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CPUE standardization for the offshore fleet fishing for Jack mackerel in the SPRFMO area

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Abstract

The nominal CPUE of the offshore fleet fishing for Jack mackerel is currently being used as a tuning index for the assessment. The index consists of the nominal average catch per fishing day for the fleets of EU, Vanuatu and Korea. China has standardized their CPUE series in 2013. This working document describes the work aimed to standardizing the CPUE series of EU, Korea, vanuatu and Russia based on the haul-by-haul data contained in the SPRFMO database. Permission to utilize that information was granted by the delegations of Korea, Vanuatu and Russia while the analysis was carried out by scientists from the EU delegation. The working document consists of a description of the data available for the analysis and the methods towards model choice to select the optimal model configuration for CPUE standardization. The final GAM model consists of a number of discrete factors (year, vessel and month) and a smoothed interaction between latitude and longitude. No significant relationships were found with El Nino indicators or sea surface temperatures. The new standardized CPUE series starts in 2006 as this is the first year for which haul by haul information was available to carry out this analysis.

1 Introduction

The assessment of Jack Mackerel in the southern Pacific is based on many different sources of information, including the nominal Catch per Unit Effort (expressed as catch per day) of the EU fleet. The use of nominal CPUE for calibrating stock assessments is known to be potentially problematic and therefore SPRFMO (2011) recommended that to serve as indices of abundance, the CPUE should be standardized to take into account factors such as historical changes in vessels, fishing areas, seasonal fishing patterns and environmental factors. This standardization approach has already been applied by China (Li et al, 2013).

In this document, the catch and effort data for the offshore fleet (Eu, Korea, Russia, Vanuatu) is analysed with the aim to develop a standardized CPUE series. Data has been obtained from the SPRFMO secretariat after permission was granted by the different contracting parties that the data could be used for this CPUE analysis.

2 Material and methods

Data from Korea, Russia and Vanuatu was made available by Craig Loveridge on 11 October 2017. Data for EU fisheries was already available as part of the SPRFMO database but also with the underlying spreadsheets that we used to submit the data to SPRFMO.Below is a presentation of an overview of the available data.

Two vessels were removed from the dataset because of apparent problems with the units used for catch reporting.

Number of vessels participating in the fishery

year	EU	KOR	RUS	VUT	(all)
2005	1	0	0	0	1
2006	1	0	0	0	1
2007	6	2	0	0	8
2008	6	2	1	4	13
2009	7	2	4	4	17
2010	5	2	0	4	11
2011	2	2	2	2	8
2012	0	2	0	2	4
2013	1	1	0	2	4
2014	2	1	0	2	5
2015	2	2	1	2	7
2016	2	2	0	1	5
2017	2	0	0	0	2

Table 2.1. Number of vessels participating in the Jack mackerel fishery by EU, Korea, Russia and Vanuatu.

Total annual catch (tonnes) by contracting party (cp), year and species (only species with more than 10 ton catch overall)

As derived from the estimated catch in the haul by haul data from the contracting parties.

vesselcp	year	BRU	CJM	EMM	EMT	GIS	MAC	MAS	SLT	UBA	(all)
EU	2005	0	5,381	0	0	0	0	108	0	0	5,489
EU	2006	0	25,486	0	0	0	0	1,123	0	0	26,609
EU	2007	0	88,253	0	0	0	0	3,157	0	0	91,410
EU	2008	0	72,572	0	0	0	0	2,288	0	0	74,860
EU	2009	407	91,926	0	0	0	0	4,134	0	0	96,467
EU	2010	108	31,207	0	0	0	0	266	0	0	31,581
EU	2011	14	1,184	0	0	0	0	0	0	0	1,198
EU	2013	63	10,011	0	0	0	0	226	0	0	10,300
EU	2014	65	20,509	0	0	0	0	742	0	88	21,404
EU	2015	152	28,006	0	0	0	0	893	29	52	29,132
EU	2016	40	11,469	0	0	0	0	791	0	176	12,476
EU	2017	83	22,003	0	0	0	0	998	0	51	23,135
EU	(all)	932	408,007	0	0	0	0	14,726	29	367	424,061
KOR	2007	0	10,523	0	0	0	0	1,199	0	0	11,722
KOR	2008	0	12,377	0	0	0	0	961	0	0	13,338
KOR	2009	0	13,759	0	59	0	0	715	0	0	14,533
KOR	2010	0	8,182	0	0	0	0	84	0	0	8,266
KOR	2011	0	9,253	0	0	99	0	24	0	0	9,376
KOR	2012	0	5,491	0	0	0	0	0	0	0	5,491
KOR	2013	0	5,266	0	0	0	0	110	0	0	5,376
KOR	2014	0	4,077	0	0	0	0	21	0	0	4,098
KOR	2015	0	5,748	0	0	0	0	79	0	0	5,827
KOR	2016	0	6,429	0	0	0	77	408	0	0	6,914
KOR	(all)	0	81,105	0	59	99	77	3,601	0	0	84,941
RUS	2008	0	4,799	0	0	0	0	386	0	0	5,185
RUS	2009	0	8,503	0	0	0	0	534	0	0	9,037
RUS	2011	0	8,228	0	0	0	0	12	0	0	8,240
RUS	2015	0	2,523	30	0	0	0	573	0	11	3,137
RUS	(all)	0	24,053	30	0	0	0	1,505	0	11	25,599
VUT	2008	0	101,955	0	0	0	0	8,458	0	0	110,413
VUT	2009	0	80,165	0	0	0	0	4,667	0	0	84,832
VUT	2010	0	45,934	0	0	0	0	639	0	0	46,573
VUT	2011	0	7,627	0	0	0	0	0	0	0	7,627
VUT	2012	0	16,462	0	0	0	0	0	0	0	16,462
VUT	2013	0	15,525	0	0	0	0	0	0	0	15,525
VUT	2014	0	15,473	0	0	0	0	0	0	0	15,473
VUT	2015	0	21,224	0	0	0	607	0	0	0	21,831
VUT	2016	0	7,385	0	0	0	553	0	0	0	7,938
VUT	(all)	0	311,750	0	0	0	1,160	13,764	0	0	326,674

Table 2.2. Summary of annual catch by species and contracting party

Summed haul durations in hours (when available)

I.e. numbers of hours fished. The data for 2017 are incomplete.

year	EU	KOR	RUS	VUT	(all)
2005	650	0	0	0	650
2006	1,131	0	0	0	1,131
2007	836	1,817	0	0	2,653
2008	3,529	1,559	553	8,935	14,576
2009	6,087	1,301	1,115	7,512	16,015
2010	3,219	1,381	0	6,357	10,957
2011	341	2,385	1,770	2,041	6,537
2012	0	920	0	4,253	5,173
2013	1,455	919	0	2,815	5,189
2014	2,453	649	0	2,809	5,911
2015	2,122	910	478	2,631	6,141
2016	1,333	1,775	0	1,118	4,226
2017	2,367	0	0	0	2,367

Table 2.3. Summed haul durations in Jack mackerel fishery by EU, Korea, Russia and Vanuatu.

