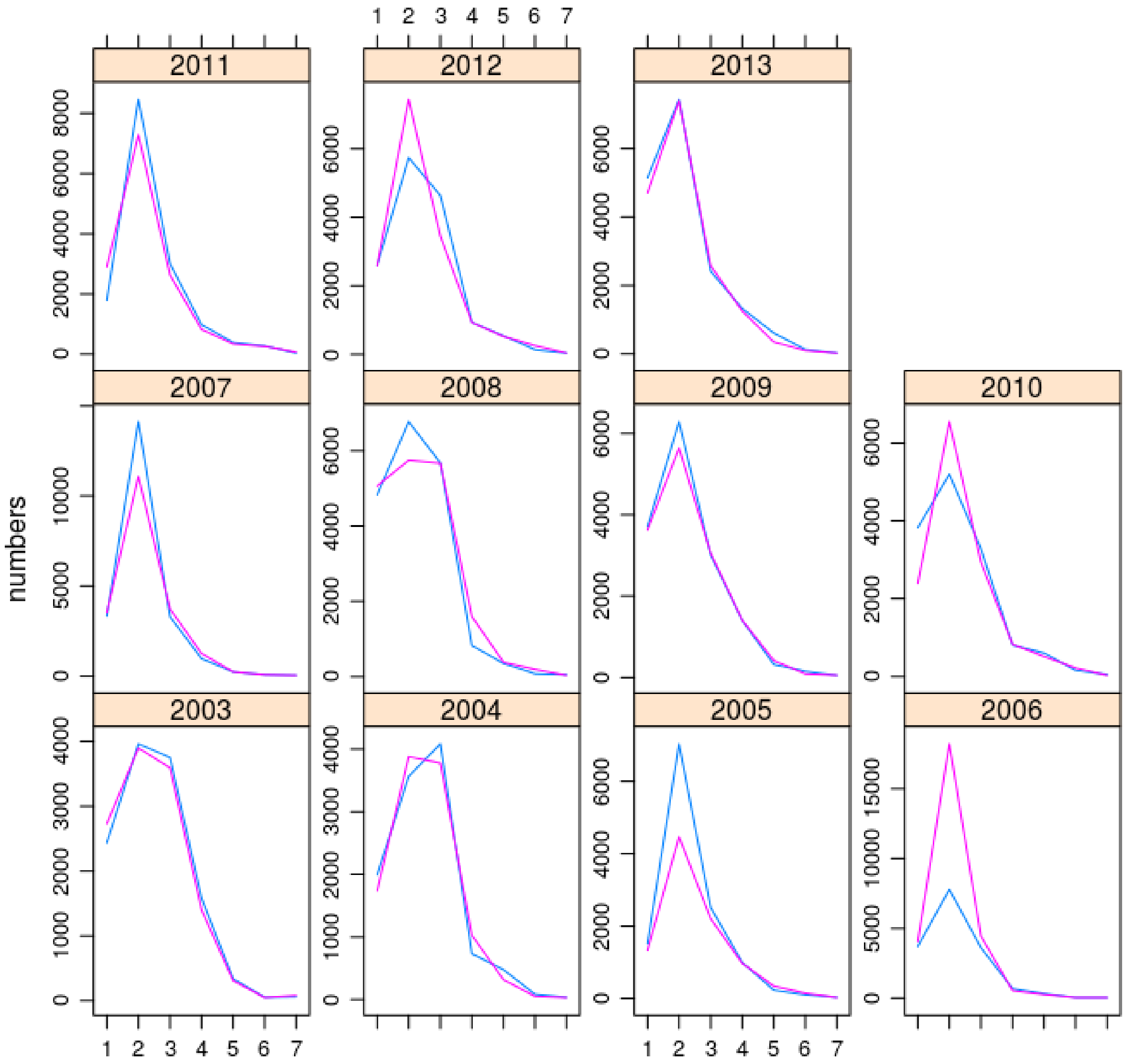

Figure 3.49: Cod-vk with IBTS Q1+Q3 catch observed VS predictions

```r
plot(fit, ids[1])
```

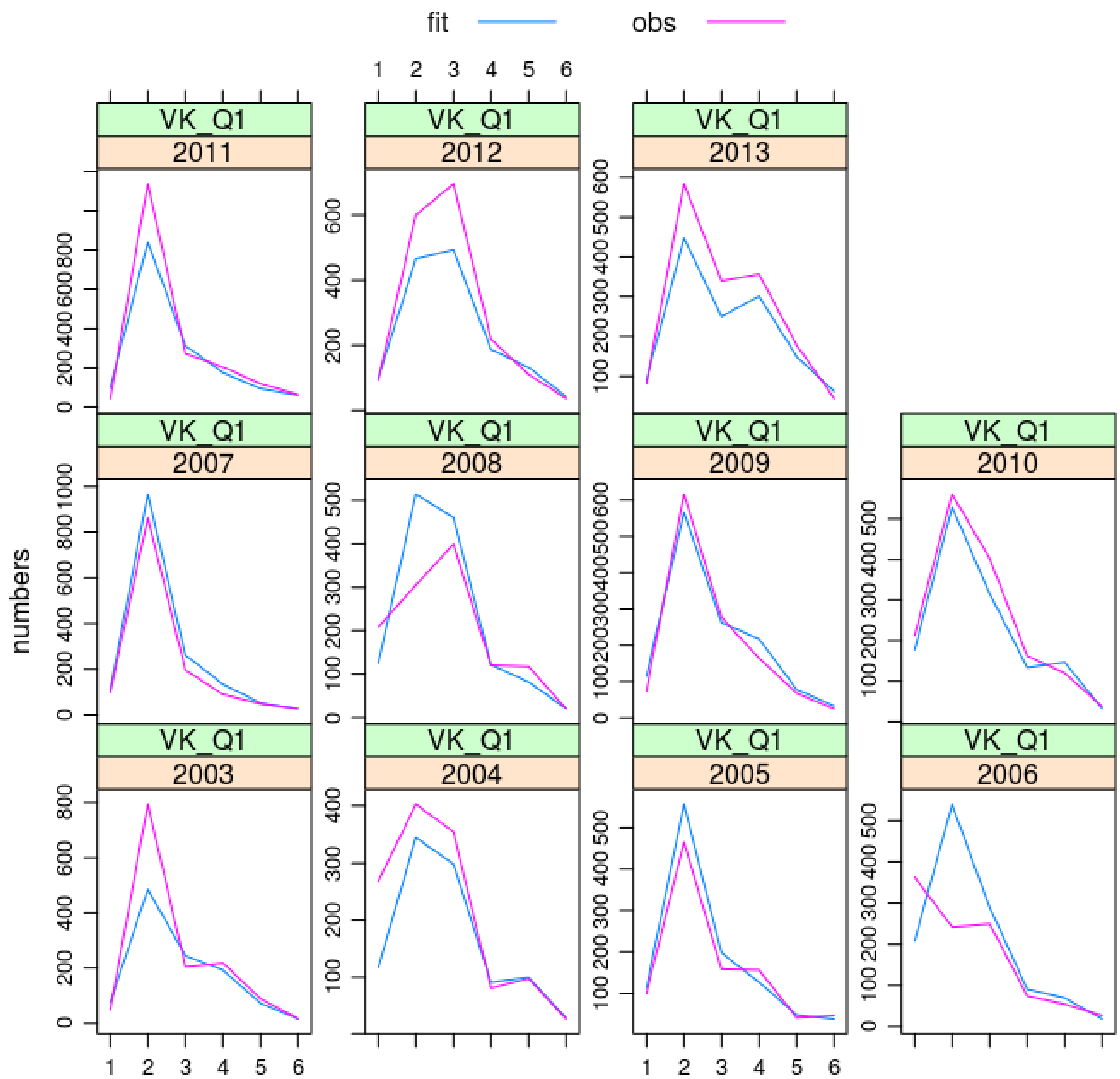

Figure 3.50: Cod-vk with IBTS Q1+Q3 index observed VS predictions

```r
plot(fit, ids[2])
```

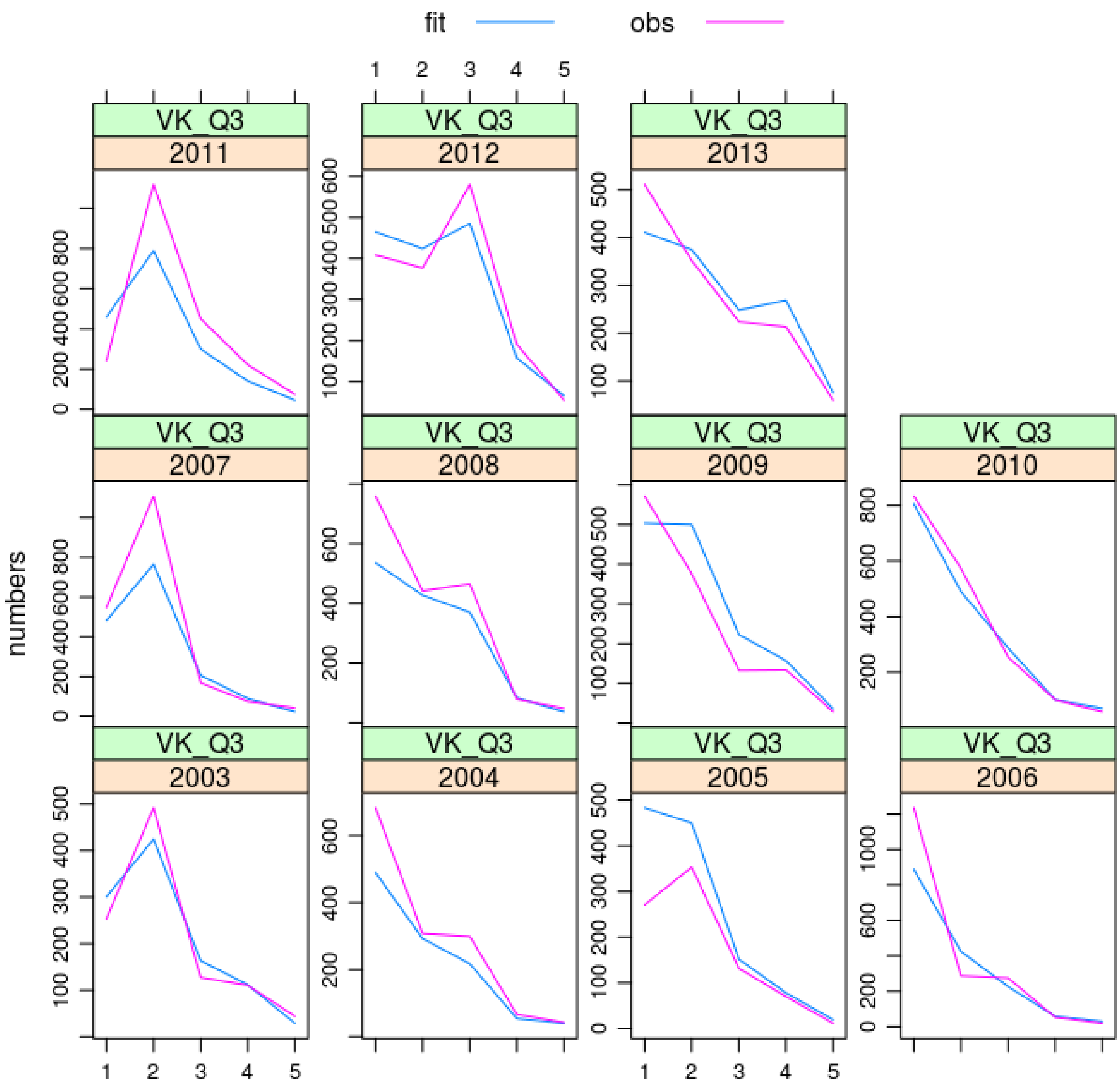

Figure 3.51: Cod-vk with IBTS Q1+Q3 index observed VS predictions

```r
wireframe(data ~ year + age, data = harvest(fit))
```

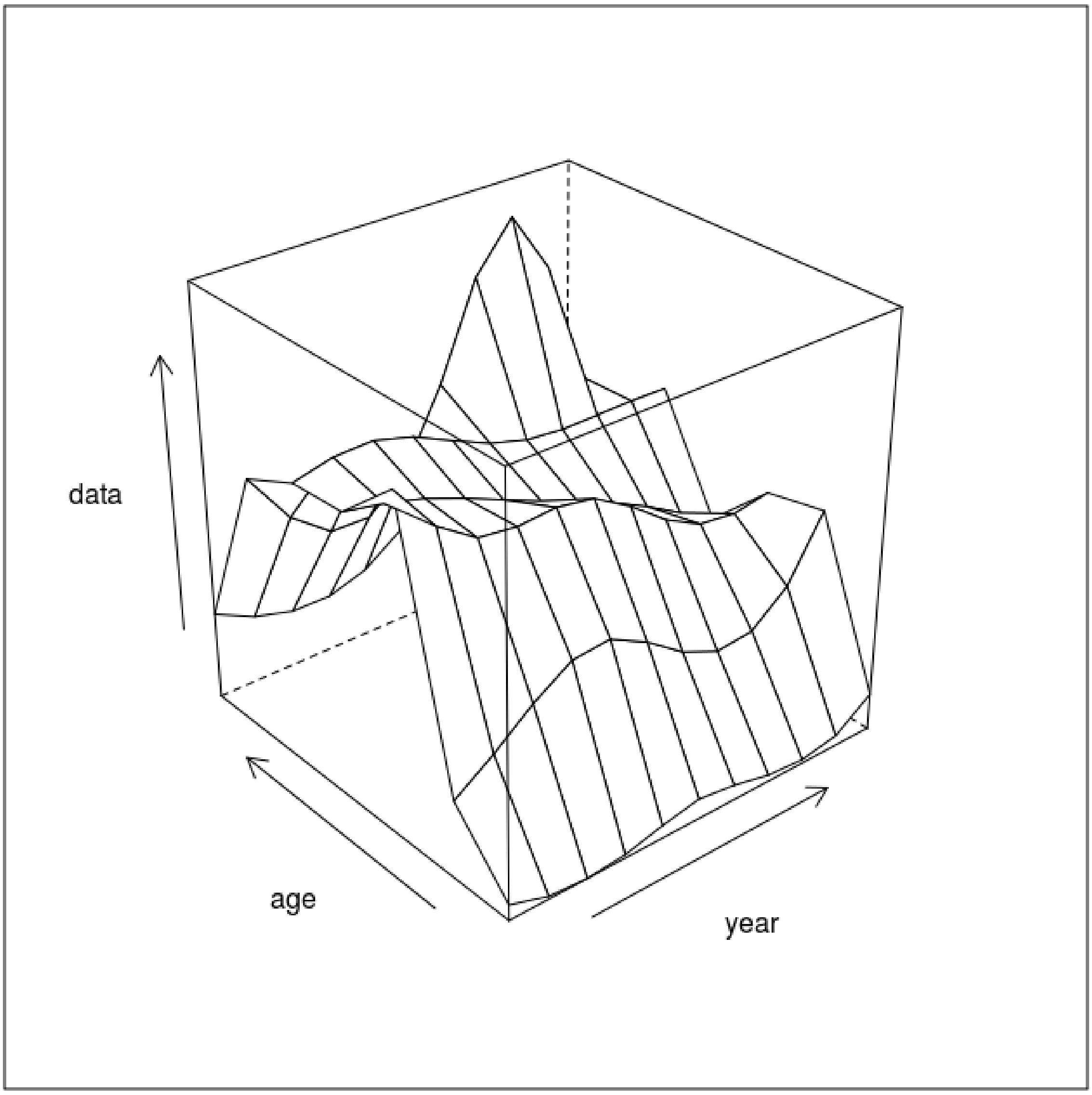

Figure 3.52: Cod-vk with IBTS Q1+Q3 assessment F-at-age surface

```
codvk.fstks <- stk + simulate(fit, 1000)
plot(codvk.fstks)
```

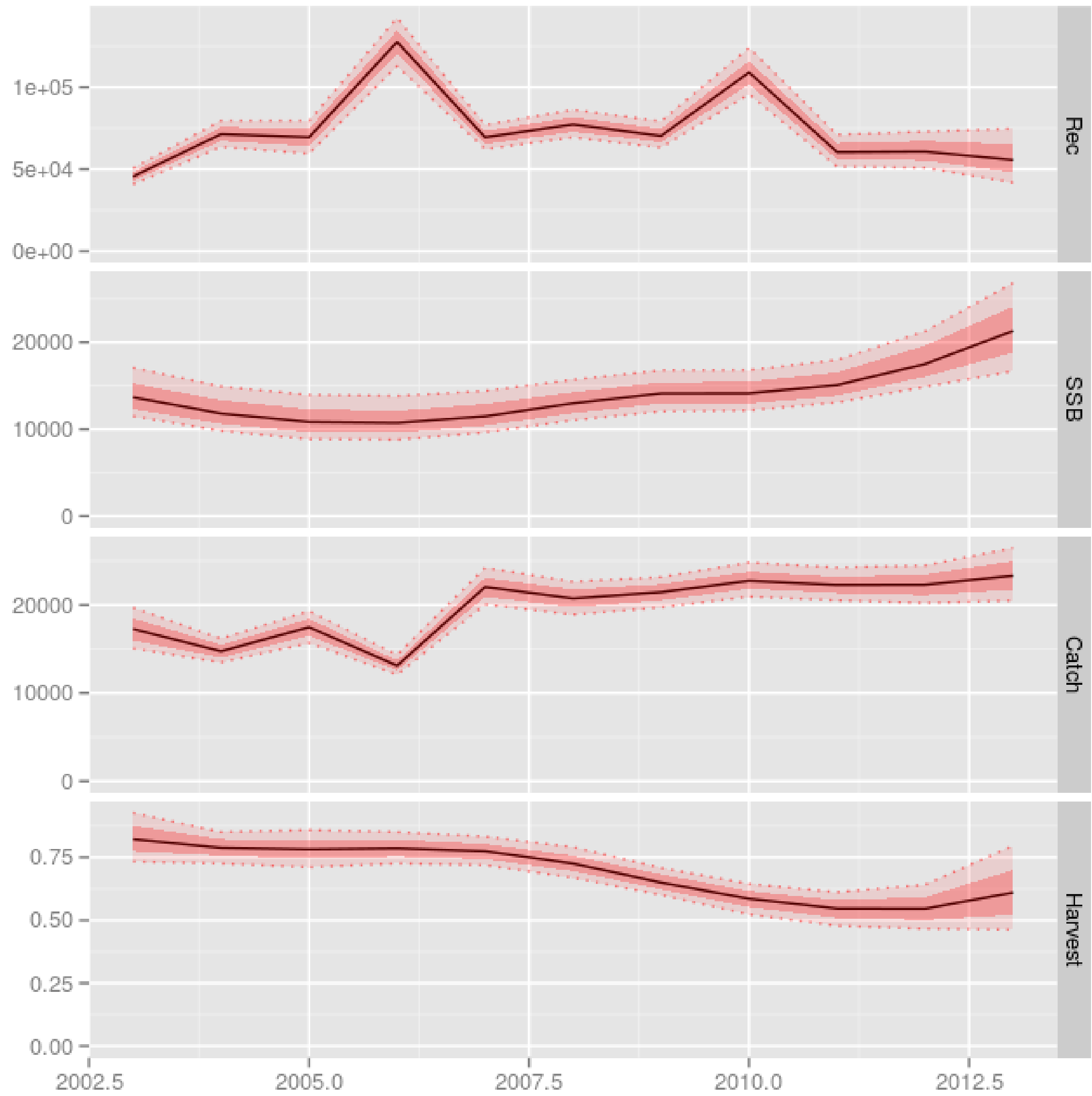

Figure 3.53: Cod-vk with IBTS Q1+Q3 assessment summary

```
codvk.fit <- fit
codvk.fstk <- stk + fit
codvk.sr <- fmle(as.FLSR(codvk.fstk, model = "bevholt"), control = list(trace = 0))
plot(codvk.sr)
```