Number of fishing days (defined as days when a haul has been reported)

year	EU	KOR	RUS	VUT	(all)
2005	44	0	0	0	44
2006	110	0	0	0	110
2007	164	145	0	0	309
2008	156	166	62	233	617
2009	160	159	83	174	576
2010	104	125	0	144	373
2011	20	155	121	100	396
2012	0	116	0	182	298
2013	137	89	0	164	390
2014	148	77	0	153	378
2015	115	95	38	122	370
2016	91	174	0	85	350
2017	143	0	0	0	143

Table 2.4. Number of fishing days in Jack mackerel fishery by EU, Korea, Russia and Vanuatu.

Number of hauls

year	EU	KOR	RUS	VUT	(all)
2005	81	0	0	0	81
2006	240	0	0	0	240
2007	643	352	0	0	995
2008	703	398	94	1,731	2,926
2009	924	291	184	1,356	2,755
2010	490	261	0	886	1,637
2011	47	432	208	273	960
2012	0	160	0	562	722
2013	198	128	0	358	684
2014	385	125	0	392	902
2015	388	198	82	435	1,103
2016	206	325	0	180	711
2017	416	0	0	0	416

Table 2.5. Summary of number of hauls by EU, Korea, Russia and Vanuatu.

Length of the fishing season (defined as the number of days between the first haul and the last haul in a year)

year	EU	KOR	RUS	VUT	(all)
2005	51	0	0	0	51
2006	240	0	0	0	240
2007	194	162	0	0	356
2008	172	188	89	245	694
2009	168	195	120	198	681
2010	122	208	0	171	501
2011	41	197	175	149	562
2012	0	167	0	263	430
2013	233	139	0	202	574
2014	170	93	0	201	464
2015	148	120	52	159	479
2016	136	188	0	167	491
2017	179	0	0	0	179

Table 2.6. Summary of length of fishing season by EU, Korea, Russia and Vanuatu.

Total catch of jack mackerel per year

As derived from the haul-by-haul estimated catches. According to SC-01-14 (European Union 2013 Annual Report) there is a difference between the haul-by-haul estimated catch by the skipper and the overall catch reported to SPRFMO for the earlier years of the time series. No attempt has been made to change the haul-by-haul data and therefore the overall quantities cannot be directly compared with the total catch in the SPRFMO catch series.

year	EU	KOR	RUS	VUT	(all)
2005	5,381	0	0	0	5,381
2006	25,486	0	0	0	25,486
2007	88,253	10,524	0	0	98,777
2008	72,573	12,377	4,800	101,955	191,705
2009	91,927	13,759	8,504	80,166	194,355
2010	31,207	8,183	0	45,934	85,324
2011	1,185	9,253	8,229	7,628	26,294
2012	0	5,492	0	16,463	21,954
2013	10,012	5,267	0	15,526	30,804
2014	20,510	4,078	0	15,473	40,061
2015	28,007	5,749	2,524	21,224	57,503
2016	11,470	6,430	0	7,385	25,284
2017	22,003	0	0	0	22,003

Table 2.7. Total catch per year of Jack Mackerel by EU, Korea, Russia and Vanuatu based on the haul-by-haul estimates.

Mean catch of jack mackerel per day

year	EU	KOR	RUS	VUT	(all)
2005	122	.	.	.	122
2006	232	.	.	.	232
2007	538	73	.	.	305
2008	465	75	77	439	264
2009	575	87	102	461	306
2010	300	65	.	319	228
2011	59	60	68	76	66
2012	.	47	.	90	69
2013	74	59	.	95	76
2014	140	53	.	101	98
2015	244	61	68	174	137
2016	126	37	.	87	83
2017	154	.	.	.	154

Table 2.8. Mean catch per day of Jack Mackerel by EU, Korea, Russia and Vanuatu.

Comparison of different CPUE metrics: by haul, by day and by week

Average CPUE by year and contracting party has been calculated by haul, by day and by week. Each of the series has been scaled to the maximum of the time series. This indicates that the nominal CPUE by day and by week give the same overall pattern which is differing from the CPUE by haul.

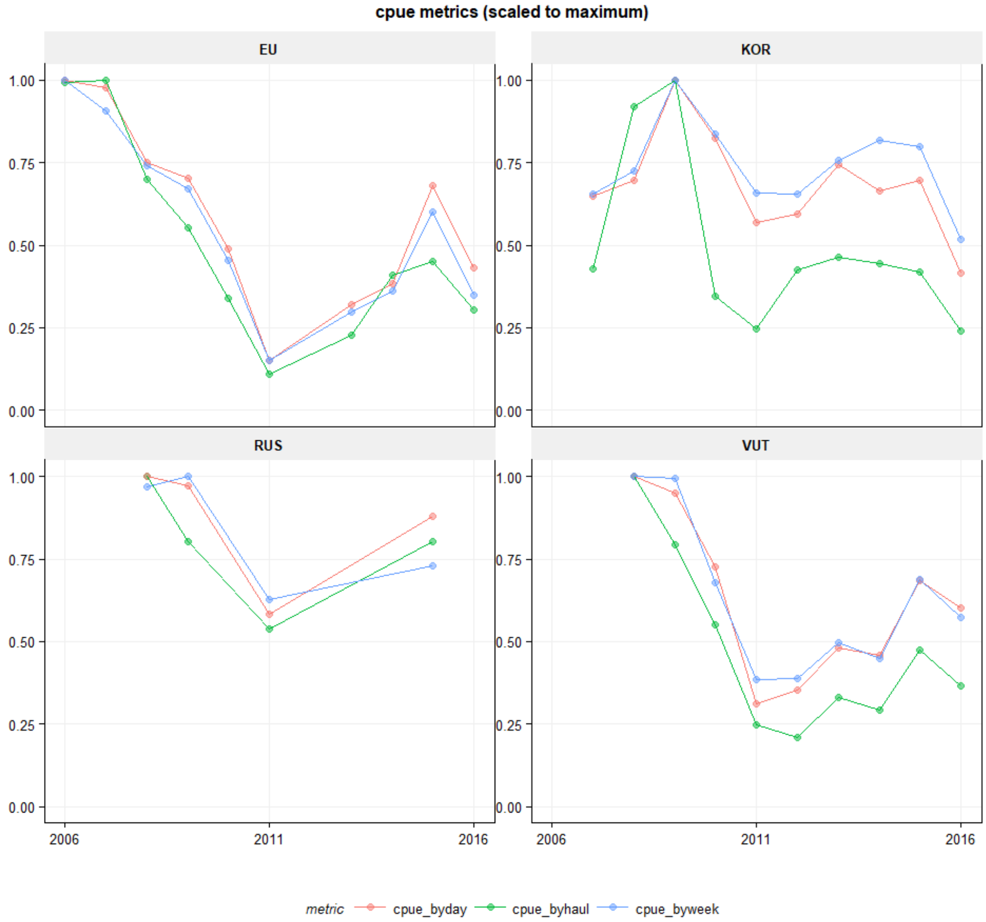


Figure 2.1. Three different CPUE metrics for EU, Korea, Russia and Vanuatu, scaled to the maximum of the time series.

All hauls of all years on one map

All haul positions for all years where Jack mackerel has been caught.

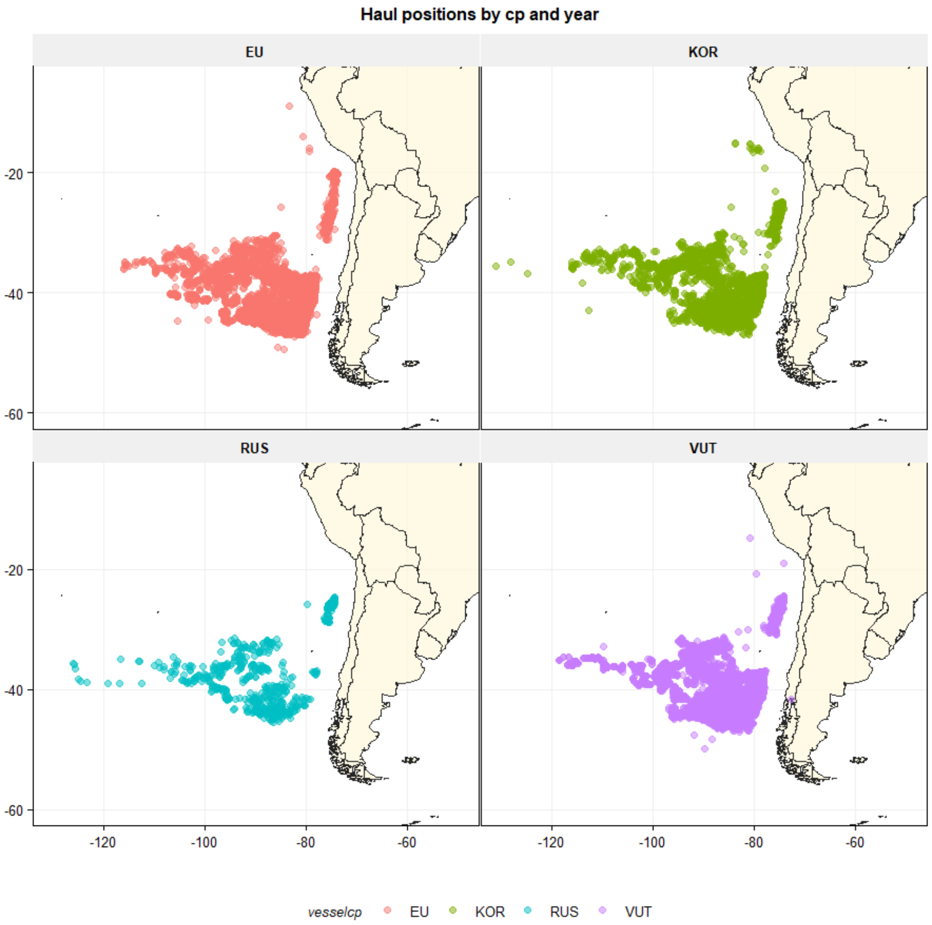


Figure 2.2. CJM Haul positions (all years combined) for EU, Korea, Russia and Vanuatu.

Haul positions by contracting party and year

The yearly postions of Jack mackerel fishery of the offshore fleets.

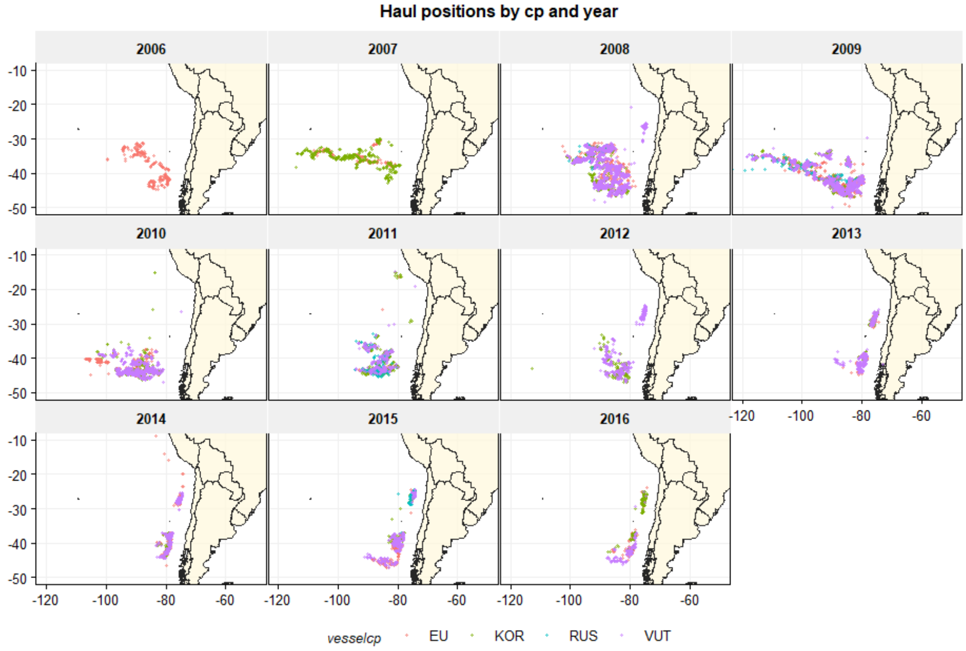


Figure 2.3. Haul positions by contracting party. Colours indicate the different contracting parties participating.

Mean catch per day of jack mackerel per one degree longitude and 1/2 degree latitude

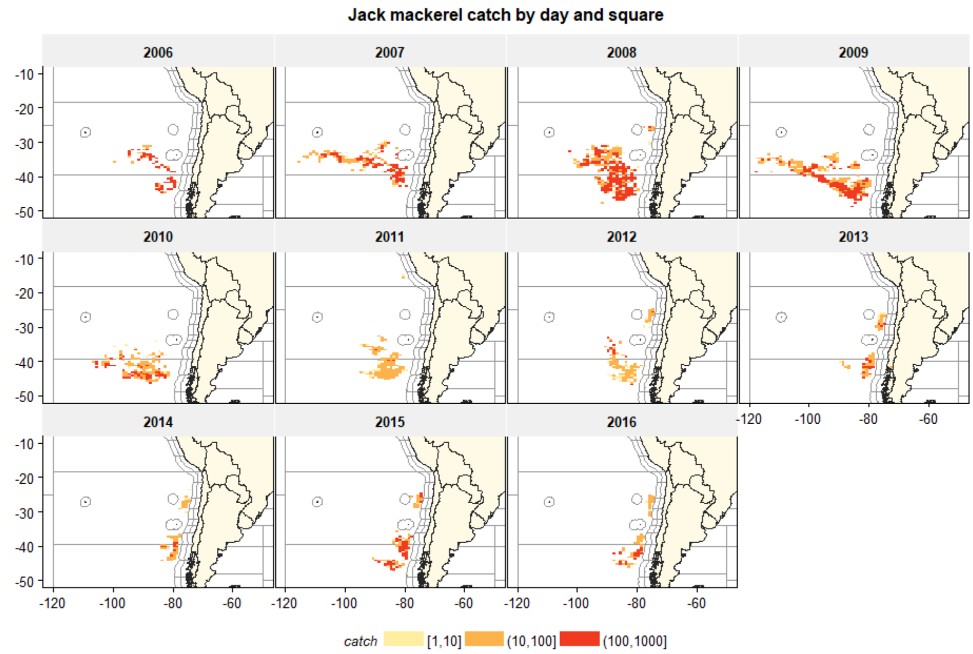


Figure 2.4. Catch per day of Jack mackerel (summed by 1 degree longitude and 0.5 degree latitude). Catch in tonnes expressed on a log scale.

Jack mackerel log CPUE by day against latitude and longitude

Figure 2.5. Log Catch per day of Jack mackerel against latitude and longitude.