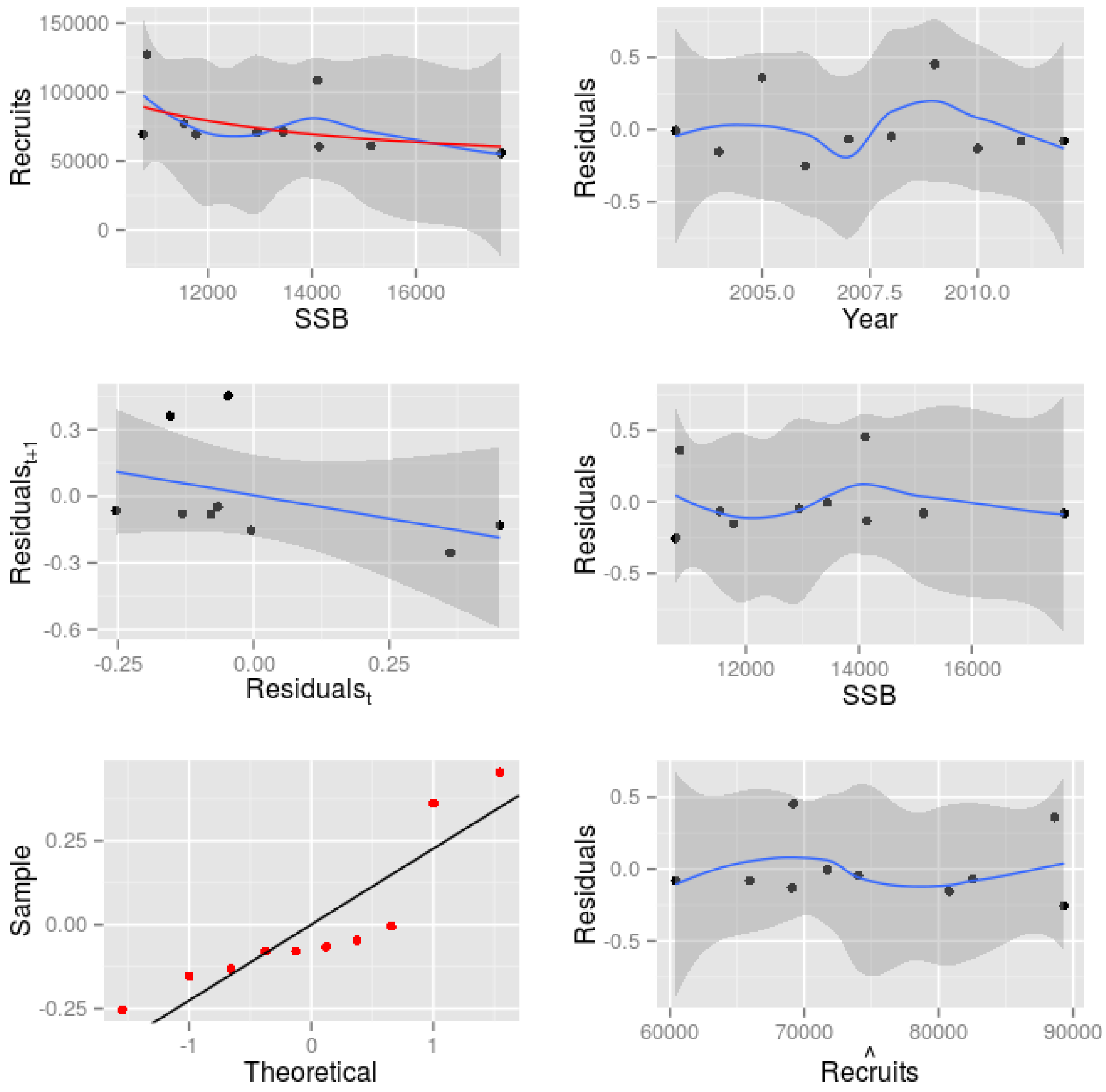

Figure 3.54: Cod-vk with IBTS Q1+Q3 stock-recruitment

3.3.3 Comparing fits

```
cod1 <- window(iter(cod, 1), start = 2003, end = 2013)
cods <- window(iter(cod, 2:1001), start = 2003, end = 2013)
codf <- window(window(iter(cod, 1), end = 2013) + cod.fit0, start = 2003)
codnwso.fstk <- window(codnwso.stk, start = 2003, end = 2013) +
    codnwso.fit0
```

```
codskvk.fstk <- window(codskvk.stk, start = 2003, end = 2013) +
    codskvk.fit0
cod4ssb <- ssb(codnw.fstks) + ssb(codso.fstks) + ssb(window(codsk.fstks,
    start = 2003, end = 2013)) + ssb(codvk.fstks)
cod2ssb <- ssb(codnwso.fstk) + ssb(codskvk.fstk)
cod4r <- rec(codnw.fstks) + rec(codso.fstks) + rec(window(codsk.fstks,
    start = 2003, end = 2013)) + rec(codvk.fstks)
cod2r <- rec(codnwso.fstk) + rec(codskvk.fstk)
cod4ssbn <- ssbn(codnw.fstks) + ssbn(codso.fstks) + ssbn(window(codsk.fstks,
    start = 2003, end = 2013)) + ssbn(codvk.fstks)
cod2ssbn <- ssbn(codnwso.fstk) + ssbn(codskvk.fstk)
```

SSB

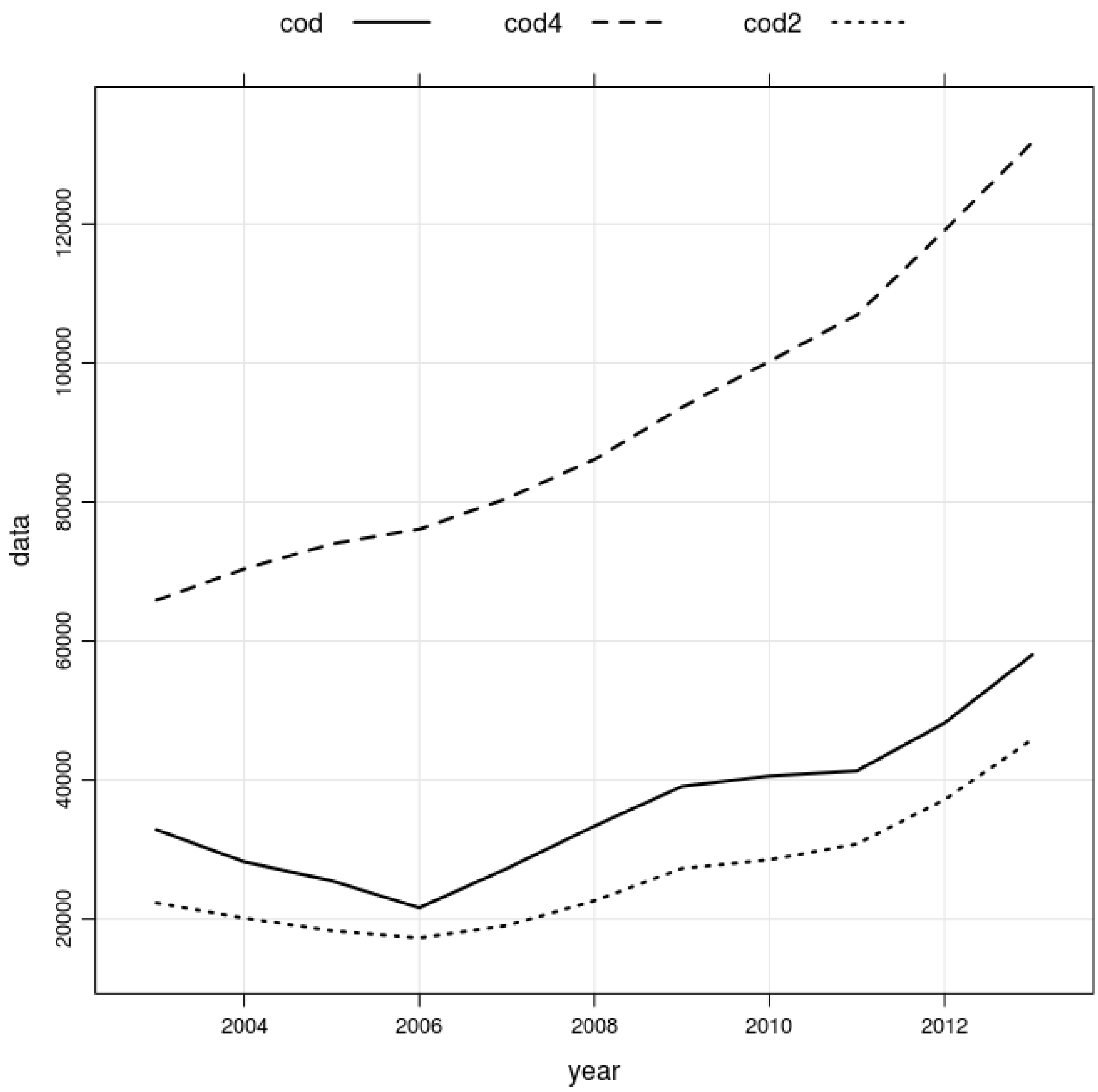

Figure 3.55: SSB of Cod for the North Sea estimated by the official assessment ("cod"), by aggregating the 4 sub-units SSB ("cod4") and by aggregating the two sub-units SSB ("cod2")

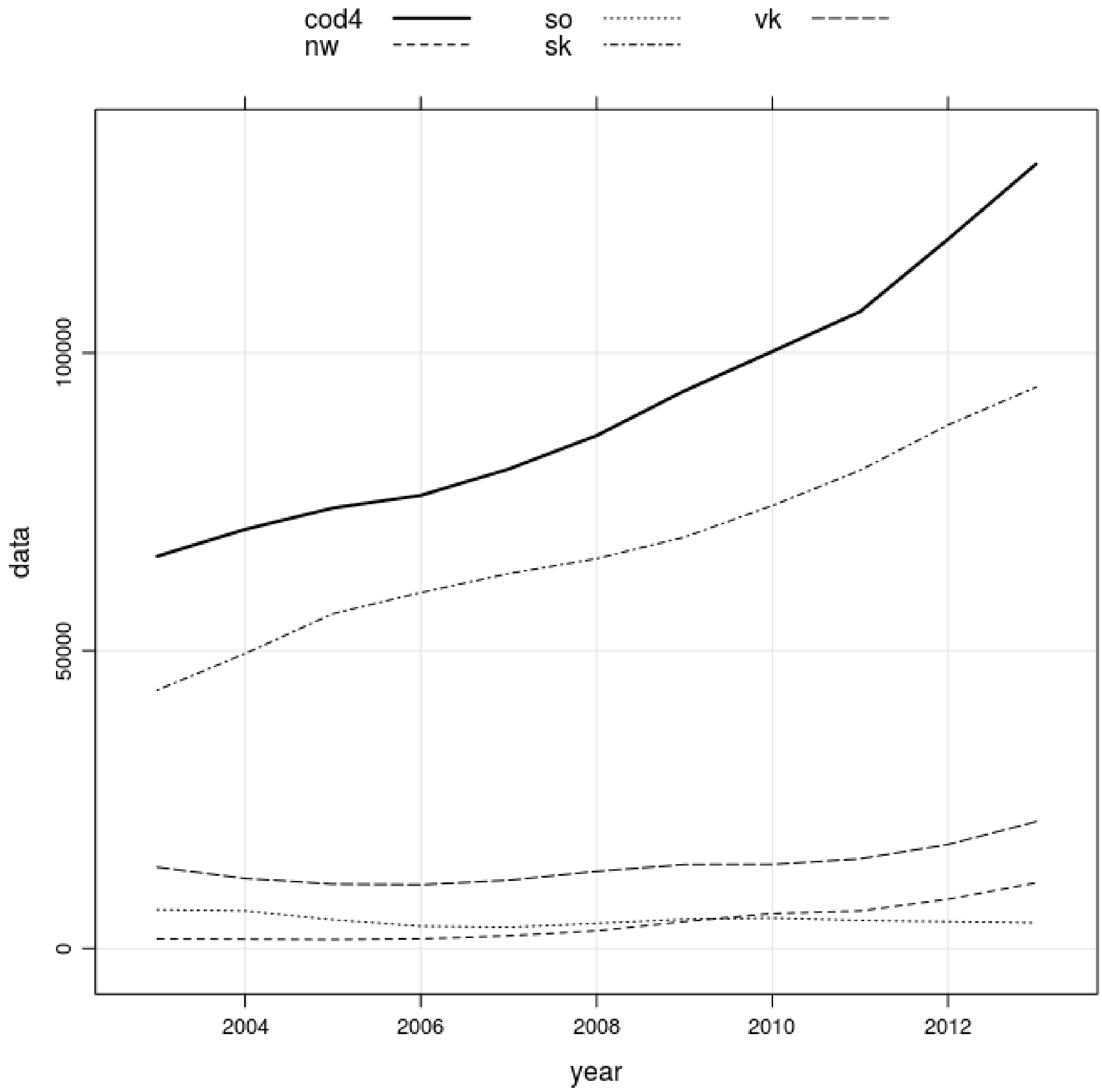

Figure 3.56: SSB of Cod estimated for each sub-unit in the case of 4 sub-units

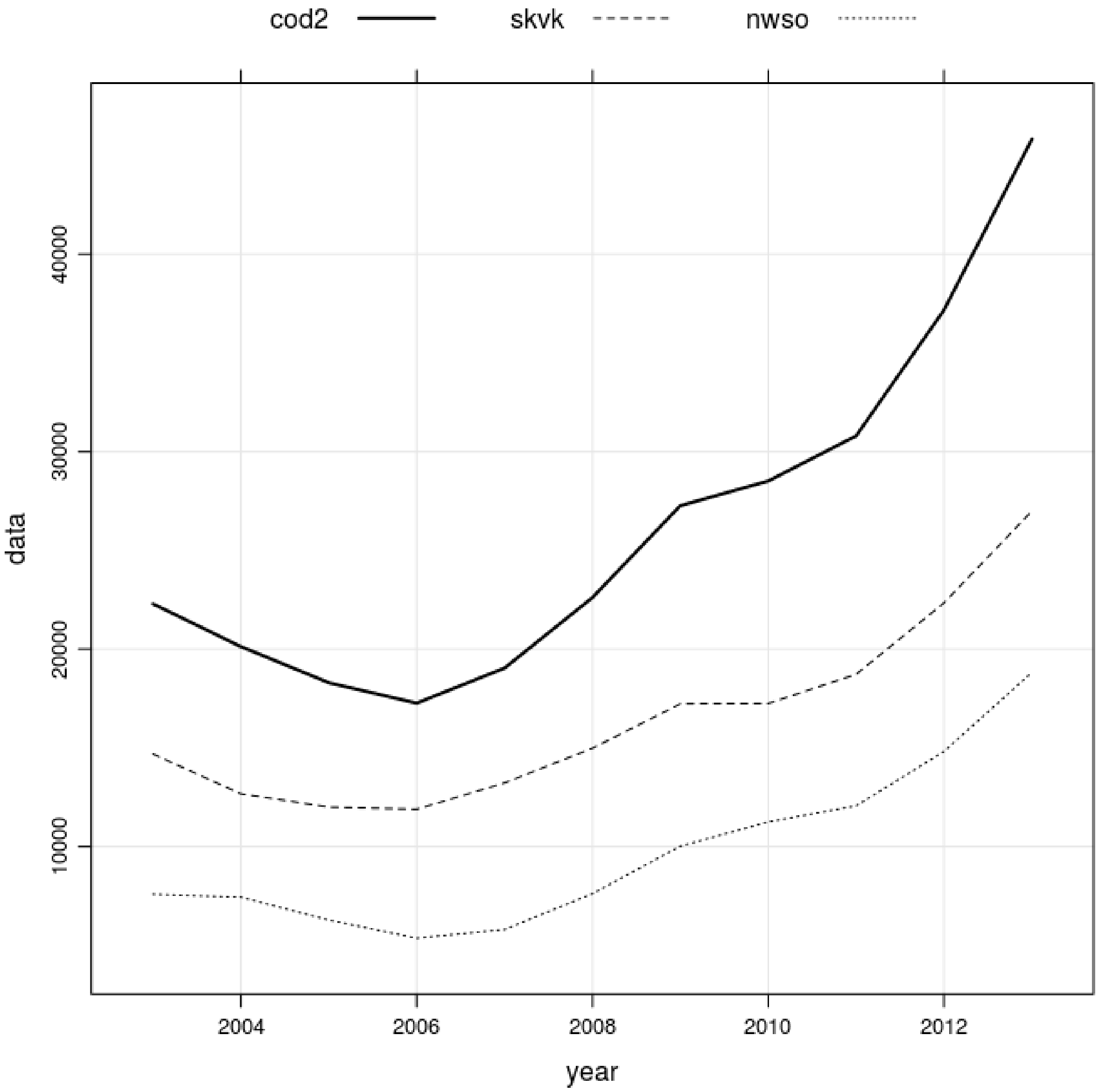

Figure 3.57: SSB of Cod estimated for each sub-unit in the case of 2 sub-units

Recruitment

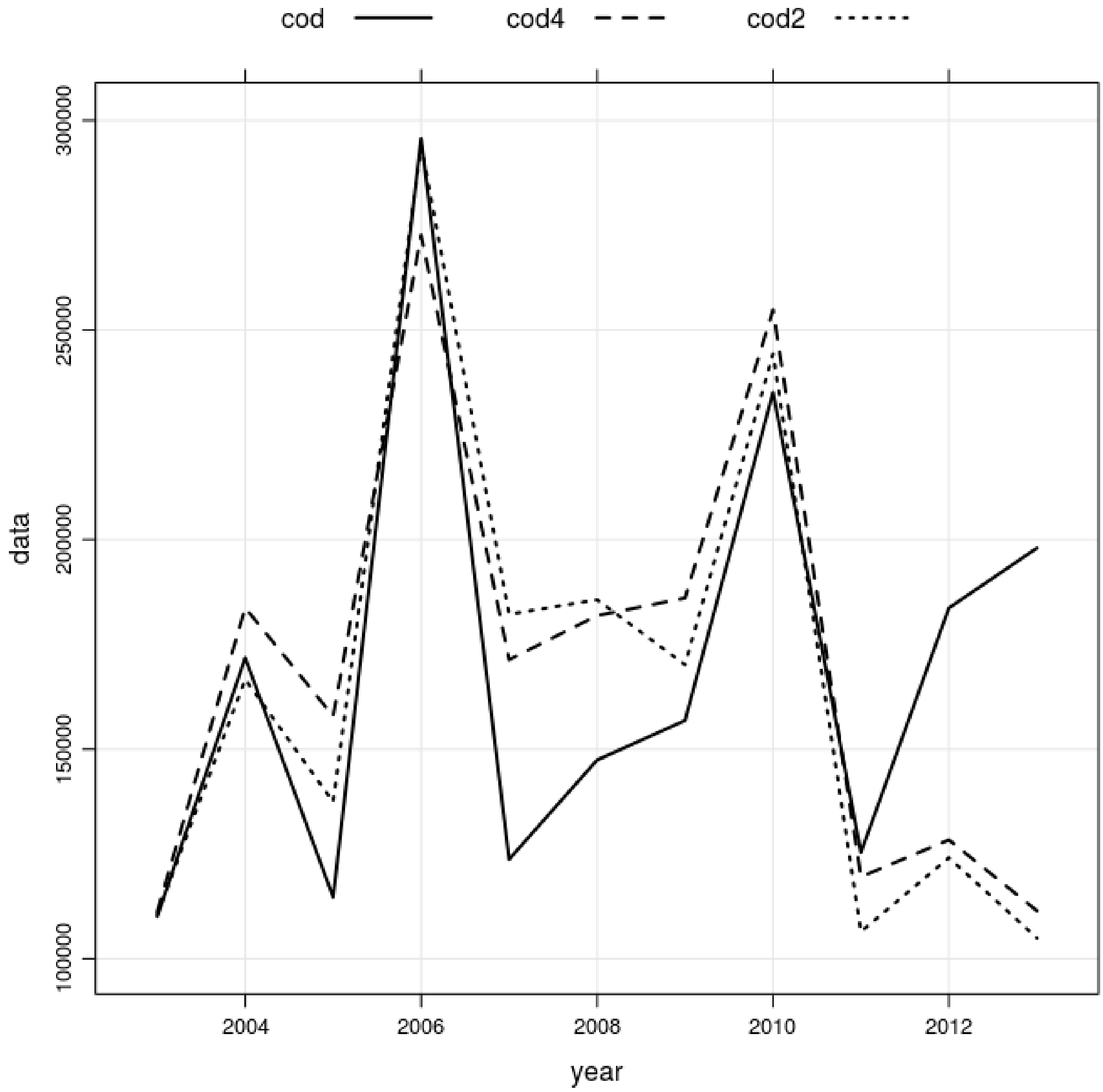

Figure 3.58: Recruitment of Cod for the North Sea estimated by the official assessment ("cod"), by aggregating the 4 sub-units recruitments ("cod4") and by aggregating the two sub-units recruitments ("cod2")