Jack mackerel catch per day and yearly average catch per day

The plot below shows the distributions of catch per day and by contracting party. The average catch per day is drawn as a dashed black line. The average catch per day of Korea shows a rather different pattern compared to the non-zero catches. This is due to the number of zero hauls in the dataset (see figure 2.7). This will need to be looked at into in more detail but for now the data from Korea has been included in the analyses, because the catch per unit effort has been aggregated per week.

Figure 2.6. Jack mackerel CPUE (log(catch / day)). Colours indicate the different contracting parties.

Proportion of fishing days with zero catch

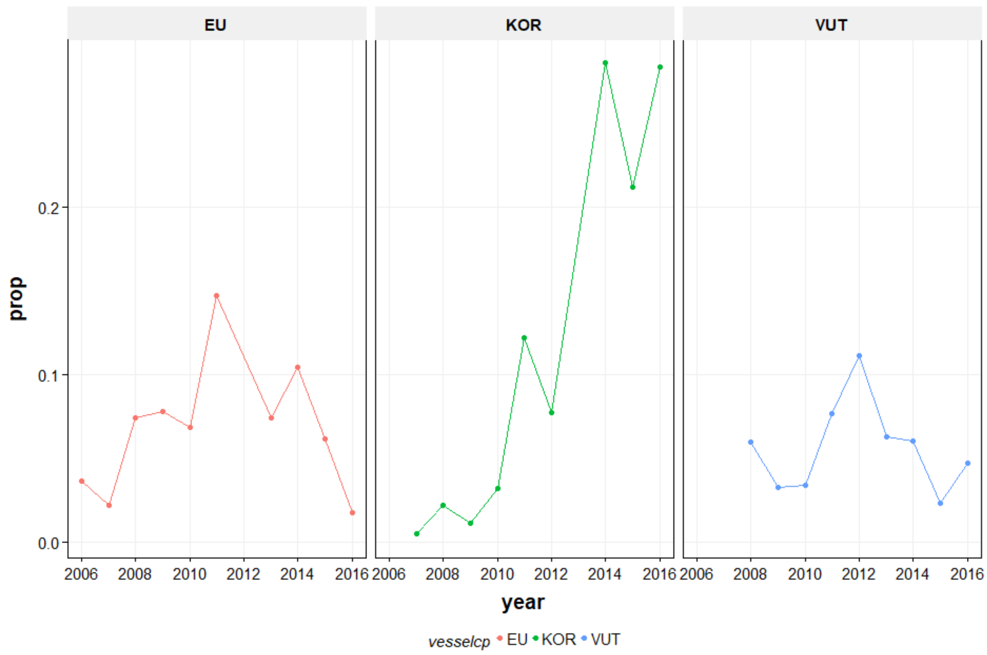


Figure 2.7. Jack mackerel: proportion of zero hauls per year and contracting party. For Russia there were too few years to plot the proportion zero hauls.

El Nino effect and Humbold_current index

It has been hypothesized that the catch rate of jack mackerel by area and season could be dependent on the climatic situation, characterized by El Nino events (NOAA, https://www.esrl.noaa.gov/psd/data/correlation/oni.data) or the Humboldt Current Index (http://www.bluewater.cl/HCI/)

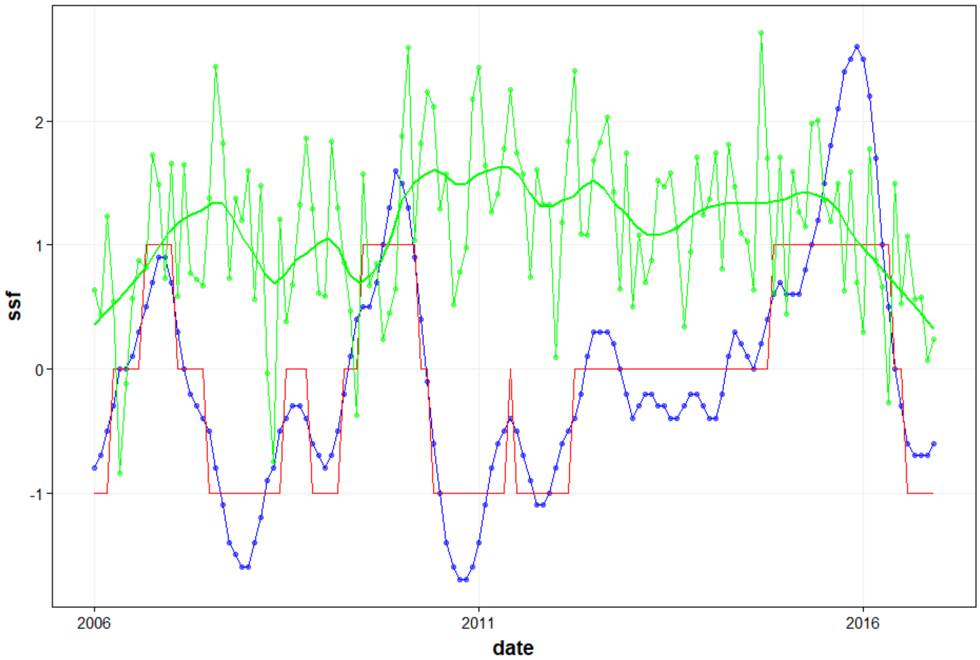


Figure 2.8. El Nino temperature anomaly (blue line) and estimated ELE indicator (red line). Humboldt Current Index (green line).

Modelling approach

The general modelling approach has been to use GAM models to assess the dependency on the weekly catch of jack mackerel on different variables. In the first instance a test has been carried out to apply a negative binomial distribution to the weekly catch data

The basic model consists of catch (per week) as the main variable, the year effect (as factor) as the main explanatory variable and the log of effort as the offset (the log is taken because of the log-link function). Then the other potential explanatory variables are explored (month, vessel, contracting party, sea surface temperature anomaly, el nino effect and interaction between lat and long). Based on the AIC criteria, the best fitting second, third etc. variable have been selected.

A leave-one-out analysis was carried out to assess the year trends in CPUE if the data from one of the contracting parties was left out.

3 Results

Negative binomial distribution of catch by week

The catch per week data fits closely to a negative binomial distribution.

Note: weeks with zero catches have been removed from the analysis but this warrants a further look into the data.

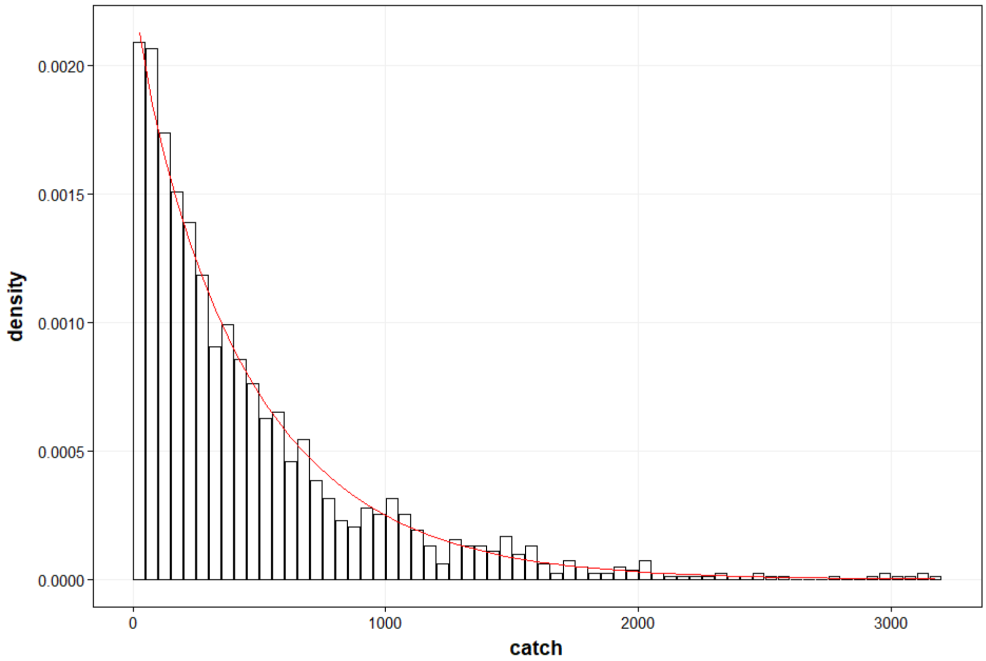
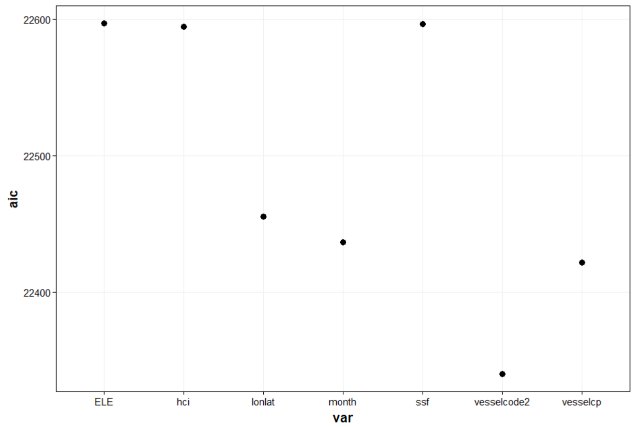


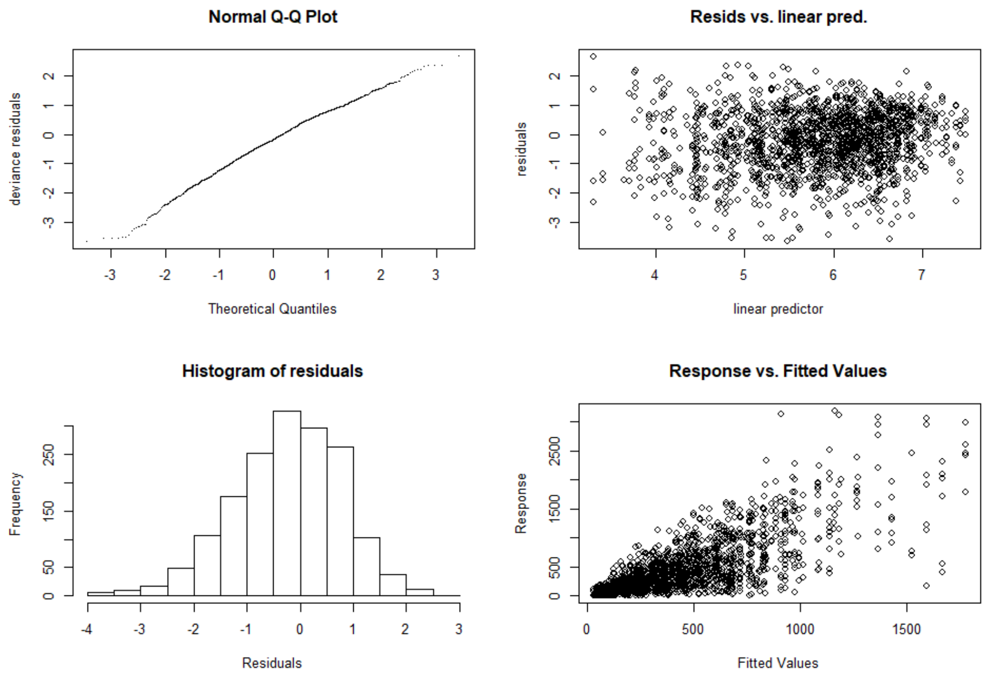
Figure 3.1. Negative binomial distribution of jack mackerel catch per week.

Modelling the first linear effect next to the year trend

The basic model consists of catch (per week) as the main variable, the year effect (as factor) as the main explanatory variable and the log of effort as the offset (the log is taken because of the log-link function). Then the other potential explanatory variables are explored (month, vessel, contracting party, sea surface temperature anomaly, el nino effect and interaction between lat and long). Based on the AIC criteria, the best fitting second variable has been selected, which was the vesselcode.