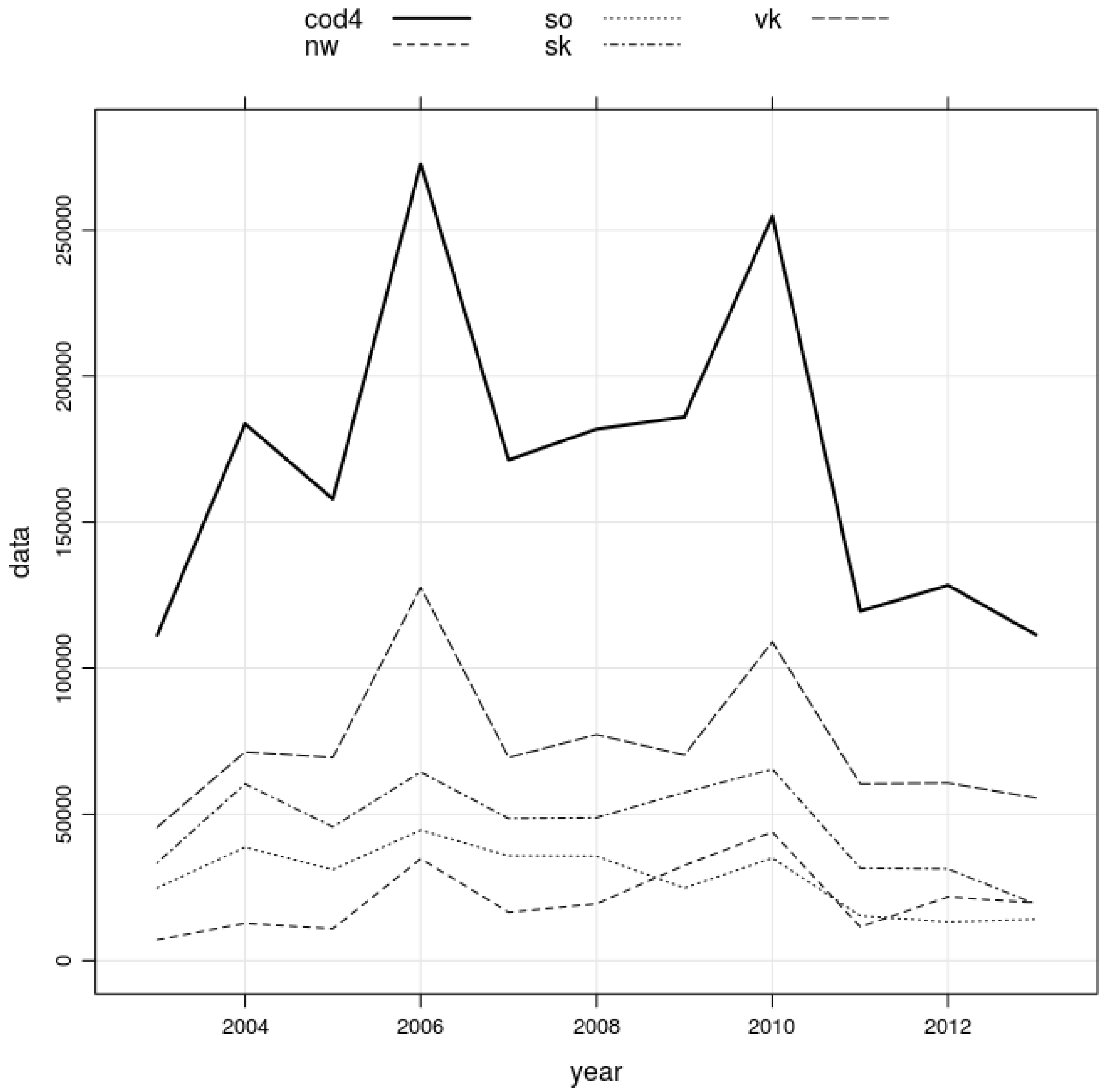

Figure 3.59: Recruitment of Cod estimated for each sub-unit in the case of 4 sub-units

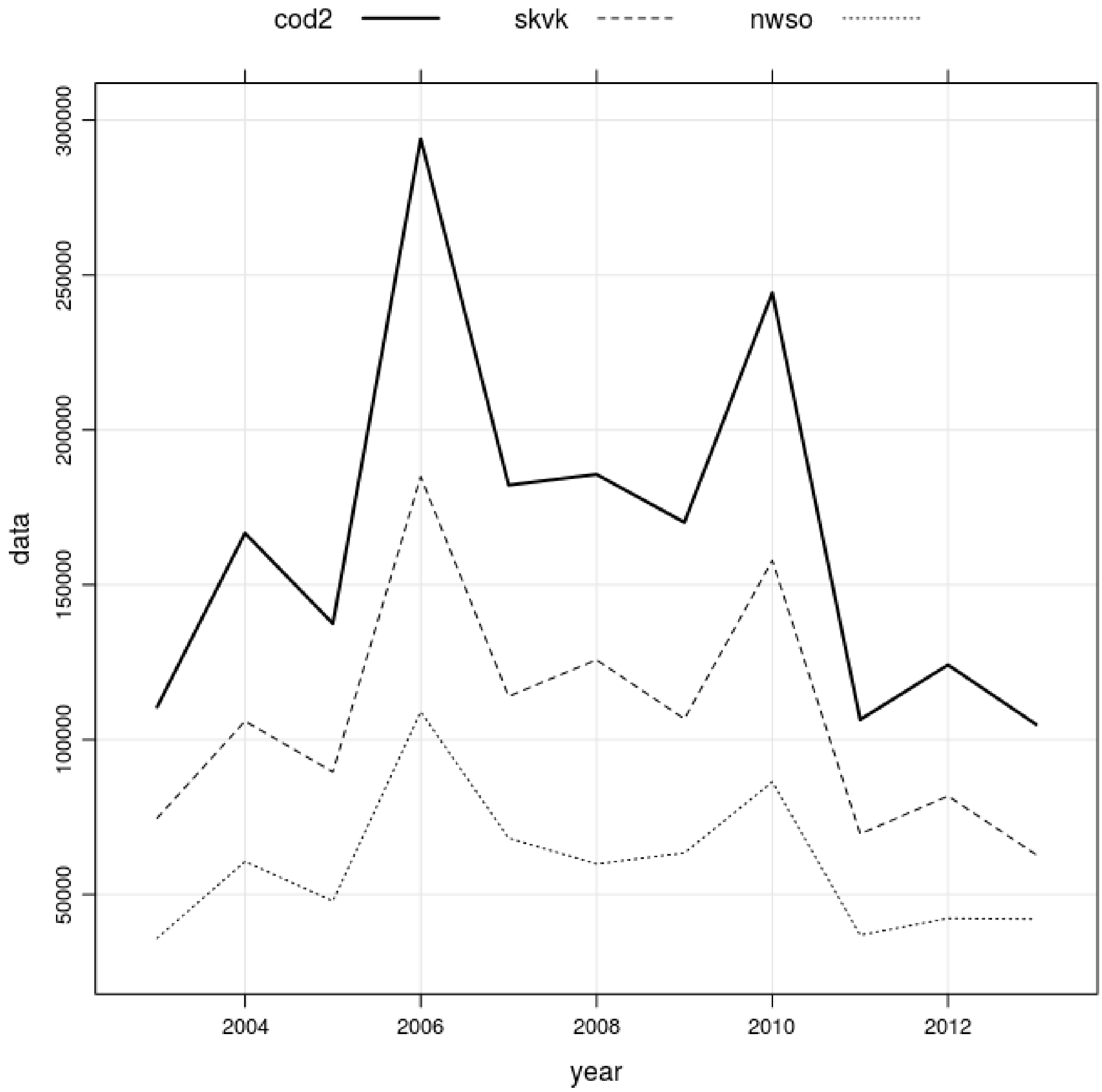

Figure 3.60: Recruitment of Cod estimated for each sub-unit in the case of 2 sub-units

Mature fraction of the population abundance

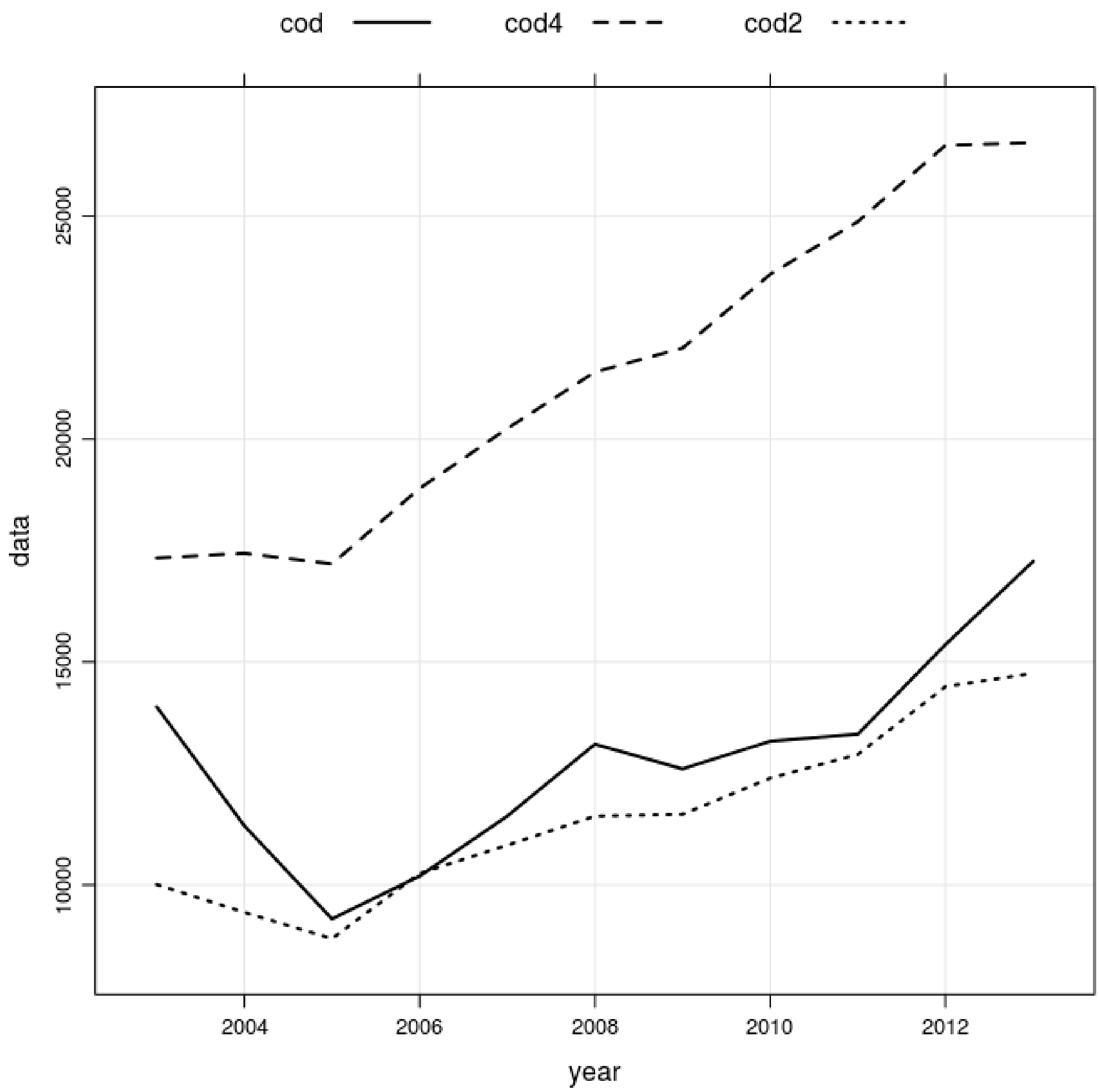

Figure 3.61: Mature fraction of the population abundance of Cod for the North Sea estimated by the official assessment ("cod"), by aggregating the 4 sub-units ("cod4") and by aggregating the two sub-units ("cod2")

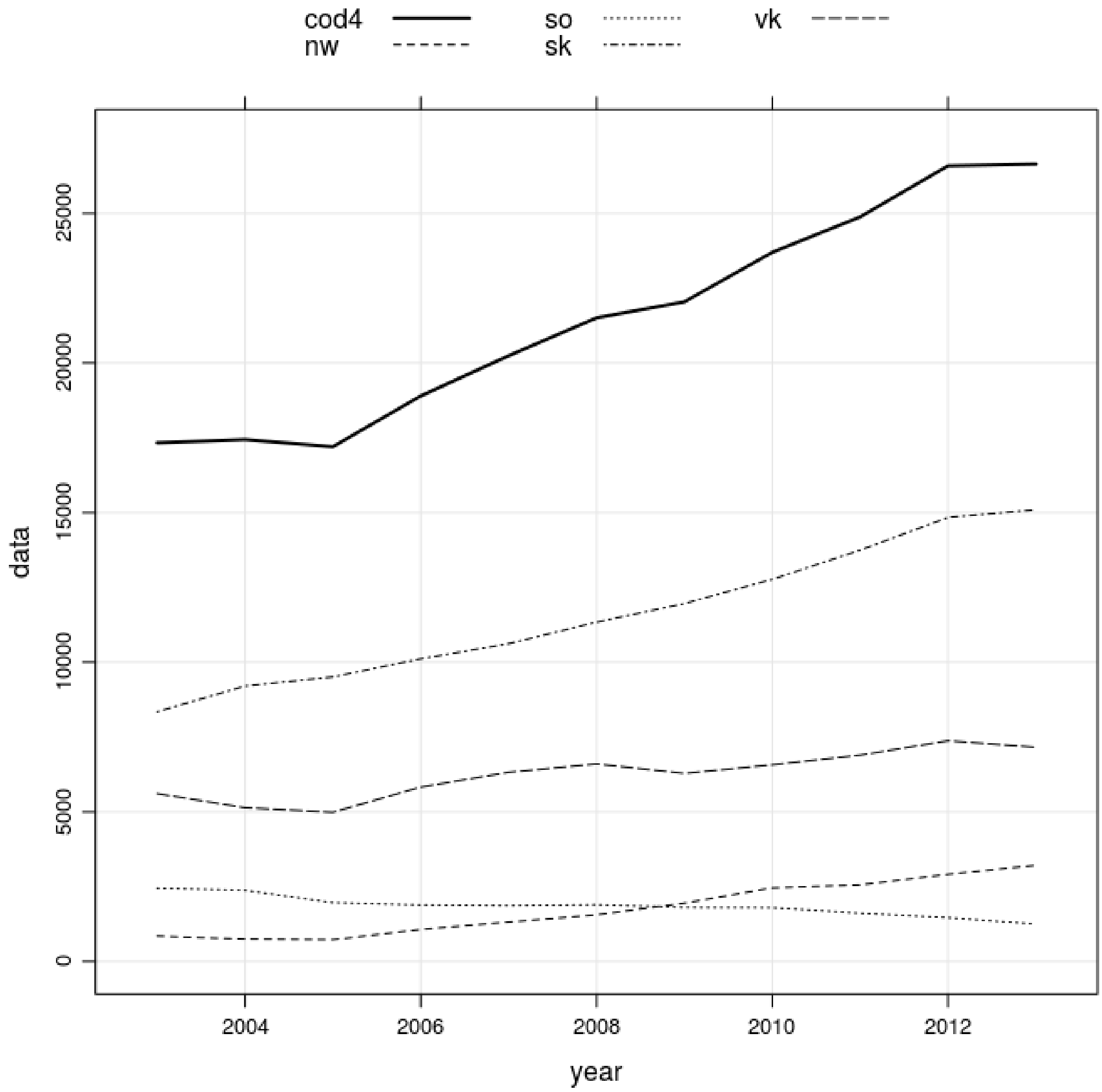

Figure 3.62: Mature fraction of the population abundance of Cod estimated for each sub-unit in the case of 4 sub-units

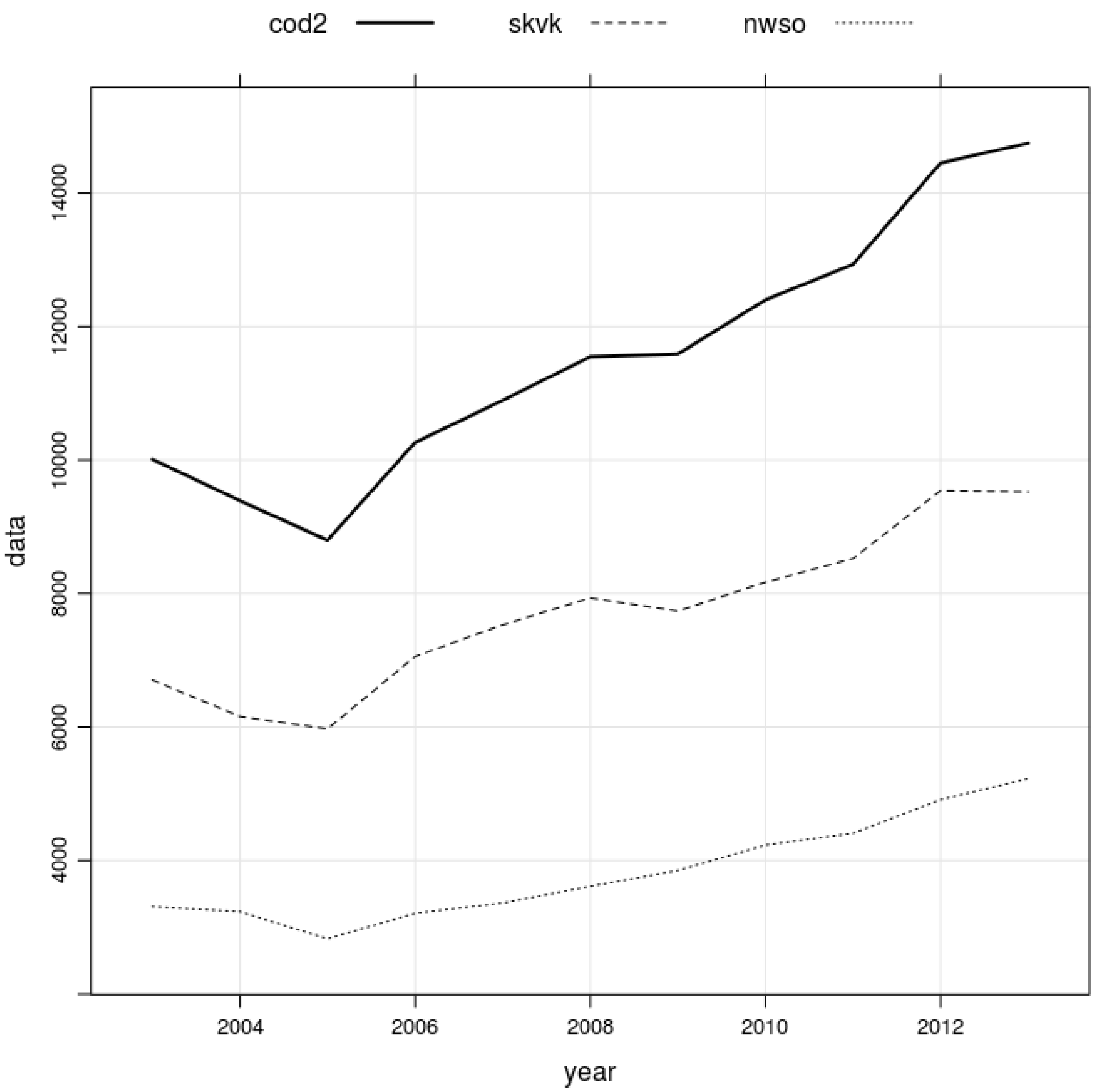

Figure 3.63: Mature fraction of the population abundance of Cod estimated for each sub-unit in the case of 2 sub-units

3.4 Results

The stock assessment outputs for the four sub-units are presented in Figures 3.19-3.54, including stock-recruitment models. With regads to the two sub-units hypothesis no attempt to improve the fits was made, so the default models were used for comparison purposes.

The assessments on the four sub-units were run trying to keep the same model structure, to avoid introducing the confounding factor of model differences in the results. The improvements introduced in the sub-models settings were effective in improving the diagnostics of the fits in all sub-units.

The SSB estimated for the aggregated stock and the two SSBs estimated from summing sub-units's SSBs by year, are presented in Figure 3.55. The SSB estimated from the 4 sub-units hypothesis is 2 to 3 fold higher than the stock estimate. This result is mainly due to the contribution of the Skagerrak sub-unit assessment. Considering the initial assumption, these results are likely related to the violation of the closed population assumption, which is supported by other information on sub-populations and their distribution described by Eero et.al (2015) and Wright, et.al (2015). These authors showed information that supports that it may be more appropriate to merge the Skagerrak and the Viking sub-units to approximate the close population assumption.

The SSB estimated from the 2 sub-units hypothesis is lower than the stock's SSB but a lot more inline with it. The differences can partly be due to different stock weights used. The ICES assessment used mean weights in the catch as stock weights, whereas in the area-disaggregated analyses, area-specific stock weights from IBTS were used. As a matter of fact, the aggregated abundance of mature individuals (Fig. 3.61) showed that the two sub-units estimates are very similar, while the four sub-units estimates are still 2 fold higher. Once more due to the Skagerrak estimates.