Catch ~ offset(log(effort)) + year + first linear effect

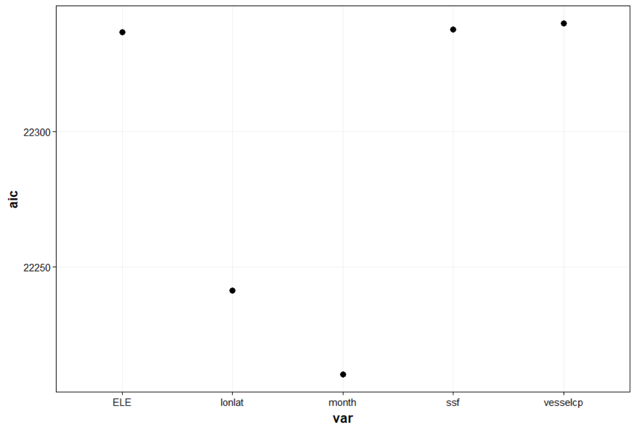


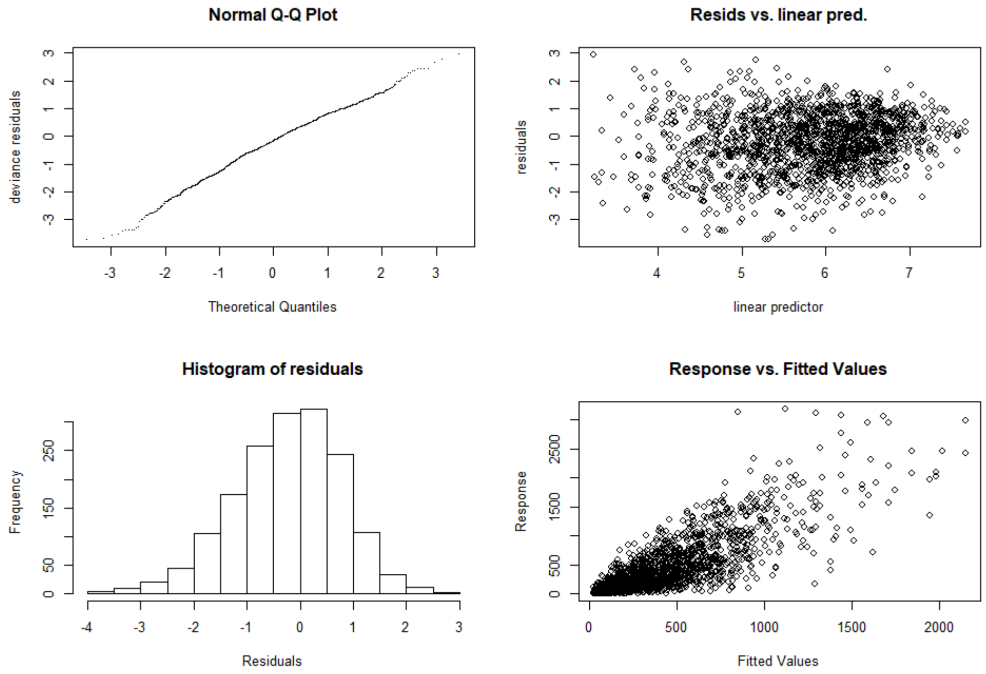


```
'gamm' based fit - care required with interpretation.
Checks based on working residuals may be misleading.

Analysis of Deviance Table

Model: Negative Binomial(1.9606), link: log

Response: catch

Terms added sequentially (first to last)

            Df Deviance Resid. Df Resid. Dev  Pr(>Chi)
NULL                         1656     2604.7
year        10   470.42      1646     2134.3 < 2.2e-16 ***
vesselcode2 23   330.38      1623     1803.9 < 2.2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Modelling the second linear effect next to the year and vessel effect

Catch ~ offset(log(effort)) + year + vessel + second linear effect

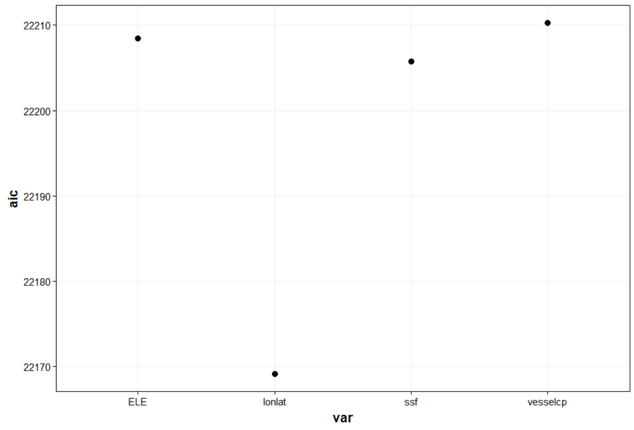


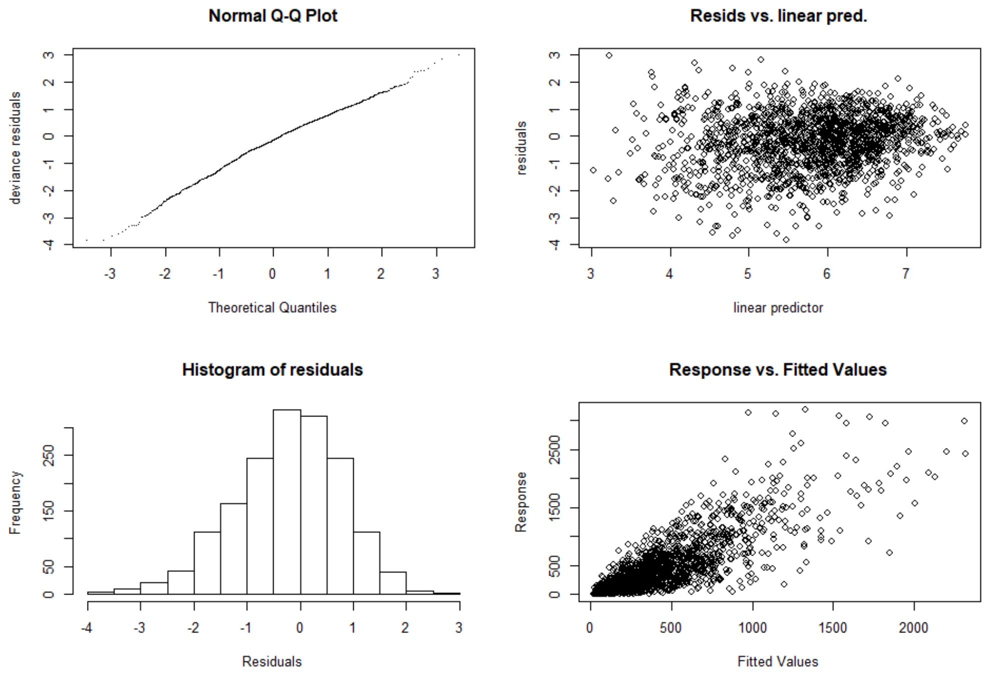



```
'gamm' based fit - care required with interpretation.
Checks based on working residuals may be misleading.

Analysis of Deviance Table

Model: Negative Binomial(2.1268), link: log

Response: catch

Terms added sequentially (first to last)

            Df Deviance Resid. Df Resid. Dev  Pr(>Chi)    
NULL                         1656     2821.0              
year        10   509.98      1646     2311.0 < 2.2e-16 ***
vesselcode2 23   358.17      1623     1952.8 < 2.2e-16 ***
month       10   155.85      1613     1797.0 < 2.2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Modelling the third linear effect next to the year, vessel and month effect

Catch ~ offset(log(effort)) + year + vessel + month + third linear effect






```
'gamm' based fit - care required with interpretation.
Checks based on working residuals may be misleading.

Analysis of Deviance Table

Model: Negative Binomial(2.1821), link: log

Response: catch

Terms added sequentially (first to last)

                  Df Deviance Resid. Df Resid. Dev  Pr(>Chi)
NULL                               1656     2892.8
year              10   523.14      1646     2369.7 < 2.2e-16 ***
month             10   226.80      1636     2142.9 < 2.2e-16 ***
vesselcode2       23   300.48      1613     1842.4 < 2.2e-16 ***
```

```
shootlon           1     0.97      1612     1841.4  0.325459
shootlat           1     8.14      1611     1833.3  0.004341 **
shootlon:shootlat  1    38.57      1610     1794.7 5.277e-10 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Exploring the El Nino effect

Catch ~ offset(log(effort)) + year + vessel + month + lat-lon + 'El Nino' or Humboldt Current Index

The El Nino effect can be taken in as the sea surface temperature anomaly or as the El Nino indicator (-1, 0, 1). The Humboldt Current index is taken as the pressure difference between Easter island and Antofagasta. The only significant effects was observed for the El Nino Sea Surface Anomaly (ssf)

ELE

```
Analysis of Deviance Table

Model: Negative Binomial(2.1964), link: log

Response: catch

Terms added sequentially (first to last)

                  Df Deviance Resid. Df Resid. Dev  Pr(>Chi)
NULL                               1656     2911.4
year              10   526.54      1646     2384.8 < 2.2e-16 ***
month             10   228.28      1636     2156.6 < 2.2e-16 ***
vesselcode2       23   302.43      1613     1854.1 < 2.2e-16 ***
shootlon           1     0.97      1612     1853.2  0.323935
shootlat           1     8.19      1611     1845.0  0.004215 **
ELE                2     5.84      1609     1839.1  0.053920 .
shootlon:shootlat  1    45.07      1608     1794.1 1.901e-11 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