With regards to recruitment, the results are not too different (Fig. 3.58). However, results when making sub-units assessments (2 or 4 areas) are more similar to each other than compared to the single stock assessment.

The summaries of stock assessment results for the 2 areas are shown in Figures 3.7 and 3.8. The biomass trends obtained from both assessments are similar, showing an increase in recent years, with a higher stock size in VK & SK compared to NW & SO. Also, fishing mortalities from these runs shows a decline in both areas, resulting in a somewhat higher level in VK & SK in the latest years compared to NW & SO.

4 Skagerrak plaice

The assessment of plaice in the Skagerrak as been challenging for a long time, mainly due to the mix of the local population with the North Sea population, both in catches and surveys, given that they co-exist in the same area.

The issues and uncertainties around the plaice stock structure in the transition area between the North Sea and the Baltic Sea have been long standing. The area IIIa, i.e. Skagerrak (ICES area IIIaN) and Kattegat (ICES area IIIaS) is not large compared to the neighboring seas, but it offers a great variability in hydrographical conditions (temperature, salinity, depth, sediment, stream etc.), leading to a complex population structure of all marine species inhabiting this area.

The last accepted assessment of the plaice stock previously defined as IIIa was in 2002. Since then, much effort was dedicated to understanding the possible origins and dynamics of the various plaice populations in more detail, based on comprehensive literature review and analysis of available data (ICES, 2012; Ulrich et al., 2013). This work concluded that plaice in Skagerrak and in Kattegat were likely not belonging to the same stock units, and should therefore not be assessed together. New qualitative hypotheses were also formulated on the linkages between the North Sea and the Skagerrak. In order to validate and possibly quantify these alternative hypotheses, new data have been collected over 2012-2013 from different sources (otoliths, genetics, hydrodynamic modelling and tagging). These have indicated that up to 50% of the fish caught in Skagerrak could have a North Sea origin (Ulrich *et.al*, 2014[1]).

A decision must therefore be made whether the resident plaice stock in Skagerrak should rather be assessed together with the larger North Sea stock (with the risk of overlooking local stock dynamics and possible local depletion) or separately but accounting for stock mixing (with the risk of a difficult and highly uncertain assessment).

The work carried out here aimed therefore to investigate how stock assessment could be set to deal with this problem of potential population mixture in the Skagerrak. There were several attempts to look at the problem, including:

- using the SSB of the North Sea stock as a covariate to the Skagerrak population assessment, which could balance out the trends of the North Sea SSB;
- assessing the stocks together;
- including a year trend on the catchability sub-models, to account for variability due to fluctuations in the North Sea stock SSB, that can spill into the Skagerrak area.

[1] Ulrich C., Boje J., Hüssy K., Christensen A., Degel H., Clausen, L.W., Hemmer-Hansen, J., 2014. Summary of results and preliminary conclusions from a Danish project on plaice (*Pleuronectes platessa*) stock structure in the transition area between the North Sea and the Baltic Sea. WD to the ICES Benchmark Workshop on Plaice

4.1 Read and process data

This section presents the code to read the datasets into R and process the data, in order to create FLR objects that can be used for the analysis.

The following objects refer to the official ICES assessment carried out with XSA, and already converted into FLR objects.

```
load("dataple/PLE-NS.RData")
ple <- stock
```

The following sections show how the data processed for this exercise was imported and processed to create the FLR objects required to run stock assessments.

```
plesk.stk <- window(stock, start = 1984)
lnd <- read.csv("dataple/Skagerrak LANUM.csv")
lwt <- read.csv("dataple/Skagerrak WELA.csv")
landings.n(plesk.stk) <- FLQuant(t(lnd[, -1]), dimnames = list(age = 1:10,
    year = lnd[, 1]))
catch.n(plesk.stk) <- landings.n(plesk.stk)
catch.n(plesk.stk)[catch.n(plesk.stk) == 0] <- 0.01
landings.wt(plesk.stk) <- FLQuant(t(lwt[, -1]), dimnames = list(age = 1:10,
    year = lwt[, 1]))
# mean weights missing replaced by historical mean
flq <- landings.wt(plesk.stk)
flq[] <- yearMeans(stock.wt(plesk.stk))
landings.wt(plesk.stk)[is.na(landings.wt(plesk.stk))] <- flq[is.na(landings.wt(plesk.stk))]
catch.wt(plesk.stk) <- landings.wt(plesk.stk)
discards.wt(plesk.stk) <- landings.wt(plesk.stk)
stock.wt(plesk.stk) <- landings.wt(plesk.stk)
catch(plesk.stk) <- computeCatch(plesk.stk)
landings(plesk.stk) <- computeLandings(plesk.stk)
discards(plesk.stk) <- computeDiscards(plesk.stk)
stock.n(plesk.stk) <- harvest(plesk.stk) <- harvest.spwn(plesk.stk) <- m.spwn(plesk.stk) <- 0

files <- system("ls dataple/", intern = T)
files <- files[grep("csv", files)][-c(9, 10)]
ple.ids <- list()
length(ple.ids) <- length(files)
names(ple.ids) <- unlist(lapply(strsplit(files, split = "\\."),
    "[[", 1))


for (i in seq_along(files)) {
    idx <- read.csv(paste("dataple/", files[i], sep = ""))
    qrt <- idx$Quarter[1]
    dnms <- list(age = unlist(lapply(strsplit(colnames(idx)[-c(1:5)],
        split = "_"), "[[", 2)), year = idx$Year)

    # check year - 2000 missing in IBTS Q3 Skagerrak
```

```
    if (length(dnms$year) < (range(dnms$year)[2] - range(dnms$year)[1] +
        1)) {
        idx <- rbind(idx, c("NS-IBTS", 2000, 3, "NS_PlaiceIIIa",
            10, rep(as.numeric(NA), 11)))
        if (dnms$year[1] == "1991")
            idx <- rbind(idx, c("NS-IBTS", 1995, 3, "NS_PlaiceIIIa",
                10, rep(as.numeric(NA), 11)))
        idx <- idx[order(idx$Year), ]
        dnms$year <- idx$Year
    }

    flq <- FLQuant(t(idx[, -c(1:5)]), dimnames = dnms)
    flq[flq == 0] <- 0.01
    idx <- FLIndex(index = flq)
    range(idx)[c("startf", "endf")] <- c((qrt - 1) * 3, qrt *
        3)
    ple.ids[[i]] <- idx
}
ple.ids <- FLIndices(ple.ids)
```

4.2 Model fits

4.2.1 Quick and dirty - the default method

```
stk <- window(ple, end = 2013)
ids <- window(lapply(ple.ids[1:2], function(x) trim(x, age = 1:9)),
    end = 2013)
ple.fit0 <- sca(stk, ids)
plot(FLStocks(a4a = stk + ple.fit0, orig = stk), auto.key = T)
```

Figure 4.1: Plaice in the North Sea - a4a default assessment

```
stk <- window(plesk.stk, end = 2013)
ids <- window(lapply(ple.ids[c("skq3")], function(x) trim(x,
    age = 1:9)), end = 2013)
plesk.fit0 <- sca(stk, ids)
plot(stk + plesk.fit0)
```

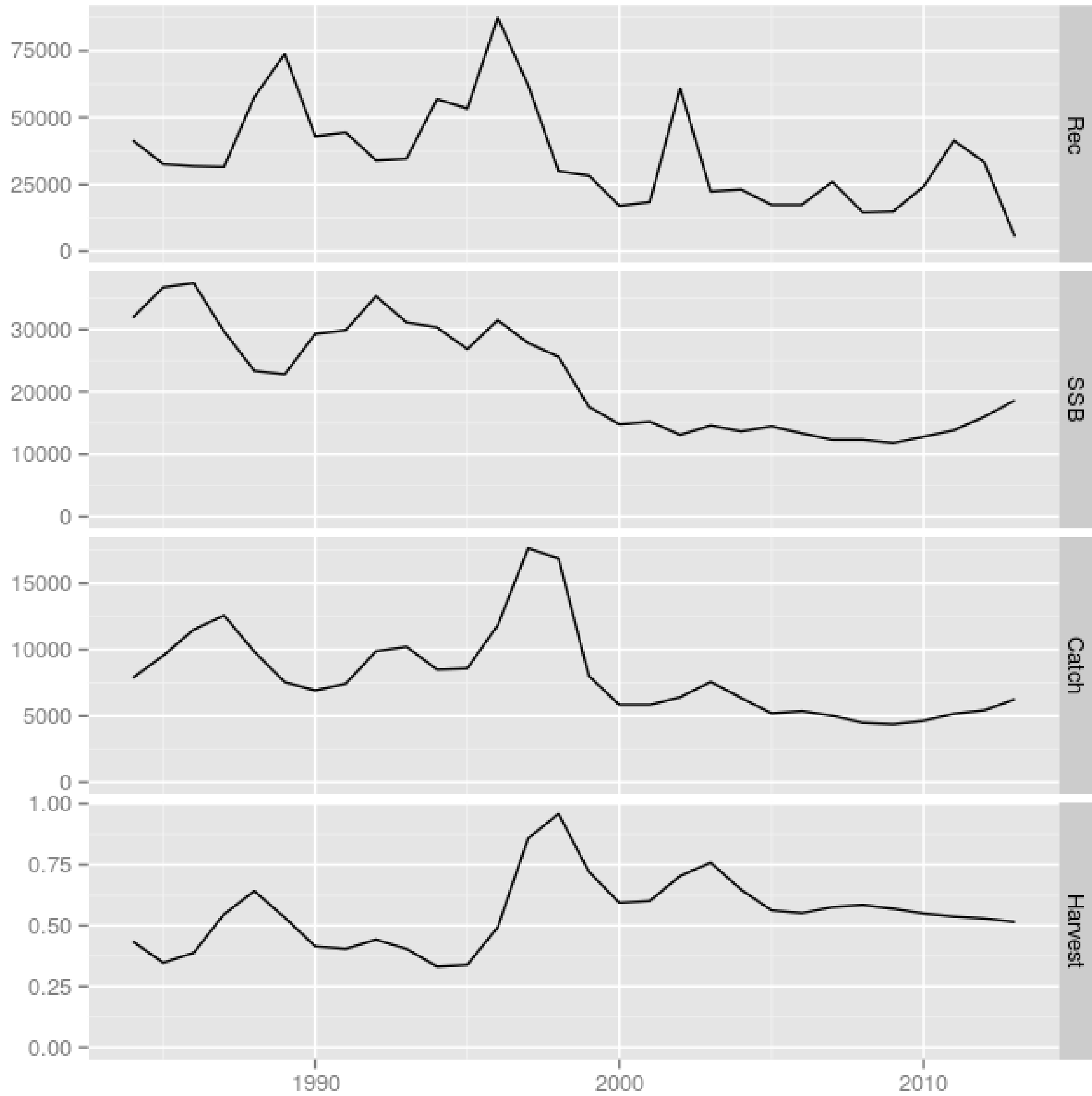

Figure 4.2: Plaice in the Skagerrak - a4a default assessment

4.2.2 Improving the fits

```
stk <- window(plesk.stk, end = 2013)
# catches at age 1 are residual and seem artificial in some
# years
catch.n(stk)[1] <- NA
```

```r
# there a couple of very high residuals in ages 9 and 10,
# will do +9
stk <- setPlusGroup(stk, 9)
```

Testing surveys

The data prepared for this exercise consisted of a series of abundance indices that were computed from the same surveys/sources of data, using distinct spatial aggregations. To decide about which indices should be used a quick visual analysis of the residuals was carried out.

```r
ids <- window(lapply(ple.ids[7:12], function(x) trim(x, age = 1:8)),
    end = 2013)
lst <- lapply(ids, function(x) try(sca(stk, FLIndices(x), fit = "assessment")))
lst.res <- lapply(ids, function(x) residuals(sca(stk, FLIndices(x)),
    stk, FLIndices(x)))
```

```
xyplot(data ~ year | age, groups = qname, data = FLQuants(lapply(lst.res,
    "[[", 1)), auto.key = list(columns = 3, lines = TRUE), pch = 19,
    cex = 0.5, type = c("p", "smooth"), main = "catch residuals")
```

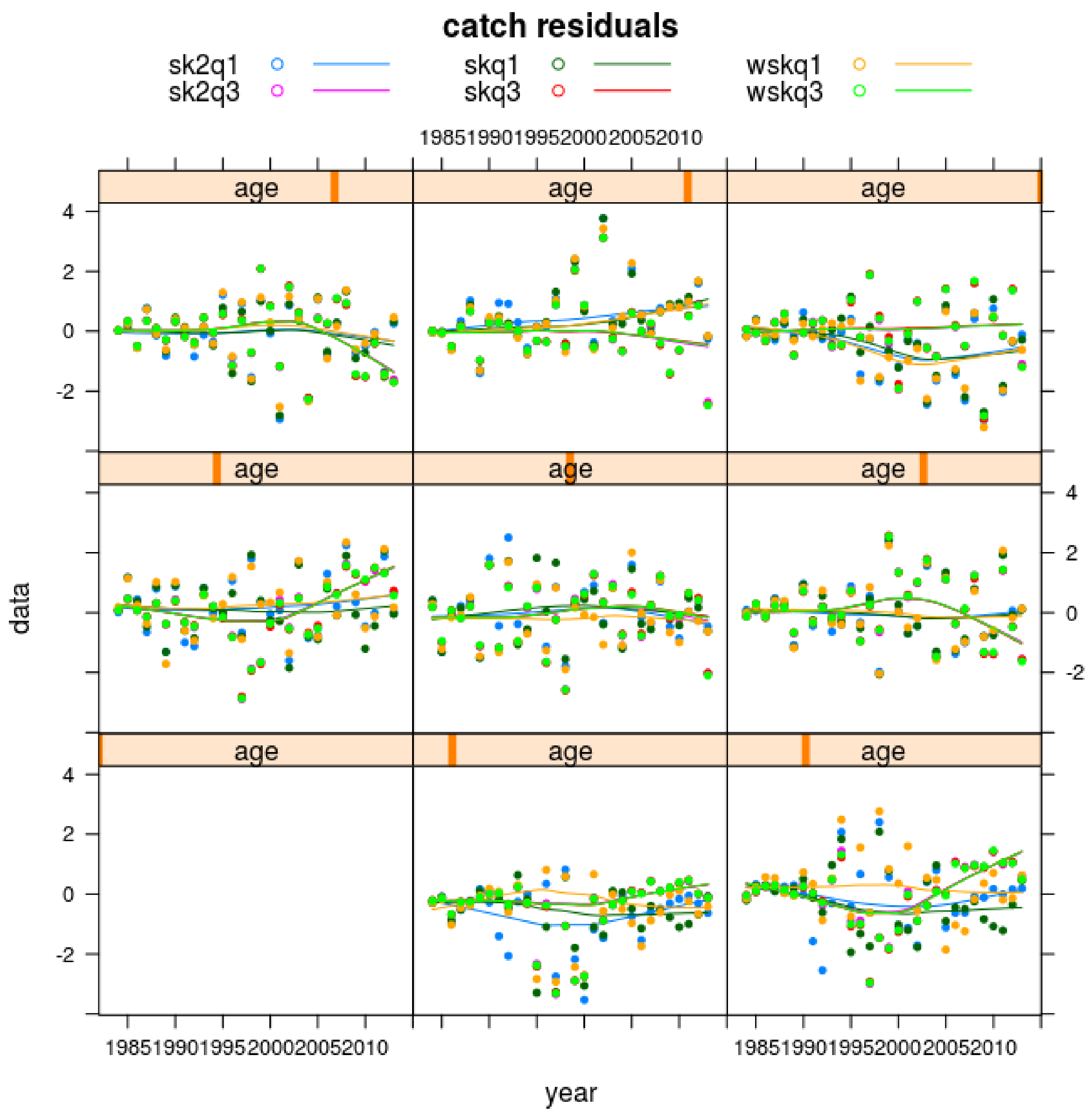

Figure 4.3: Plaice in the Skagerrak - a4a default assessment with one survey at the time catch residuals

```
xyplot(data ~ year | age, groups = qname, data = FLQuants(lapply(lst.res,
    "[[", 2)), auto.key = list(columns = 3, lines = TRUE), pch = 19,
    cex = 0.5, type = c("p", "smooth"), main = "catchability residuals")
```

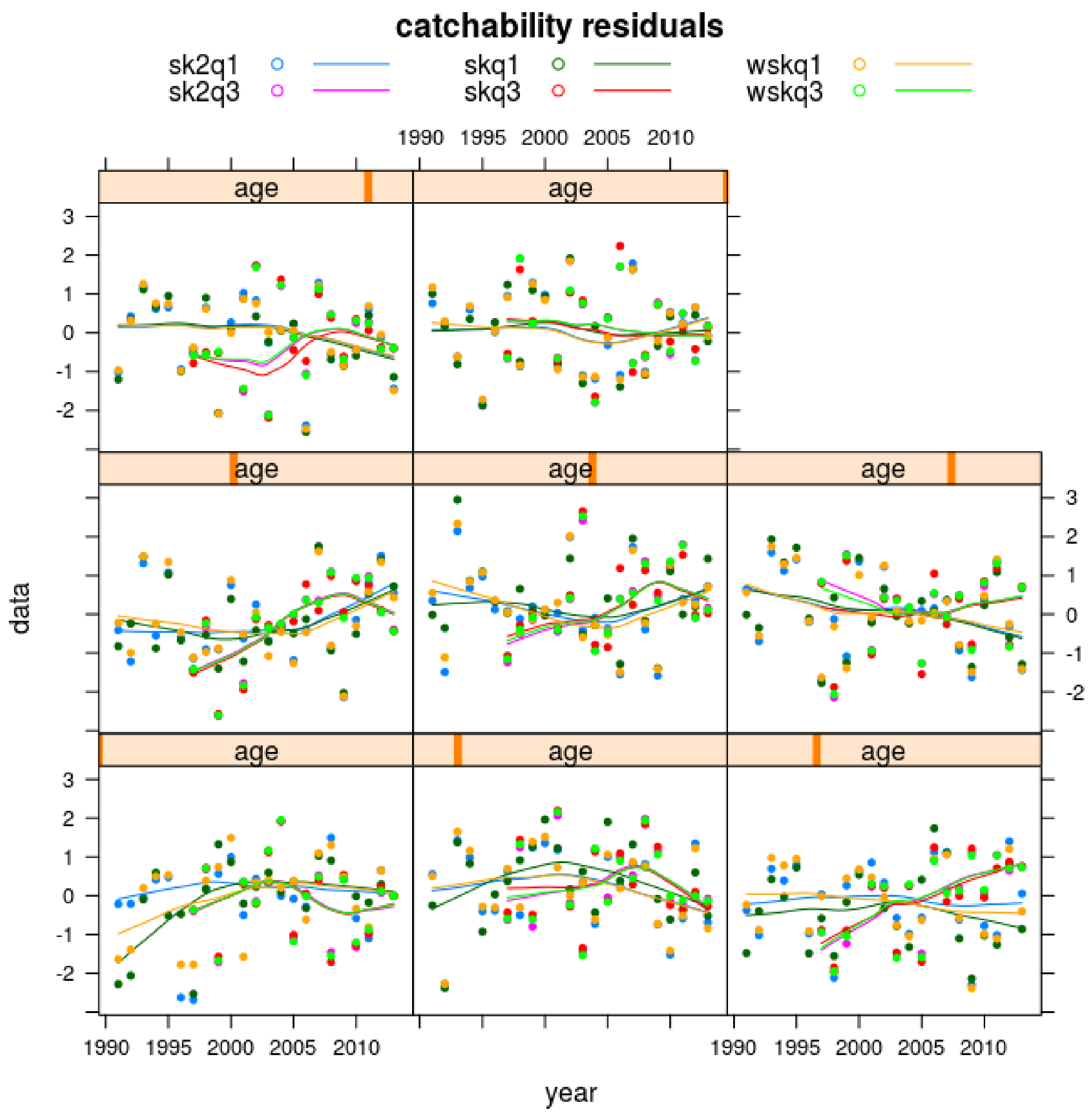

Figure 4.4: Plaice in the Skagerrak - a4a default assessment with one survey at the time survey residuals

The difference between the 1st quarter and the 3rd quarter surveys are higher than between surveys. To proceed with the analysis the better established indices were kept, IBTS in the Skagerrak quarters 1 and 3.

```
stk <- window(plesk.stk, end = 2013)
# catches at age 1 are residual and seem artificial in some
# years
stk <- trim(stk, age = 2:9)
# there a couple of very high residuals in ages 9 and 10,
```

```r
# will do +9
stk <- setPlusGroup(stk, 9)
ids <- window(lapply(ple.ids[c("skq1", "skq3")], function(x) trim(x,
    age = 2:8)), end = 2013)
fmod <- ~te(age, year, k = c(3, 3)) + s(age, k = 5) + s(year,
    k = 25)
qmod <- list(~s(age, k = 4), ~s(age, k = 4))
fit <- sca(stk, ids, fmodel = fmod, qmodel = qmod, fit = "assessment")
```

```r
res <- residuals(fit, stk, ids)
plot(res)
```