SSF

```
Analysis of Deviance Table

Model: Negative Binomial(2.19), link: log

Response: catch

Terms added sequentially (first to last)

                  Df Deviance Resid. Df Resid. Dev  Pr(>Chi)
NULL                               1656     2903.1
year              10   525.02      1646     2378.1 < 2.2e-16 ***
month             10   227.61      1636     2150.4 < 2.2e-16 ***
vesselcode2       23   301.56      1613     1848.9 < 2.2e-16 ***
shootlon           1     0.97      1612     1847.9   0.32462
shootlat           1     8.17      1611     1839.8   0.00427 **
ssf                1     5.81      1610     1833.9   0.01590 *
shootlon:shootlat  1    39.52      1609     1794.4  3.25e-10 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

HCI

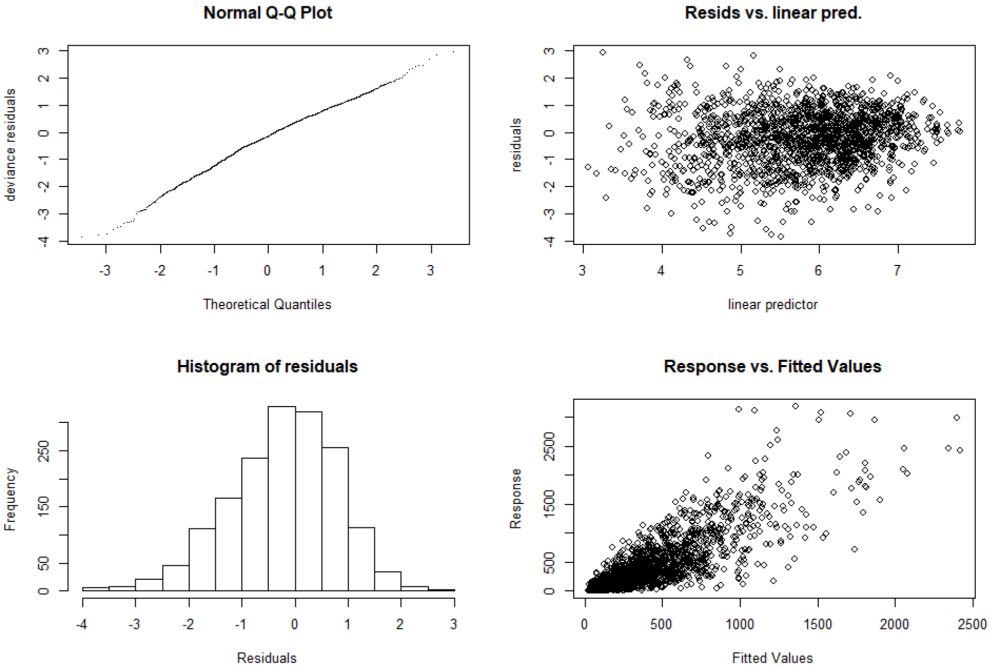
```
Analysis of Deviance Table

Model: Negative Binomial(2.1821), link: log

Response: catch

Terms added sequentially (first to last)

                  Df Deviance Resid. Df Resid. Dev  Pr(>Chi)    
NULL                               1656     2892.8              
year              10   523.14      1646     2369.7 < 2.2e-16 ***
month             10   226.80      1636     2142.9 < 2.2e-16 ***
vesselcode2       23   300.48      1613     1842.4 < 2.2e-16 ***
shootlon           1     0.97      1612     1841.4  0.325459    
shootlat           1     8.14      1611     1833.3  0.004341 ** 
hci                1     0.00      1610     1833.3  0.963921    
shootlon:shootlat  1    38.57      1609     1794.7 5.279e-10 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Modelling the spatial and year smoothers

In this section we explore the added benefits of using the interaction between lat, long and year and whether the smoothers available in GAM provide additional benefits over GLMs. Four different models are compared.

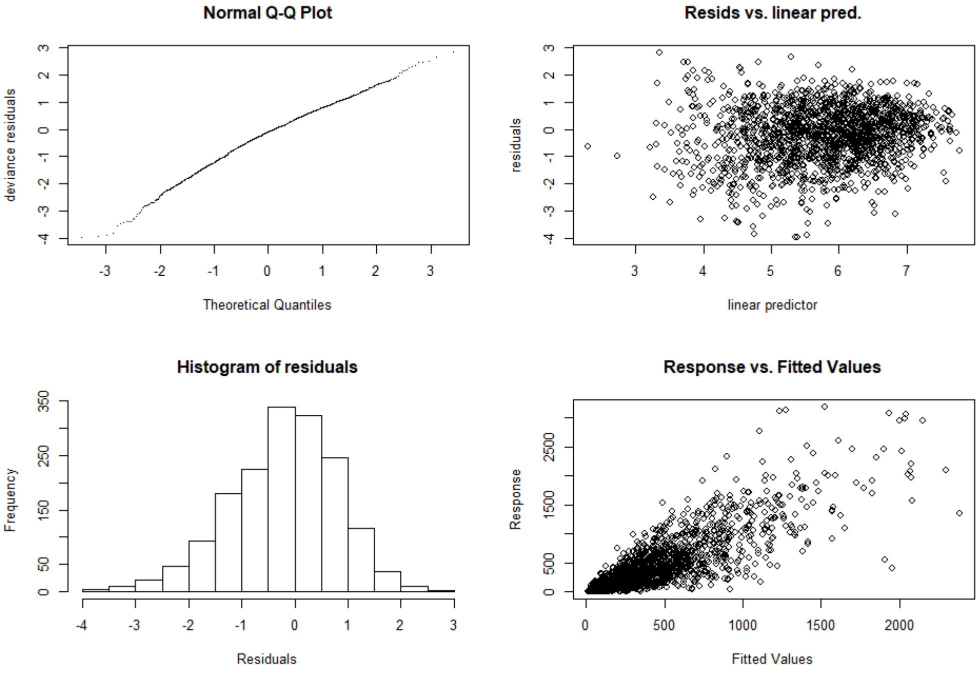
```
1) catch ~ year + month + vesselcode2 + ssf + shootlon * shootlat + offset(log(effort))

2) catch ~ year + month + vesselcode2 + ssf + shootlon*shootlat*year + offset(log(effort))

3) catch ~ year + month + vesselcode2 + ssf + s(shootlon,shootlat) + offset(log(effort))

4) catch ~ year + month + vesselcode2 + ssf + s(shootlon,shootlat, by = year) + offset(log(effort))
```

```
1) catch ~ year + month + vesselcode2 + ssf + shootlon * shootlat +
    offset(log(effort))
```