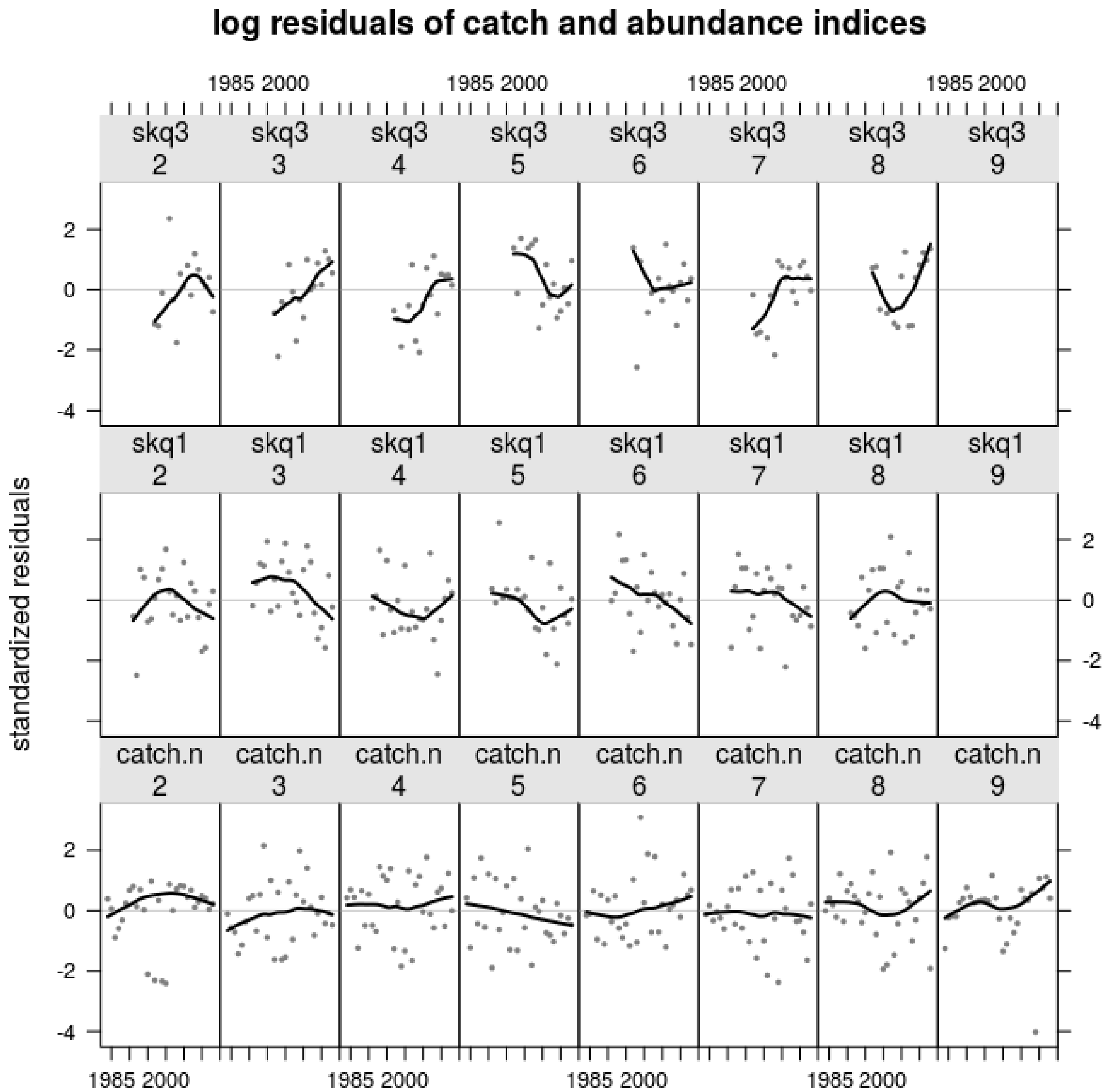

Figure 4.5: Plaice-sk with IBTS Q1+Q3 assessment residuals

```r
qqmath(res)
```

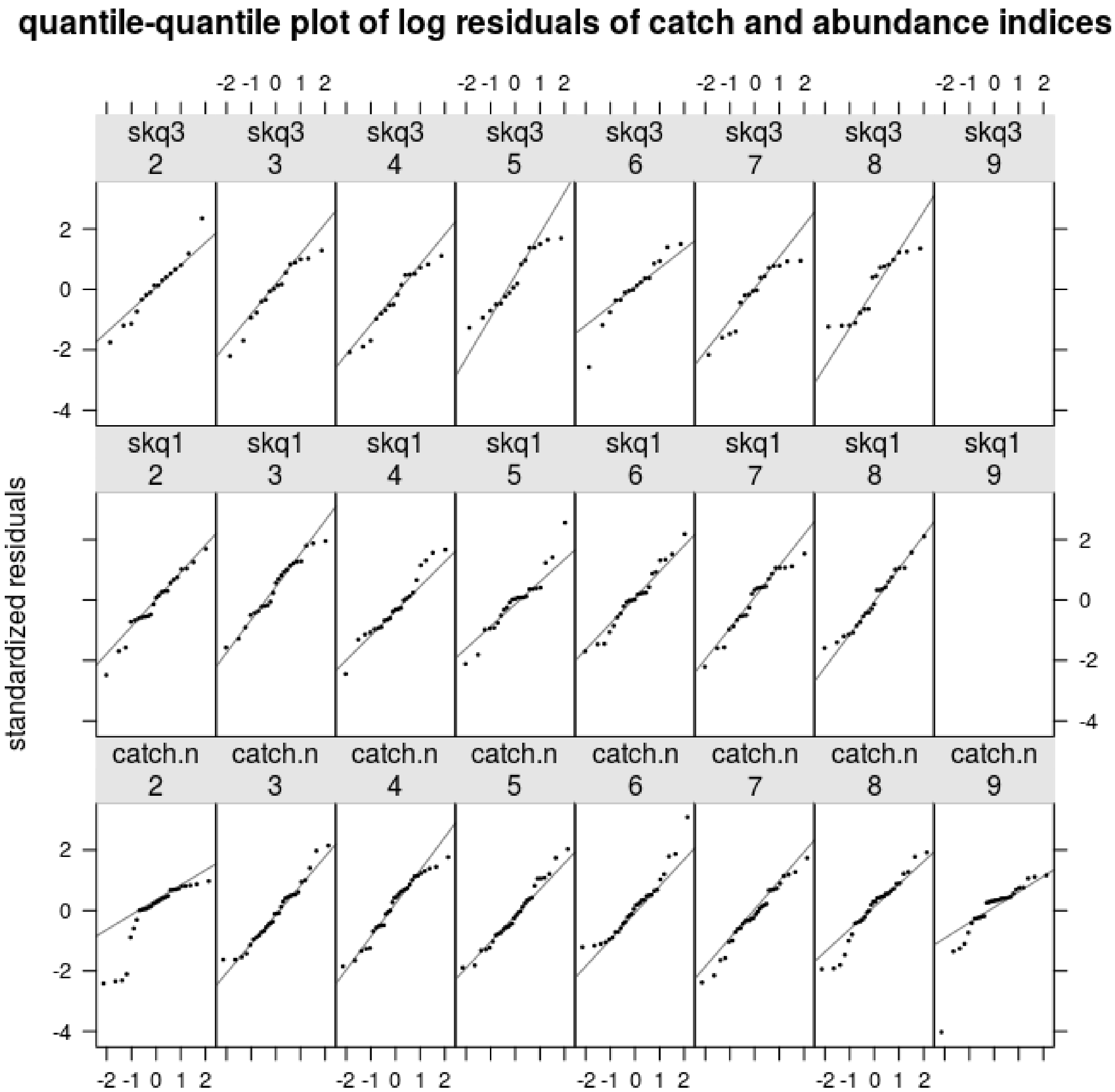

Figure 4.6: Plaice-sk with IBTS Q1+Q3 assessment residuals

```r
bubbles(res)
```

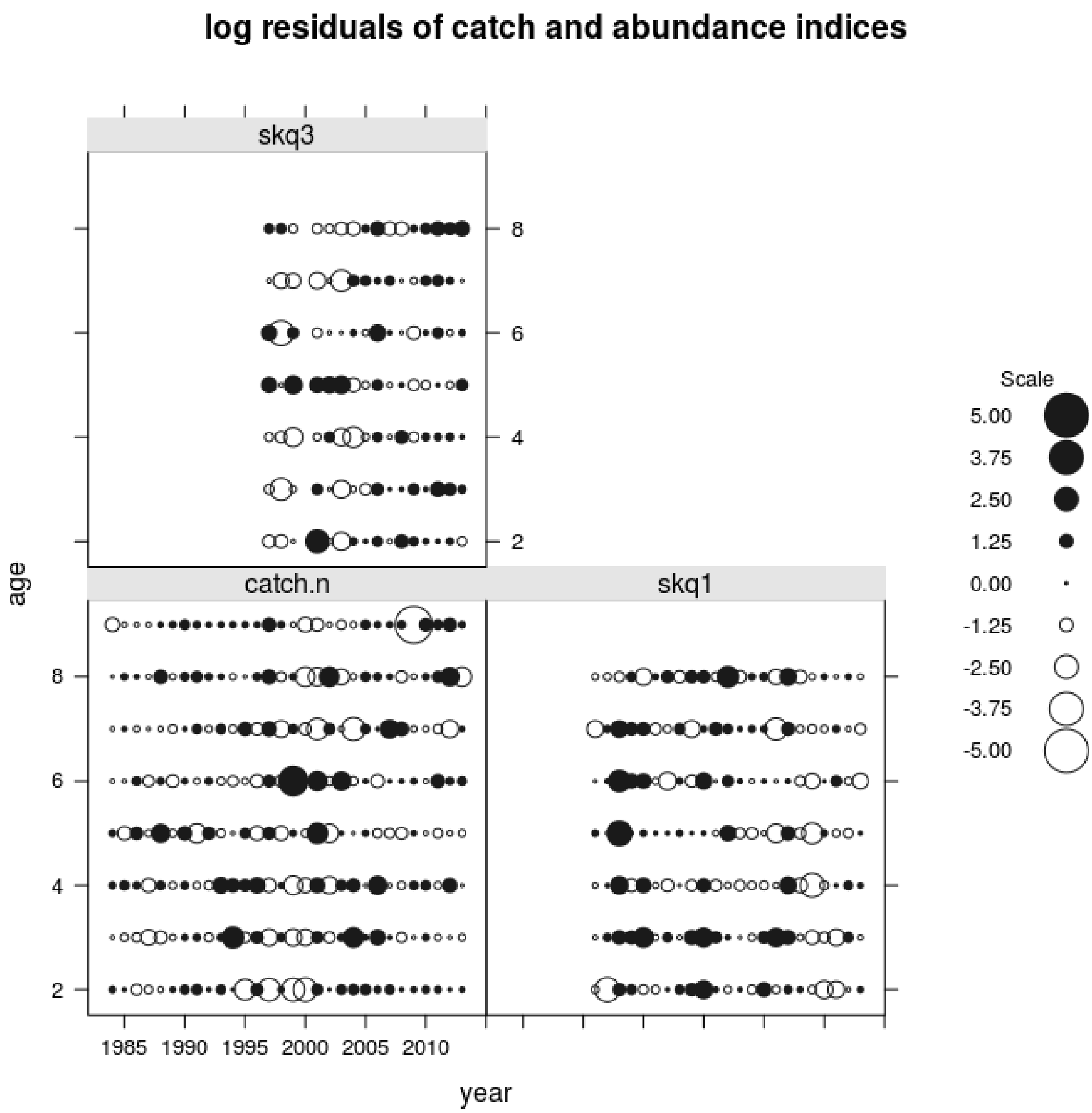

Figure 4.7: Plaice-sk with IBTS Q1+Q3 assessment residuals

```
plot(fit, stk)
```

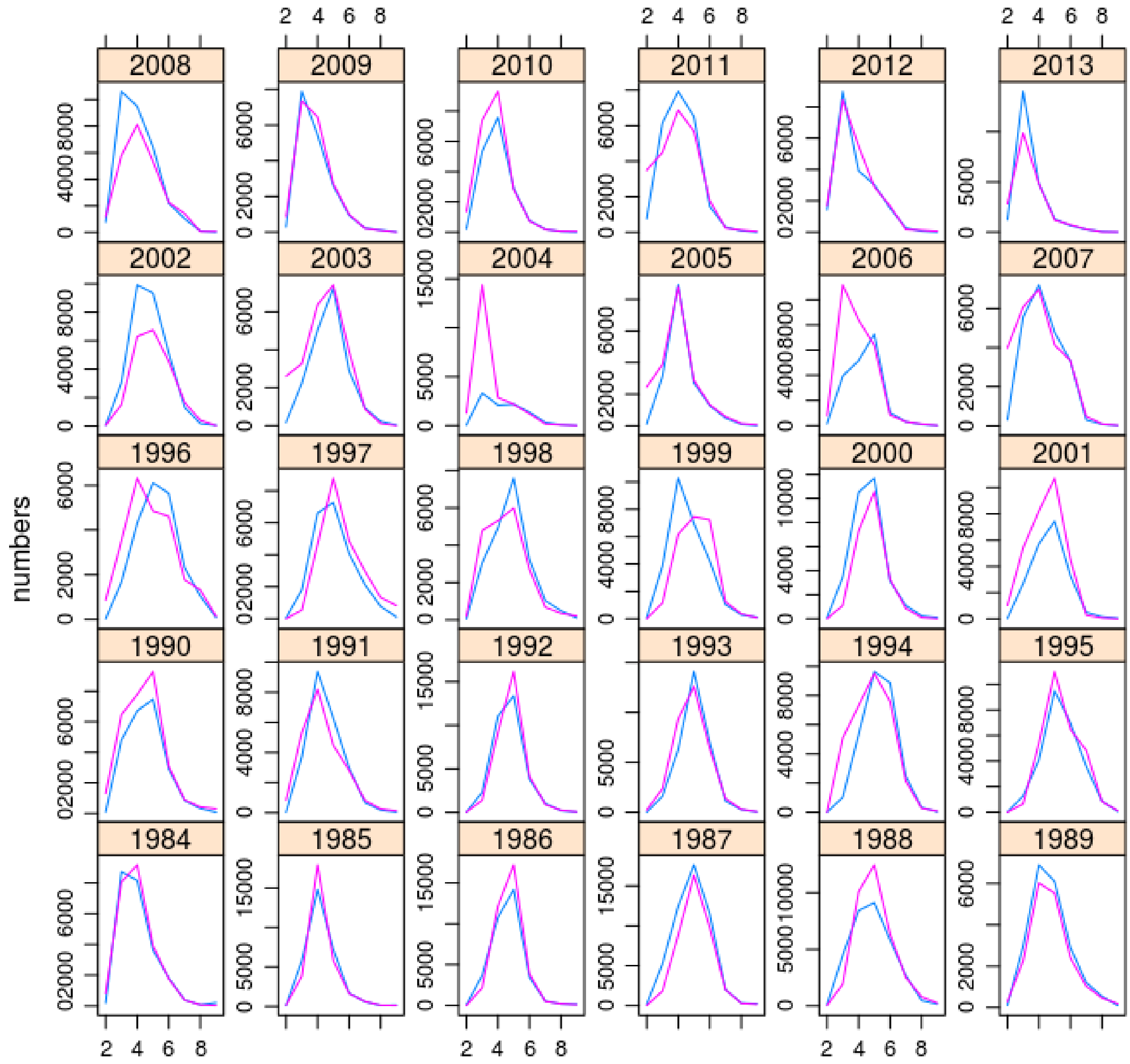

Figure 4.8: Plaice-sk with IBTS Q1+Q3 catch observed VS predictions

```r
plot(fit, ids[1])
```

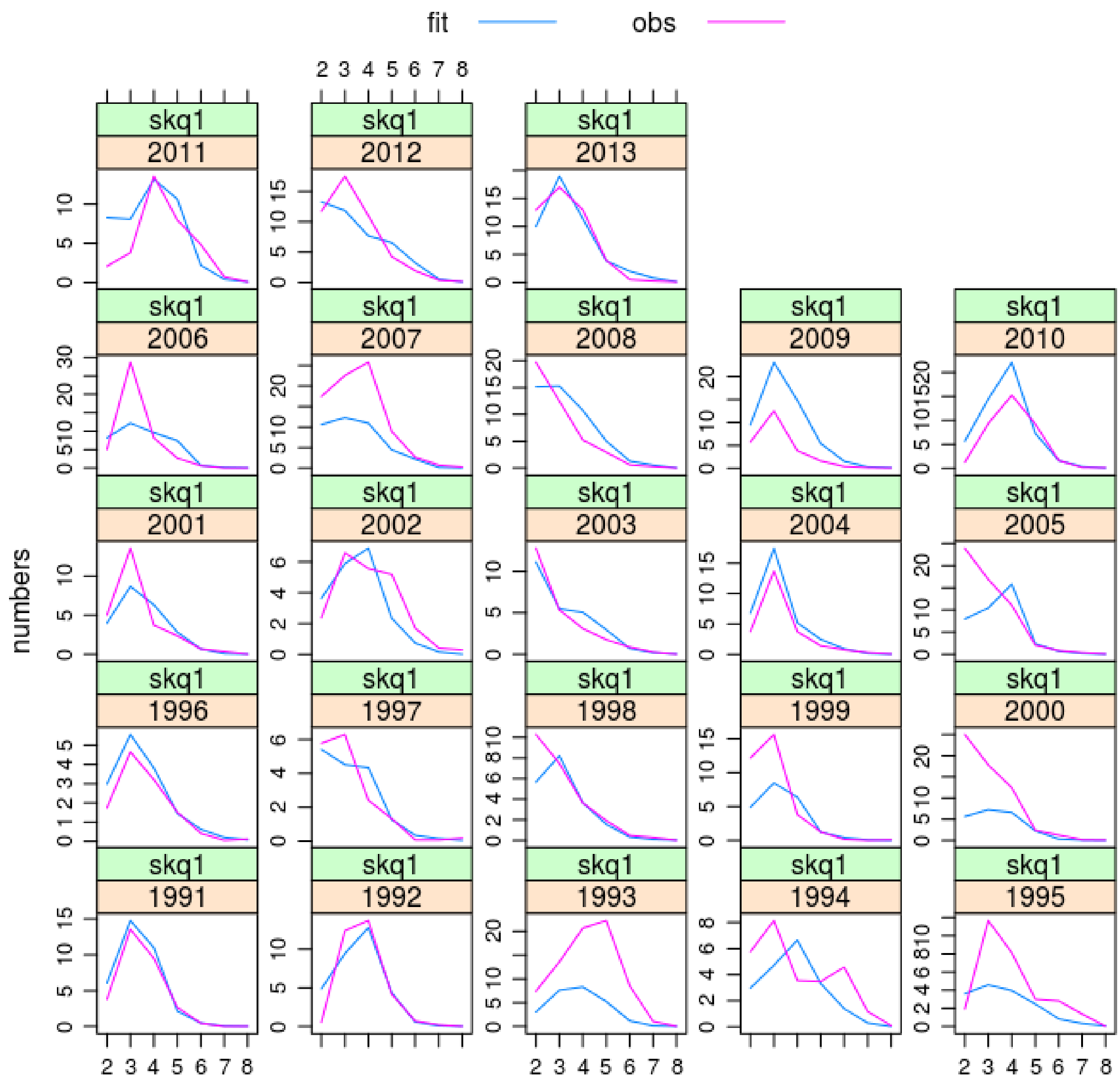

Figure 4.9: Plaice-sk with IBTS Q1+Q3 index observed VS predictions

```r
plot(fit, ids[2])
```

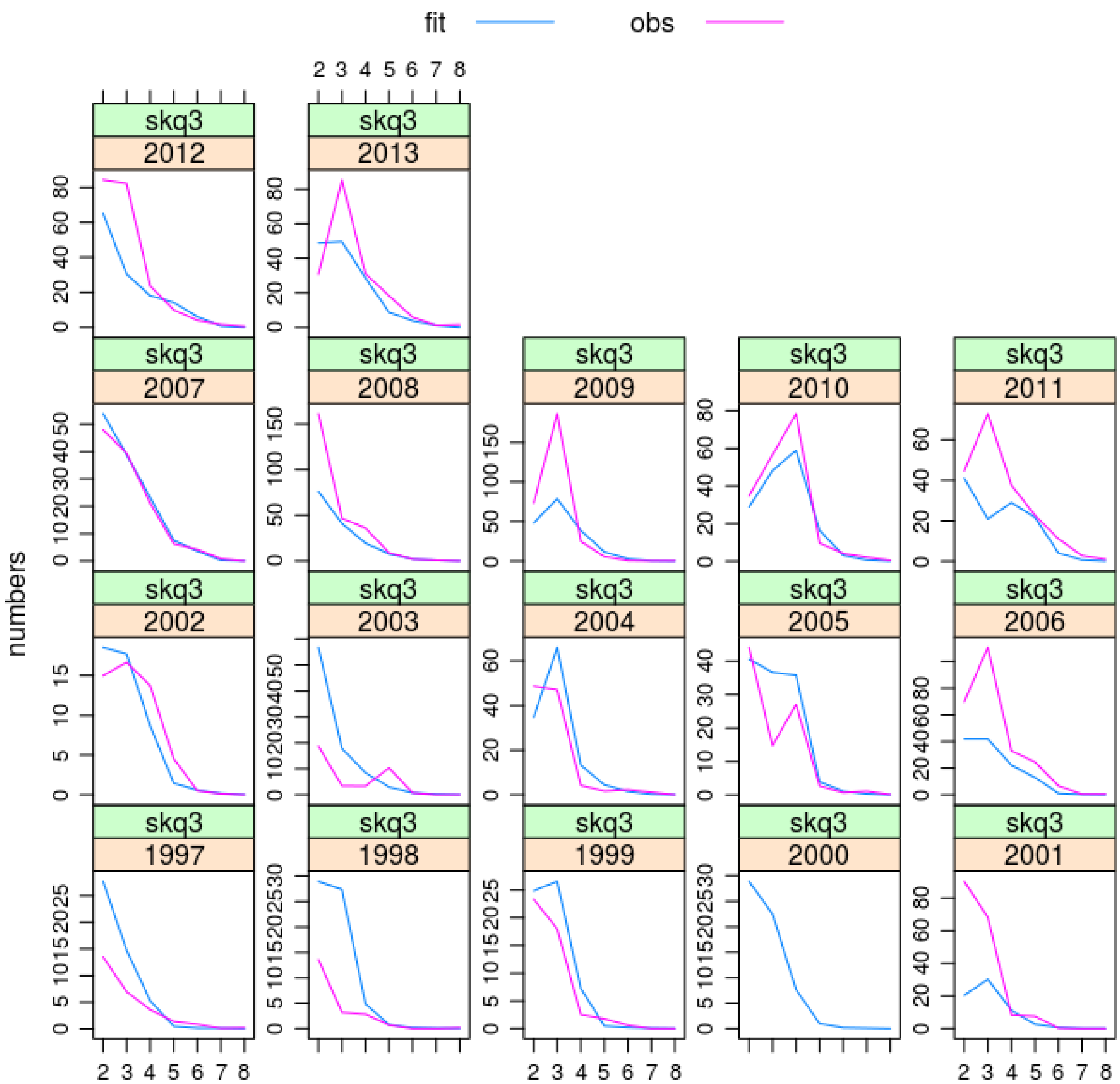

Figure 4.10: Plaice-sk with IBTS Q1+Q3 index observed VS predictions

```
wireframe(data ~ year + age, data = harvest(fit))
```

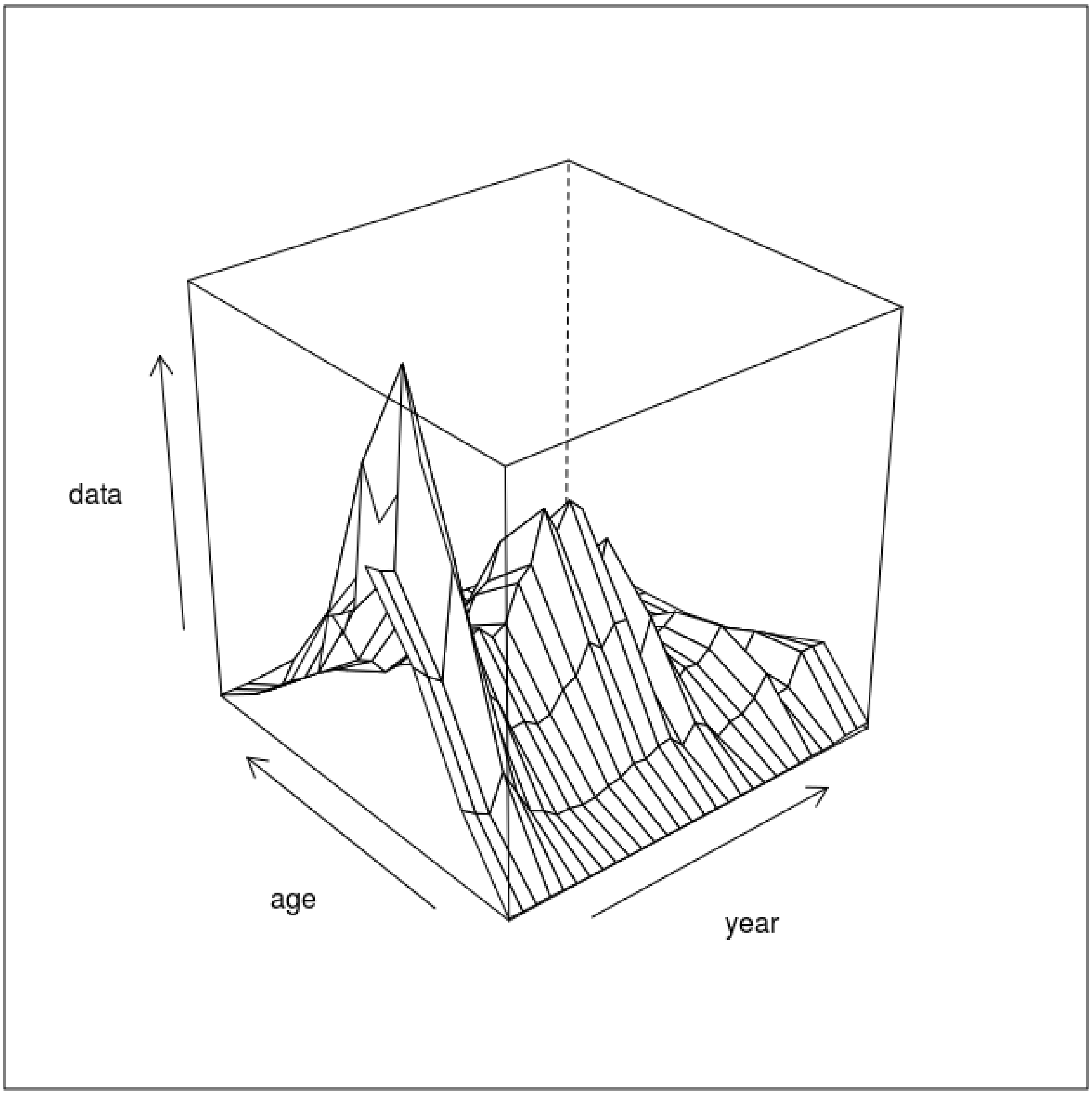

Figure 4.11: Plaice-sk with SKIBTS Q1+Q3 assessment F-at-age surface

```
plesk.fstks <- stk + simulate(fit, 1000)
plot(plesk.fstks)
```

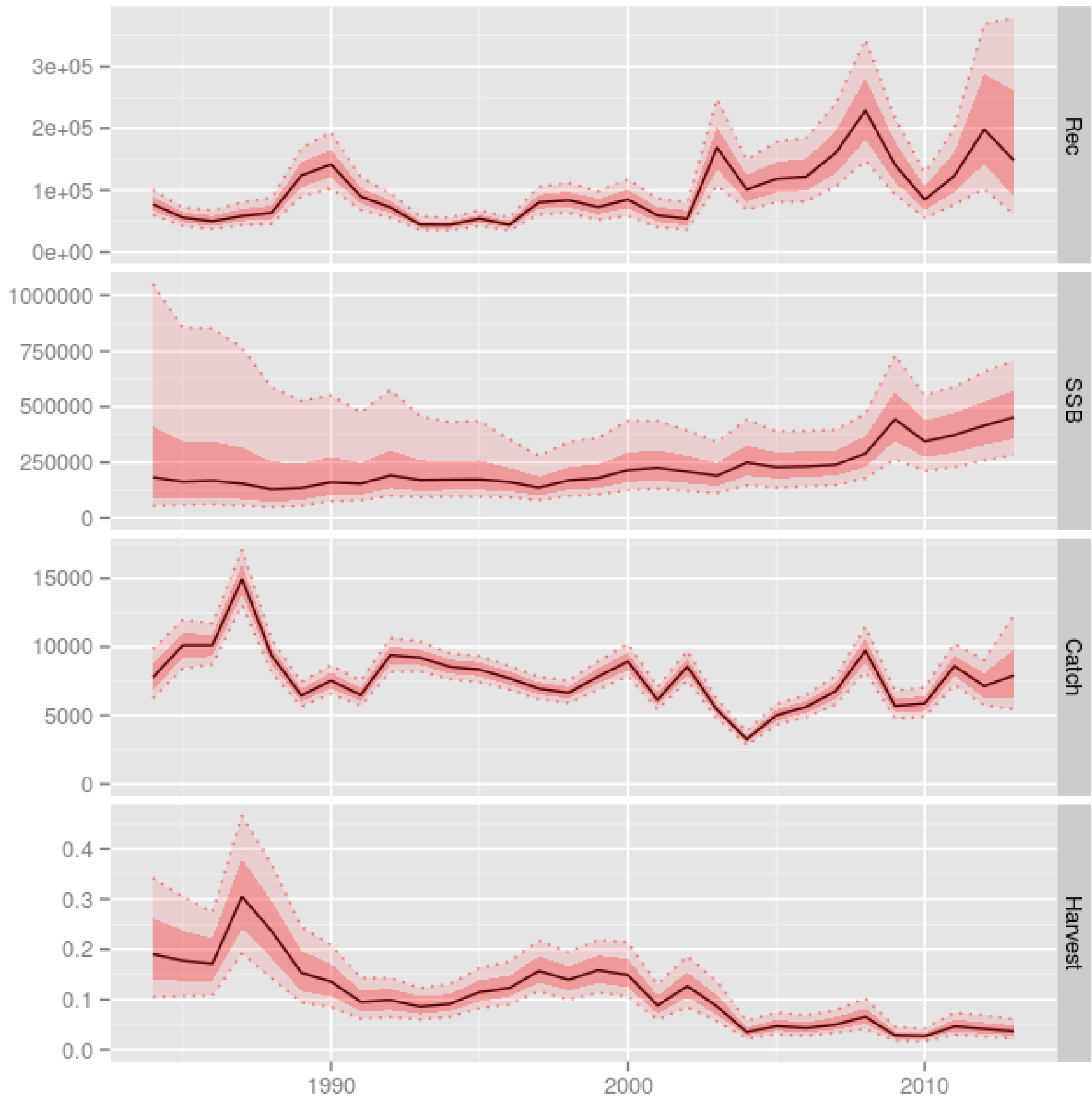

Figure 4.12: Plaice-sk with SKIBTS Q1+Q3 assessment summary

```
plesk.fit <- fit
plesk.fstk <- stk + fit
plesk.sr <- fmle(as.FLSR(plesk.fstk, model = "bevholt"), control = list(trace = 0))
plot(plesk.sr)
```

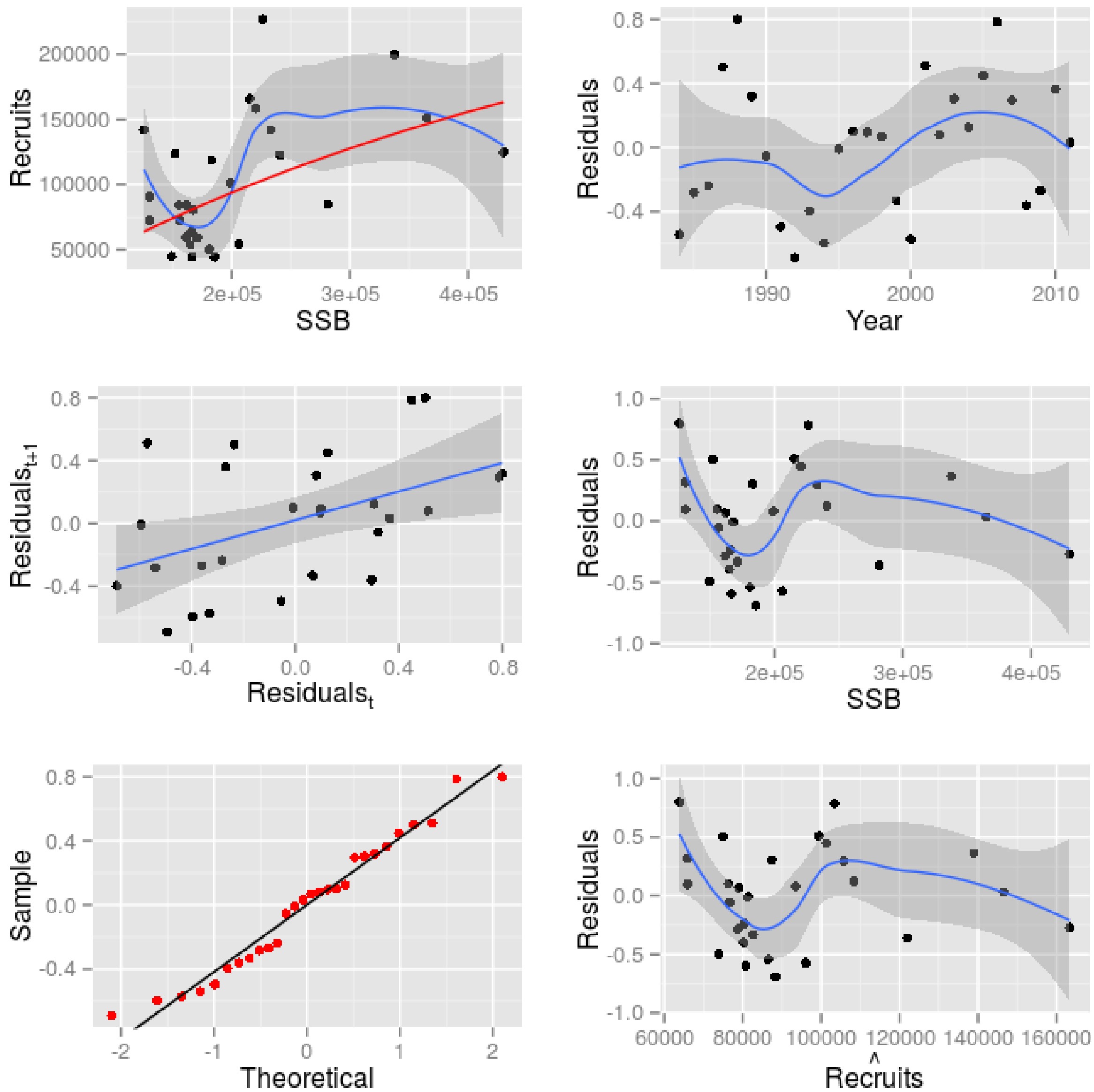

Figure 4.13: Plaice-sk with SKIBTS Q1+Q3 stock-recruitment

Assessing the local stock by trying to disentangle the North Sea SSB

The increase in biomass in the North Sea may be impacting the Skagerrak stock estimate. Figure 4.14 show the similarities between both indicators. Which in turn produces a decreasing trend in fishing mortality.

```
flqs <- mcf(FLQuants(`North Sea` = ssb(ple), Skagerrak = ssb(stk +
    fit)))
plot(flqs)
```

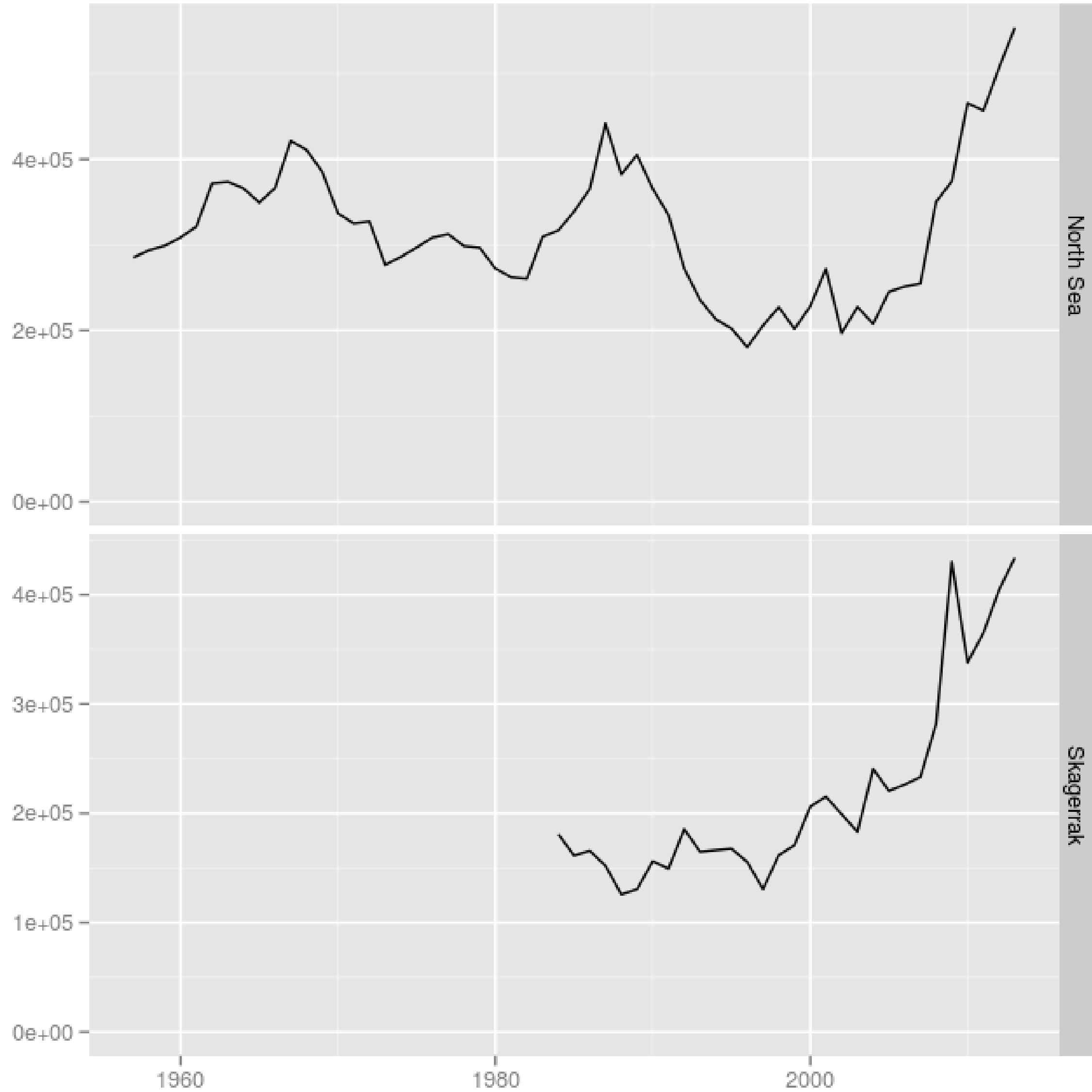

Figure 4.14: Plaice SSB estimated for the North Sea and the Skagerrak

To try to remove the effect that the North Sea stock maybe introducing in the Skegerrak, a year trend in catchability was introduced, on the basis this could be caused by an increase in availability of fish. The same sub-models were kept similar to avoid introducing confounding in the results.

```
stk <- window(plesk.stk, end = 2013)
# catches at age 1 are residual and seem artificial in some
# years
stk <- trim(stk, age = 2:9)
# there a couple of very high residuals in ages 9 and 10,
```

```
# will do +9
stk <- setPlusGroup(stk, 9)
ids <- window(lapply(ple.ids[c("skq1", "skq3")], function(x) trim(x,
    age = 2:8)), end = 2013)
fmod <- ~te(age, year, k = c(3, 3)) + s(age, k = 5) + s(year,
    k = 25)
qmod <- list(~s(age, k = 4) + s(year, k = 3), ~s(age, k = 4) +
    s(year, k = 3))
fit <- sca(stk, ids, fmodel = fmod, qmodel = qmod, fit = "assessment")
```

```
res <- residuals(fit, stk, ids)
plot(res)
```

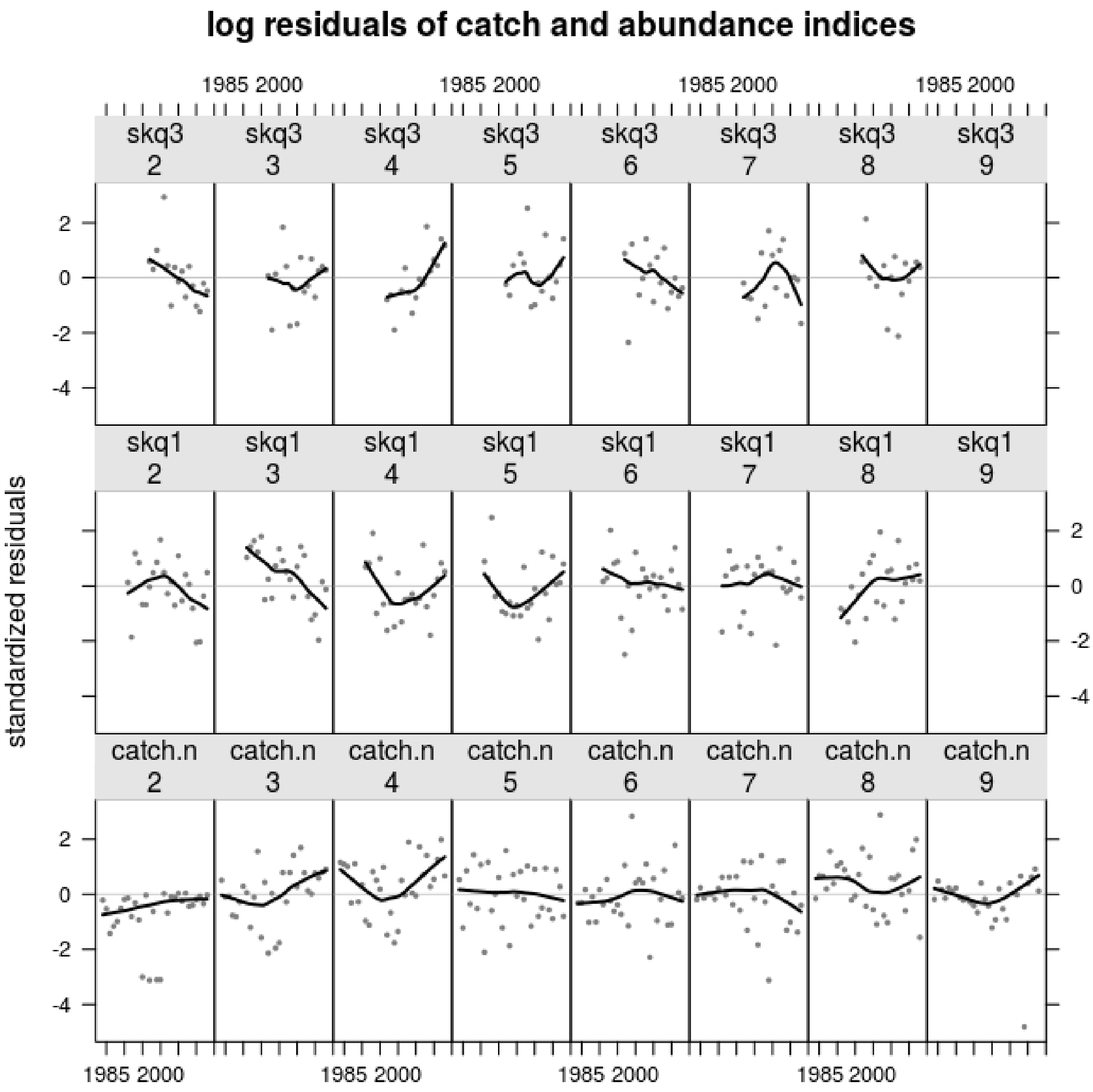

Figure 4.15: Plaice-sk with SKIBTS Q1+Q3 + increase q assessment residuals

```
qqmath(res)
```

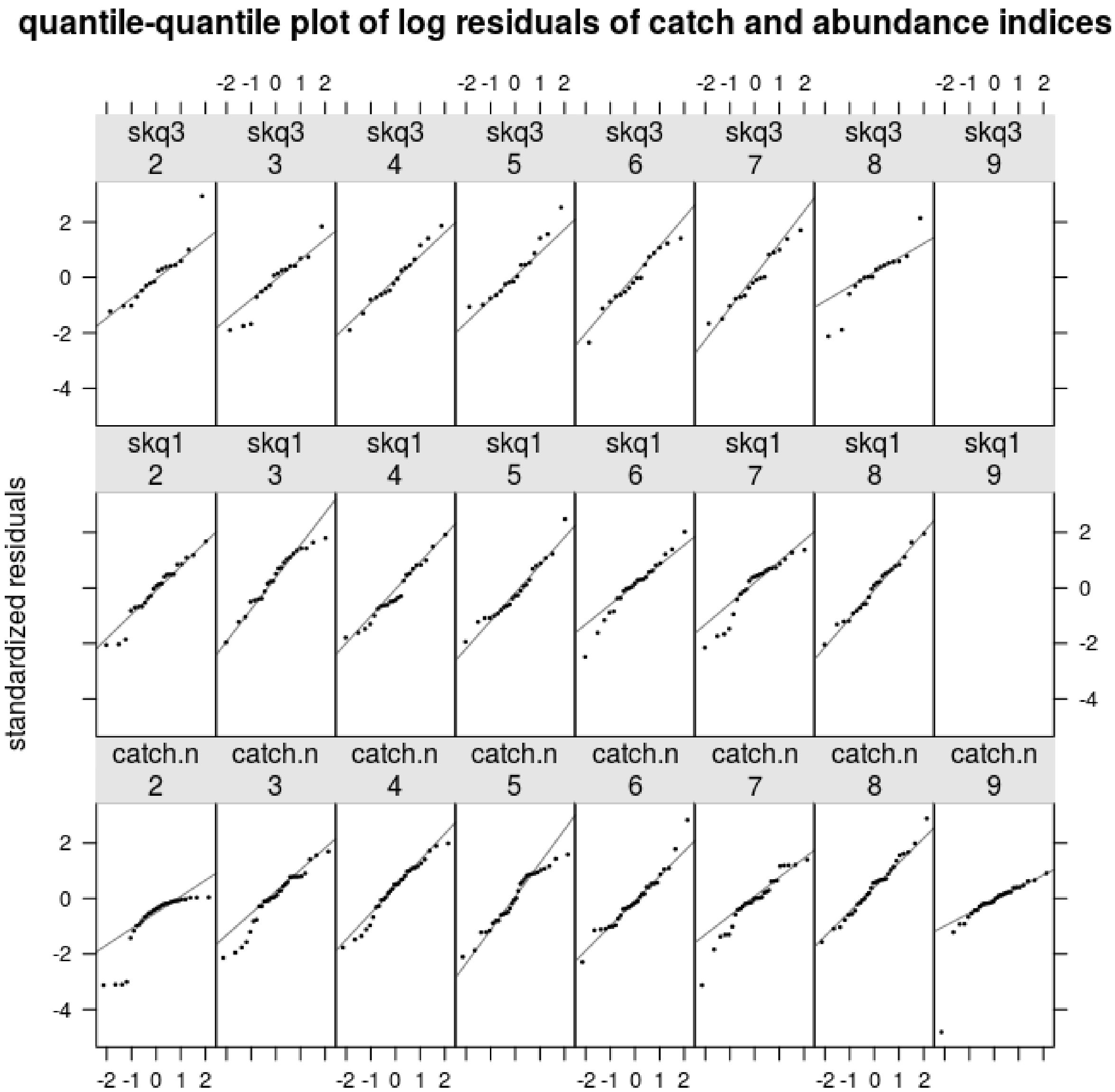

Figure 4.16: Plaice-sk with SKIBTS Q1+Q3 + increase q assessment residuals

```
bubbles(res)
```

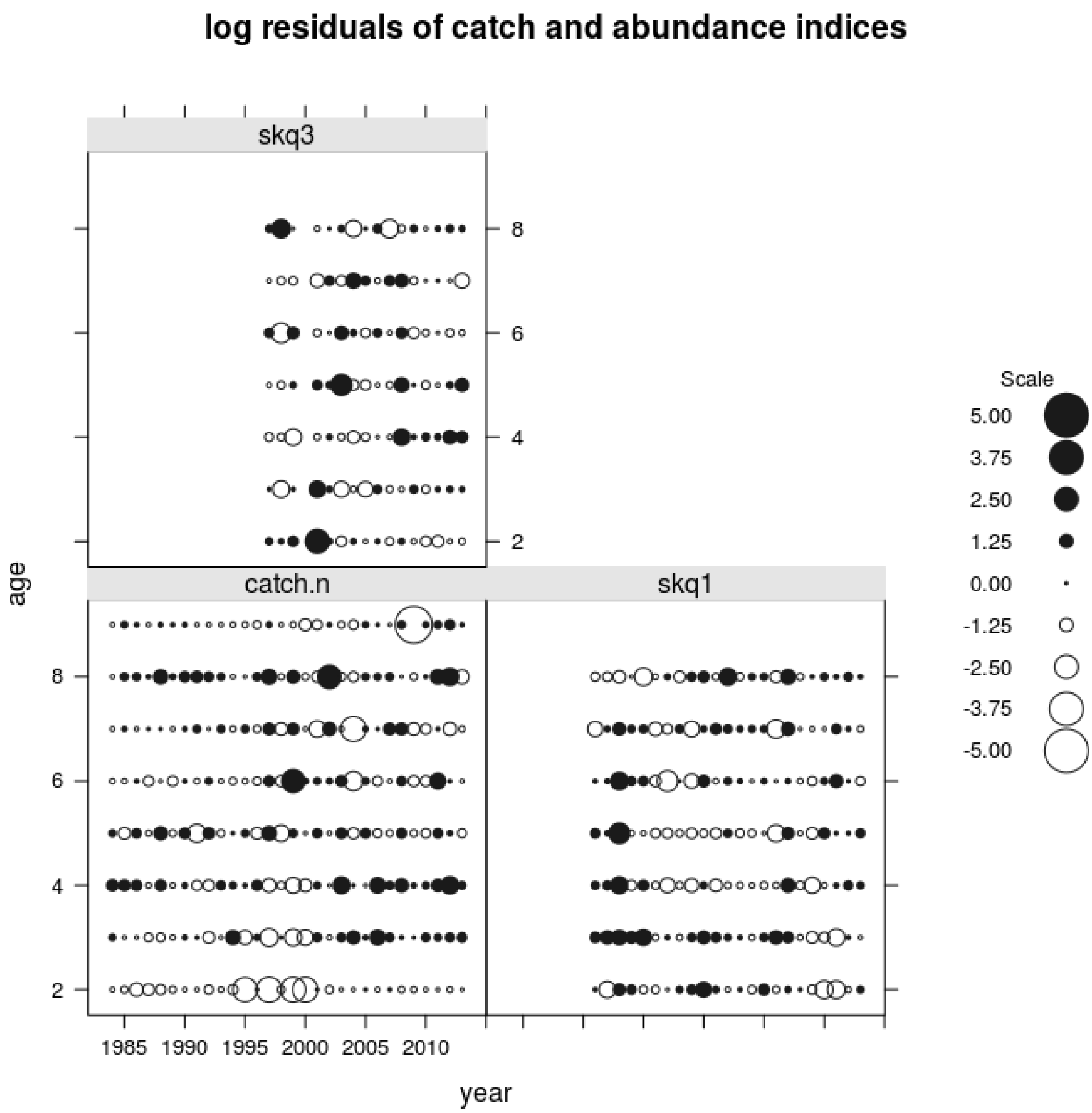

Figure 4.17: Plaice-sk with SKIBTS Q1+Q3 + increase q assessment residuals

```
plot(fit, stk)
```

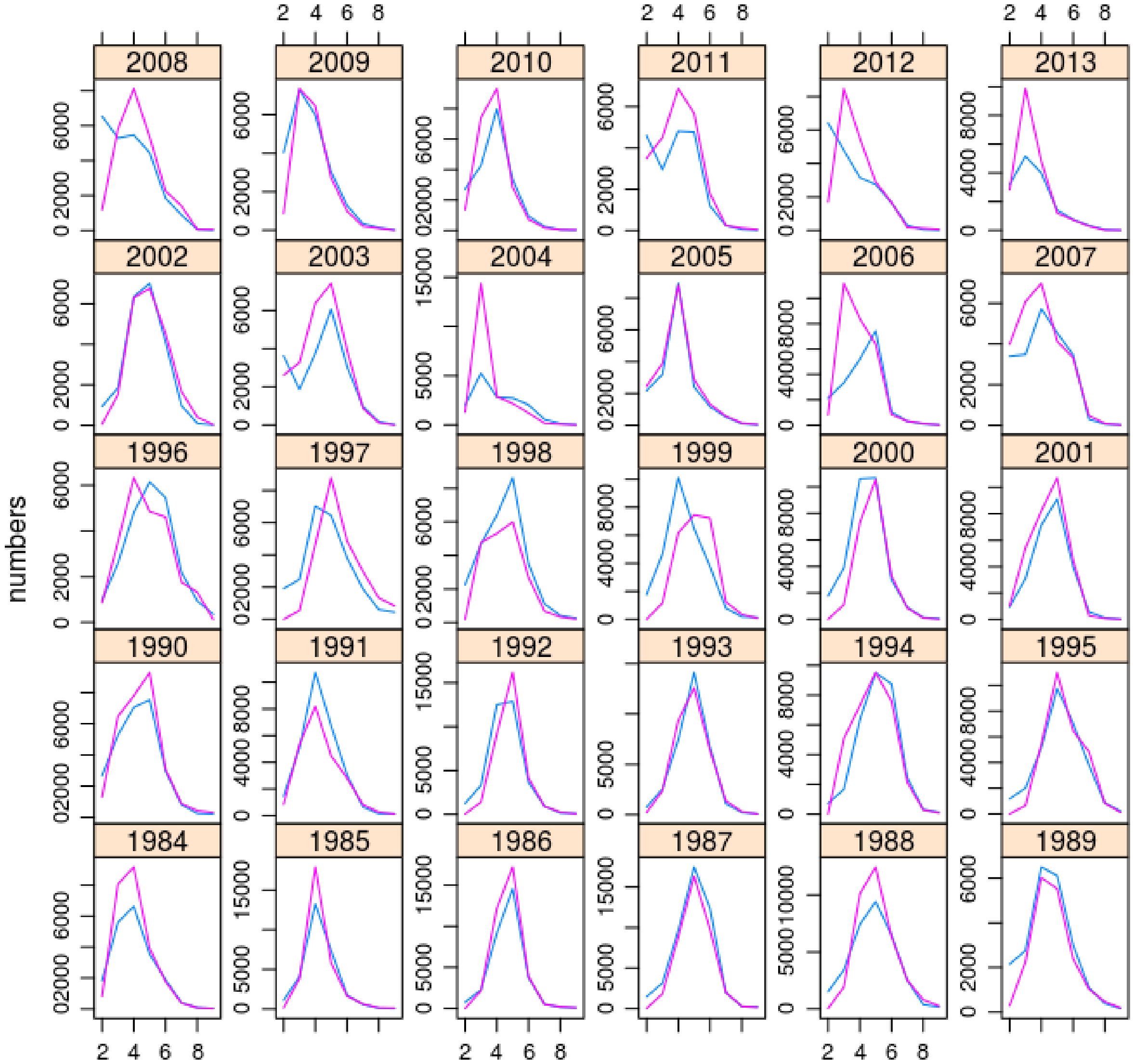

Figure 4.18: Plaice-sk with SKIBTS Q1+Q3 + increase q catch observed VS predictions

```
plot(fit, ids[1])
```

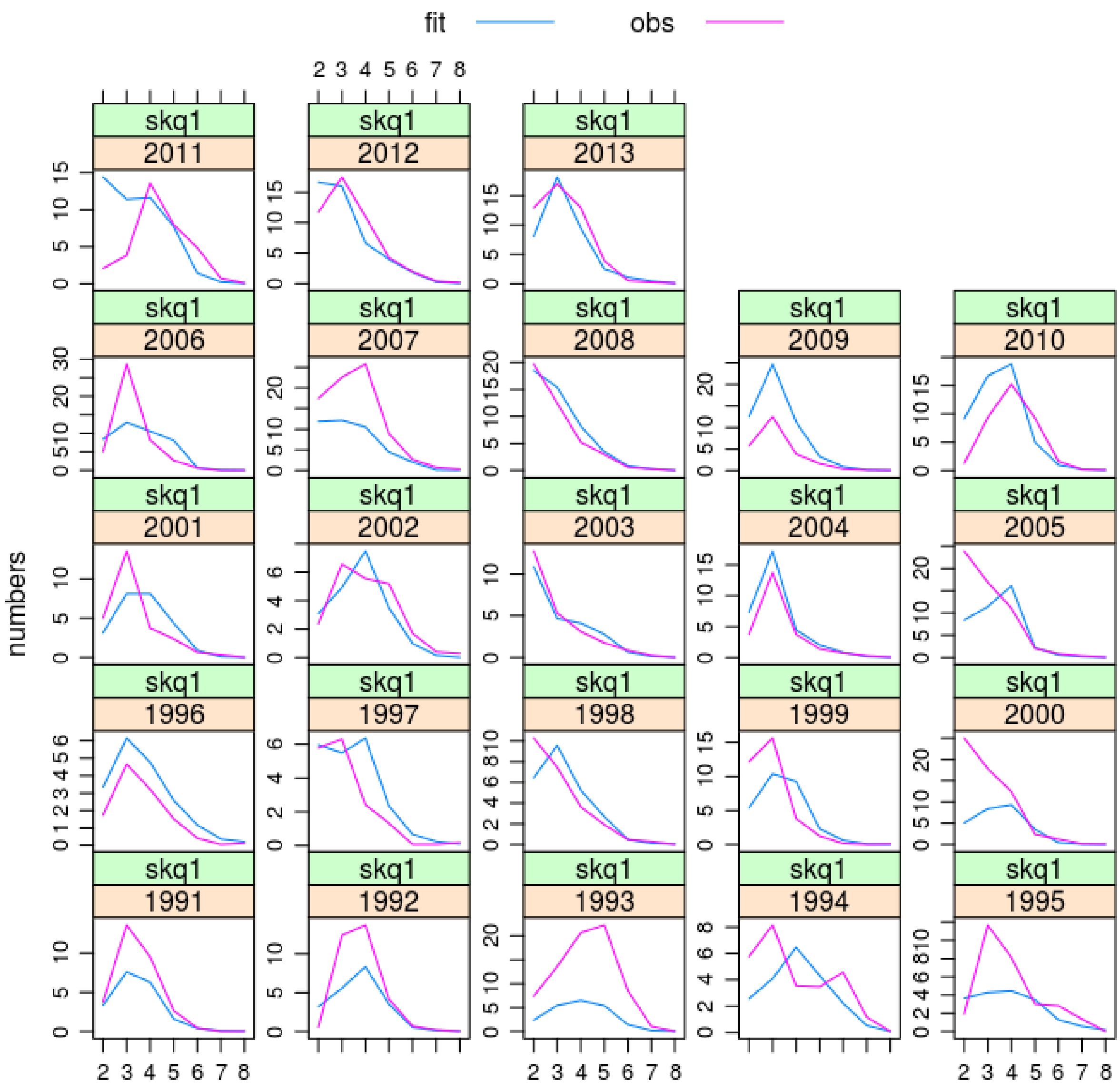

Figure 4.19: Plaice-sk with SKIBTS Q1+Q3 + increase q index observed VS predictions

```r
plot(fit, ids[2])
```

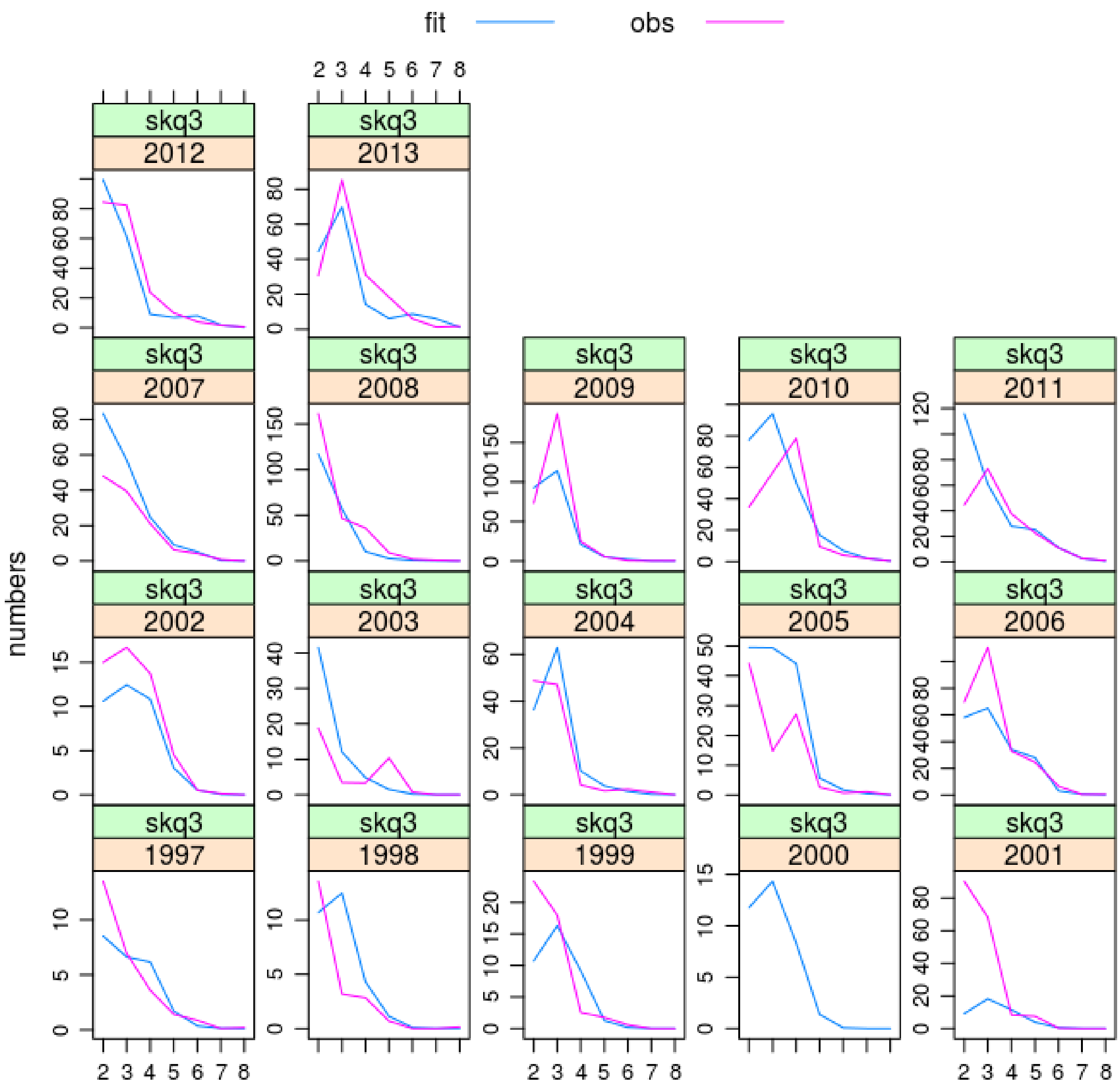

Figure 4.20: Plaice-sk with SKIBTS Q1+Q3 + increase q index observed VS predictions

```
wireframe(data ~ year + age, data = harvest(fit))
```

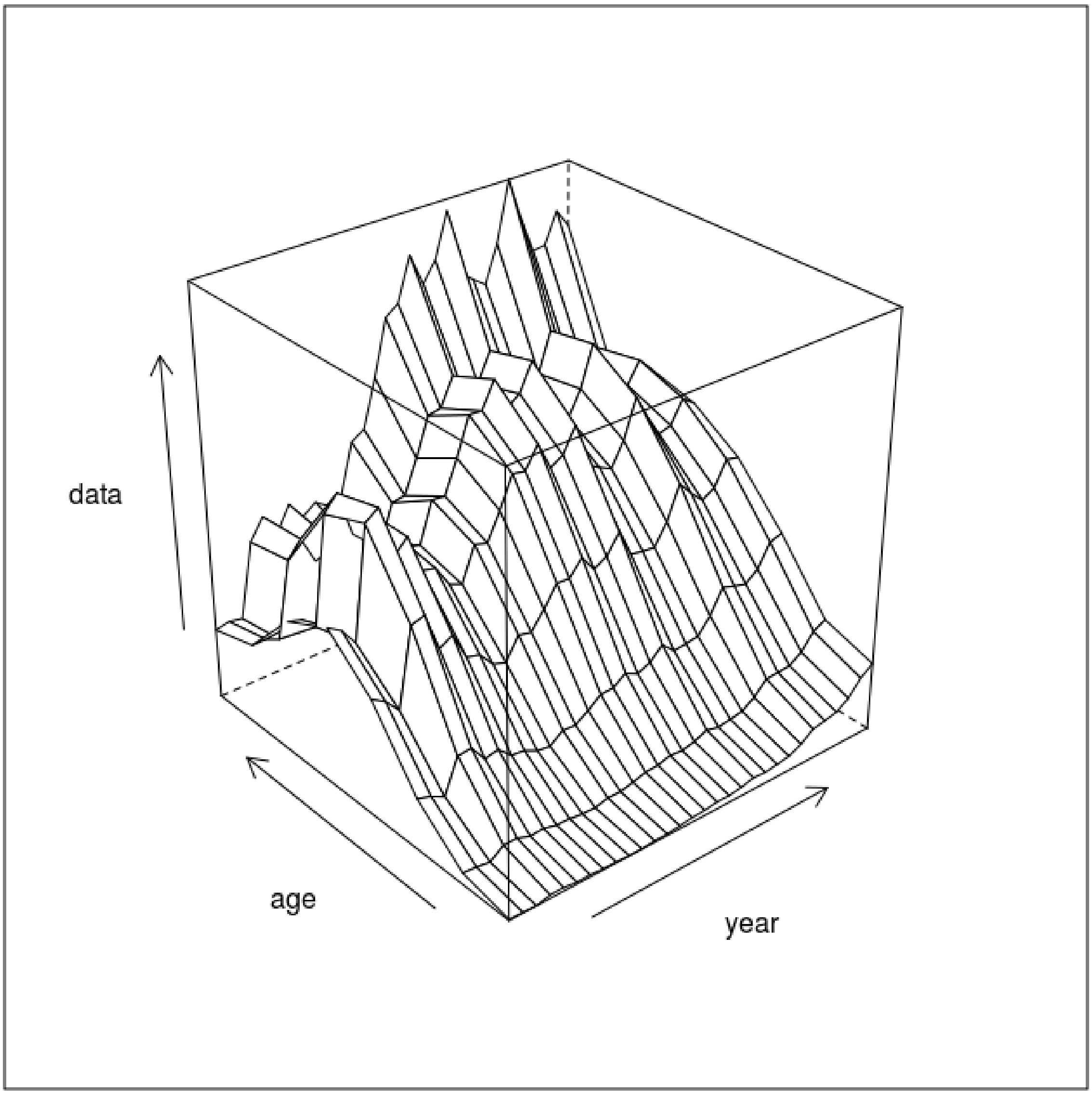

Figure 4.21: Plaice-sk with SKIBTS Q1+Q3 + increase q assessment F-at-age surface

```r
plesk2.fstks <- stk + simulate(fit, 1000)
plot(plesk2.fstks)
```

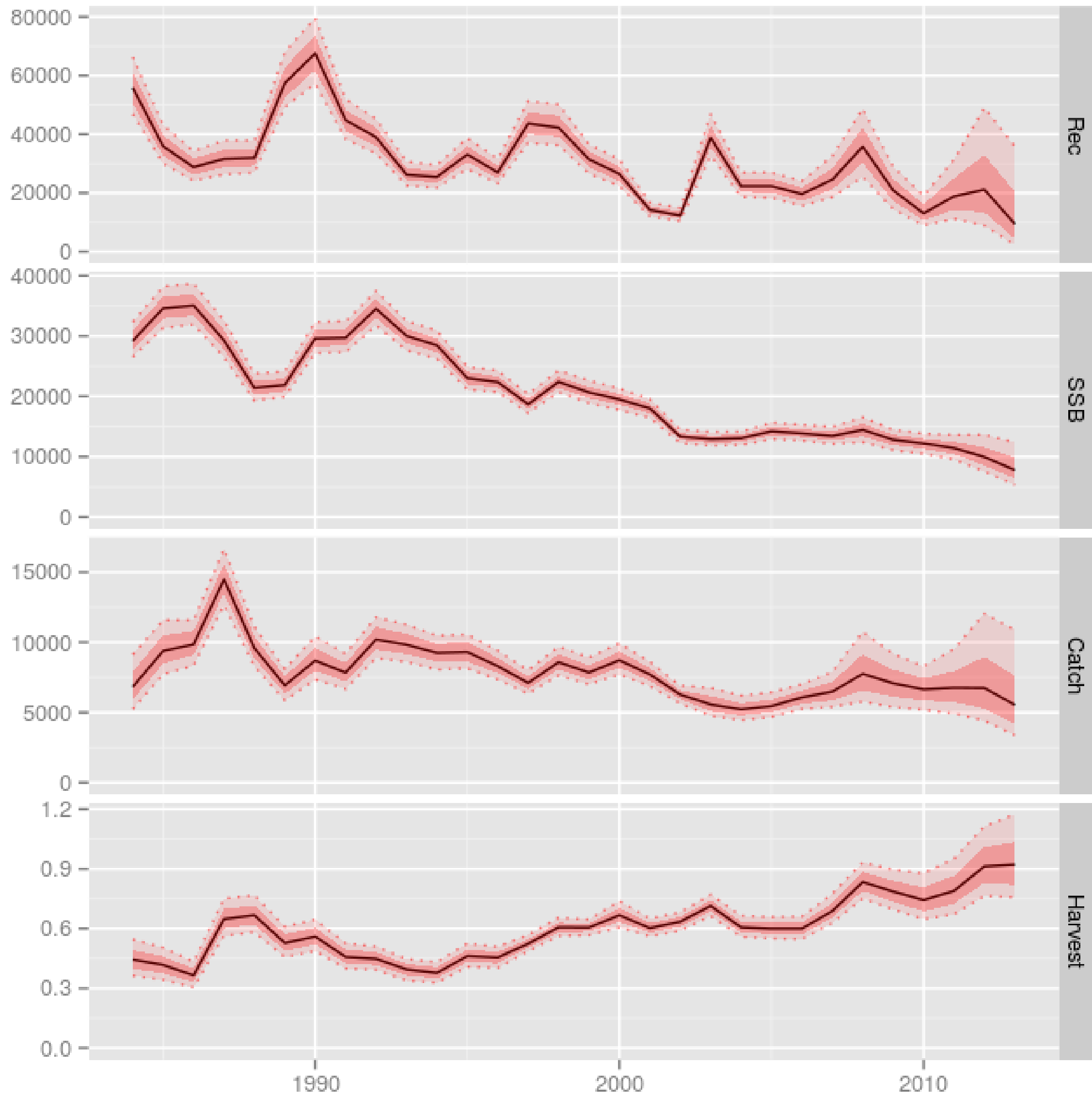

Figure 4.22: Plaice-sk with SKIBTS Q1+Q3 + increase q assessment summary

```
plesk2.fit <- fit
plesk2.fstk <- stk + fit
plesk2.sr <- fmle(as.FLSR(plesk2.fstk, model = "bevholt"), control = list(trace = 0))
plot(plesk2.sr)
```

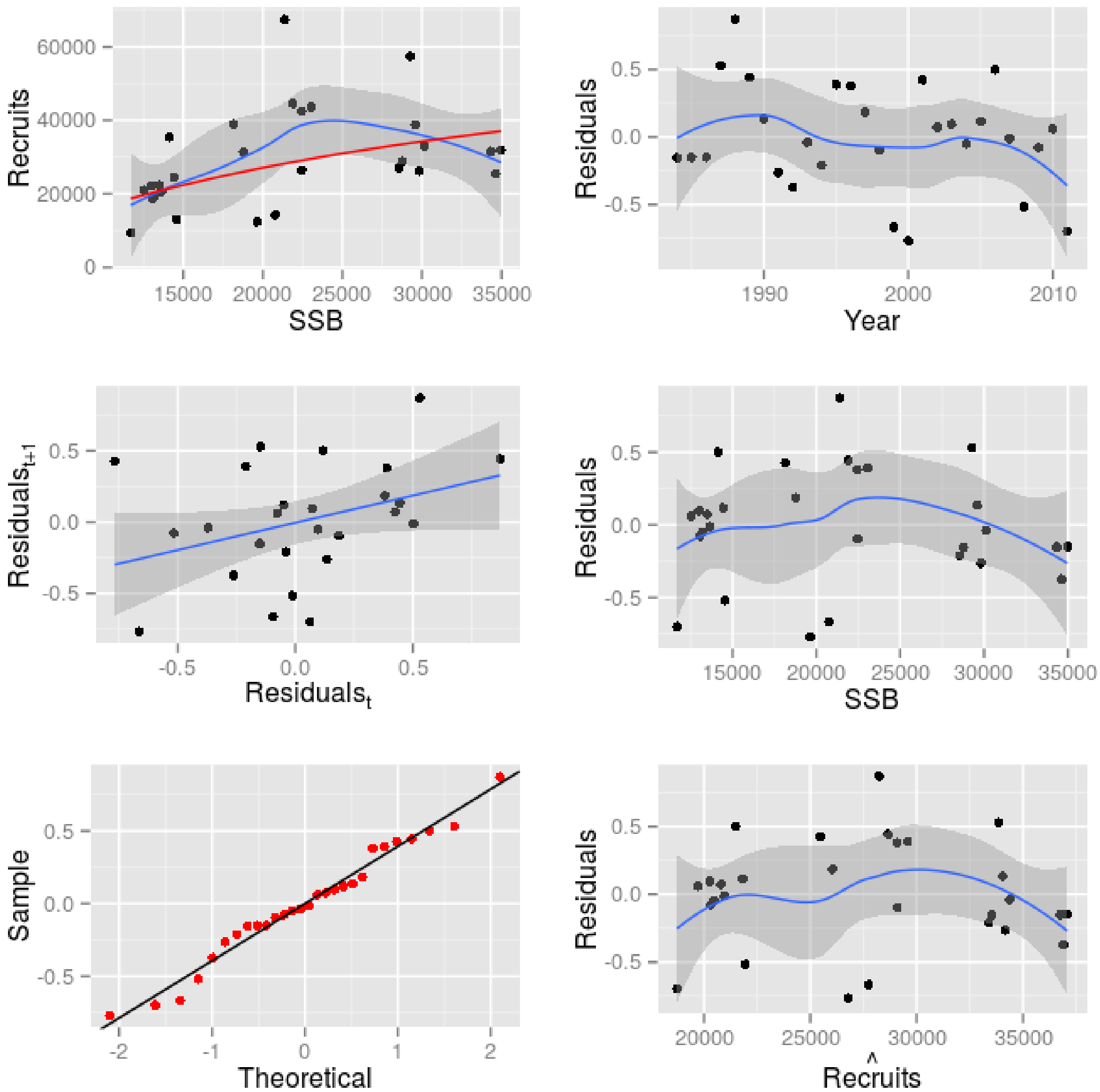

Figure 4.23: Plaice-sk with SKIBTS Q1+Q3 + increase q stock-recruitment

4.3 Results

The hypothesis of having a spill of abundance from the North Sea into the Skagerrak, which can be detected by adding a year trend in an abundance index, is quite strong and has to be taken with care.

The results obtained clearly showed a large shift in the stock status between the two

options tested (Figure 4.24). In both cases the models seem well fitted without any major effect detected in the visual diagnostics.

```
plot(FLStocks(with = plesk2.fstk, without = plesk.fstk))
```

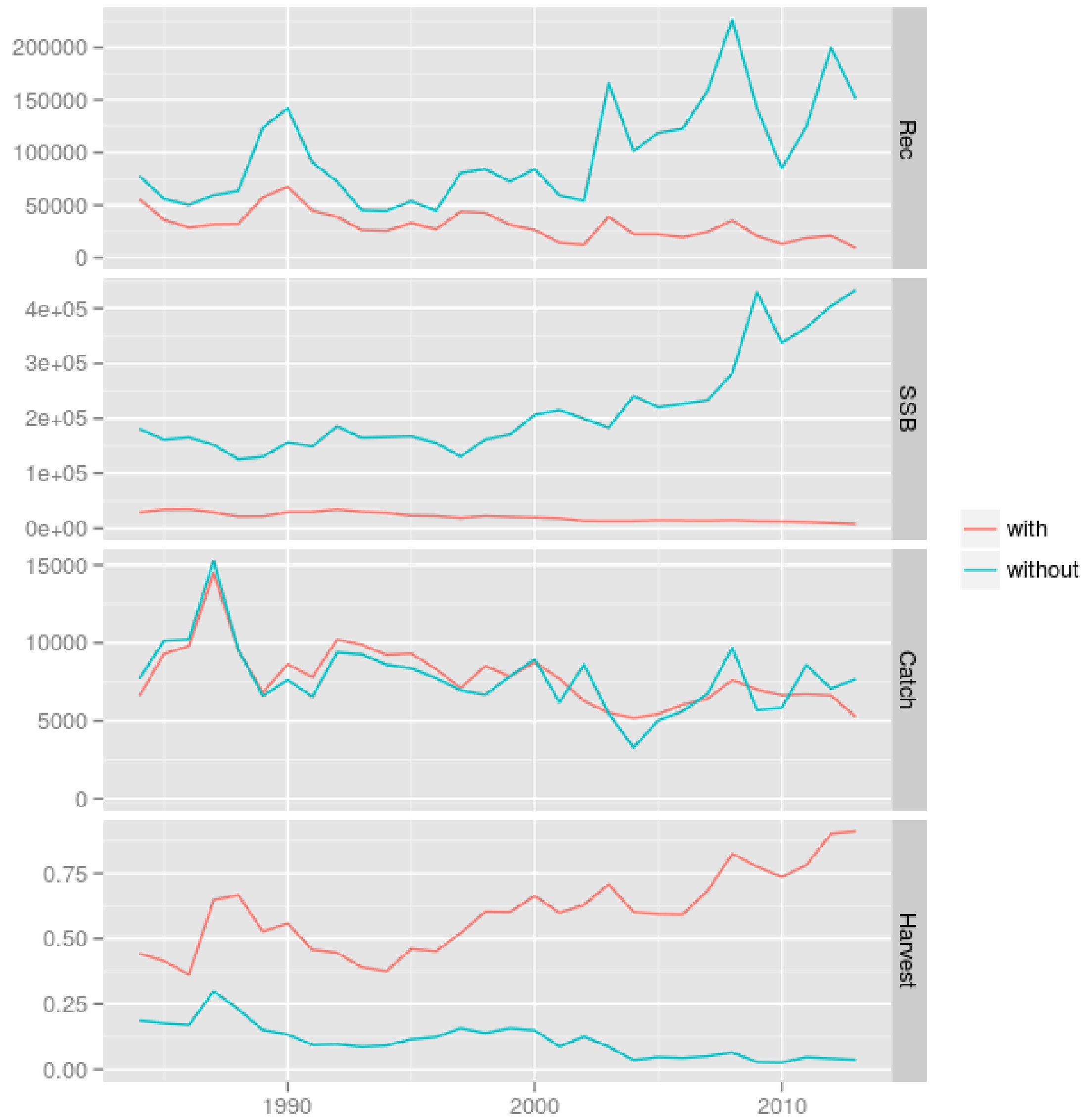

Figure 4.24: Plaice-sk with SKIBTS Q1+Q3. Comparison between q with year trend ("with") or not ("without")

To further test this hypothesis more could be done, *e.g.* fitting other families of models, like separable models, stock-recruitment models, etc, to test if the model choice is influencing the results obtained.

5 Discussion and conclusions

The analysis presented here shouldn't be used to split or merge stocks. Such decisions have to be based on an holistic perspective of the stock boundaries and potential mix with other populations. Exercises like the one carried out here build on initial indications that spatial differentiation exists, and contribute to the body of evidence supporting the hypothesis, or rejecting it.

It can, however, be used to improve scientific advice, by taking into account the productivity of the stock's components, whether they are sub-units of a larger stock or stocks within a larger management unit; and/or spatial differentiation in technical measures, which result in uneven changes in the exploitation pattern for each exploited component.

From the stock assessment point of view, the break down of a stock into sub-units will have impact only if the stock components have differences in productivity that can be detected by the stock assessment model. Otherwise, the dynamics will be similar in each component, and any uneven change in the exploitation pattern, can be tested with a weighted average of partial fishing mortalities, deployed to the stock.

The assumptions that constituted the starting point of this exercise require more research. In particular they must be tested through simulations.

The FLa4a stock assessment framework allowed the group to run the exercises in due time and showed that it can reproduce established stock assessment models like SAM or XSA.

6 Acknowledgements

The research leading to this publication was partially funded by the Danish Ministry for Food, Agriculture and Fisheries and the European Fisheries Fund through the projects "Optimal sustainable use of cod stocks accessible for Danish fisheries" (J.no.33010-13-k-0269) and "MSC certification of plaice fisheries in area IIIa—basic investigations and development of a management plan" (European Fisheries Fund: contract no. 33010-12-a-0253).