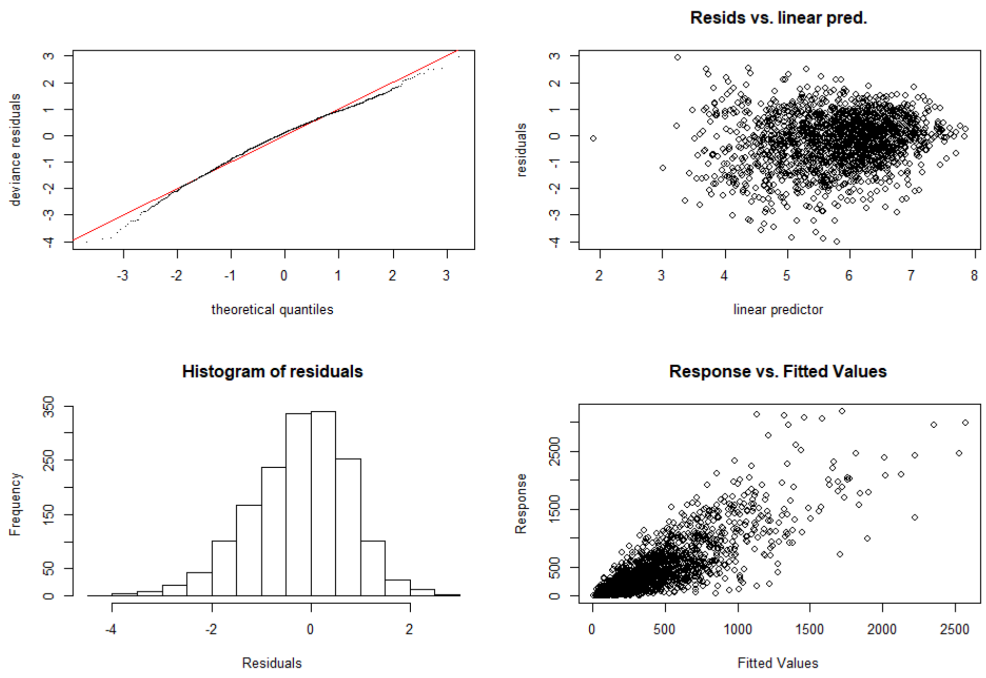

```
'gamm' based fit - care required with interpretation.
Checks based on working residuals may be misleading.
```

```
2) catch ~ year + month + vesselcode2 + ssf + shootlon * shootlat *
    year + offset(log(effort))
```



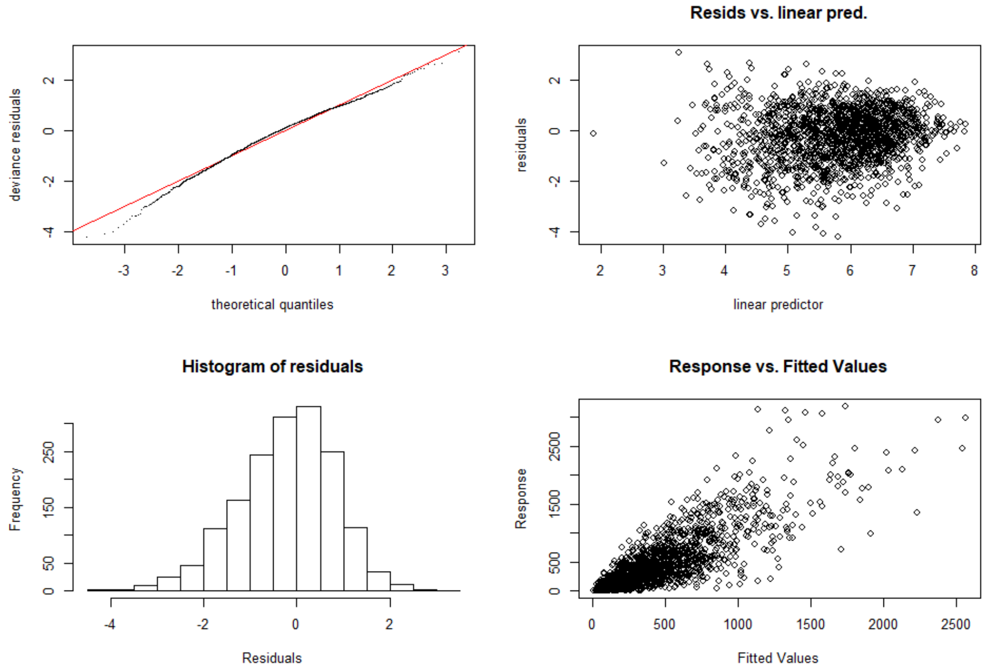

```
'gamm' based fit - care required with interpretation.
Checks based on working residuals may be misleading.
```

```
3) catch ~ year + month + vesselcode2 + ssf + s(shootlon, shootlat) +
    offset(log(effort))
```




```
Method: UBRE   Optimizer: outer newton
step failed after 5 iterations.
Gradient range [6.053139e-06,6.053139e-06]
(score 0.1162717 & scale 1).
Hessian positive definite, eigenvalue range [0.002562341,0.002562341].
Model rank =  74 / 74

Basis dimension (k) checking results. Low p-value (k-index<1) may
indicate that k is too low, especially if edf is close to k'.

                     k' edf k-index p-value
s(shootlon,shootlat) 29  24    0.79  <2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
4) catch ~ year + month + vesselcode2 + ssf + s(shootlon, shootlat,
    by = year) + offset(log(effort))
```




```
Method: UBRE   Optimizer: outer newton
step failed after 5 iterations.
Gradient range [7.138007e-06,7.138007e-06]
(score 0.2151611 & scale 1).
Hessian positive definite, eigenvalue range [0.002528392,0.002528392].
Model rank =  74 / 74

Basis dimension (k) checking results. Low p-value (k-index<1) may
indicate that k is too low, especially if edf is close to k'.

                       k'  edf k-index p-value
s(shootlon,shootlat) 29.0 24.5    0.79  <2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Final model

The final model was selected as the following model:

Catch ~ offset(log(effort)) + year + vessel + month + ssf + s(lat-lon)

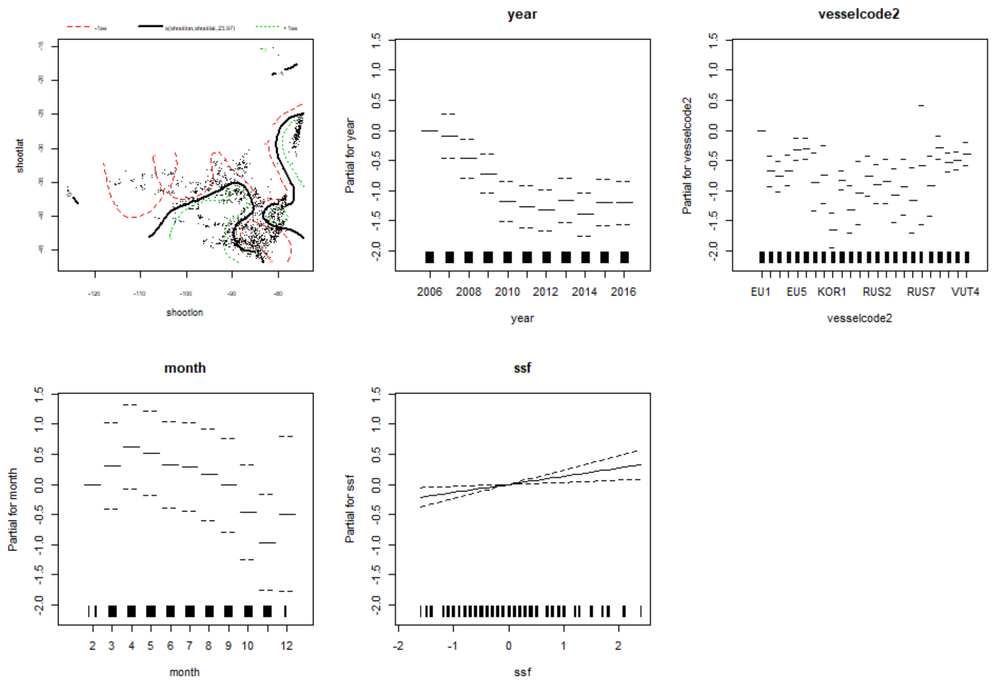


Figure 3.2. Jack mackerel final model diagnostics.

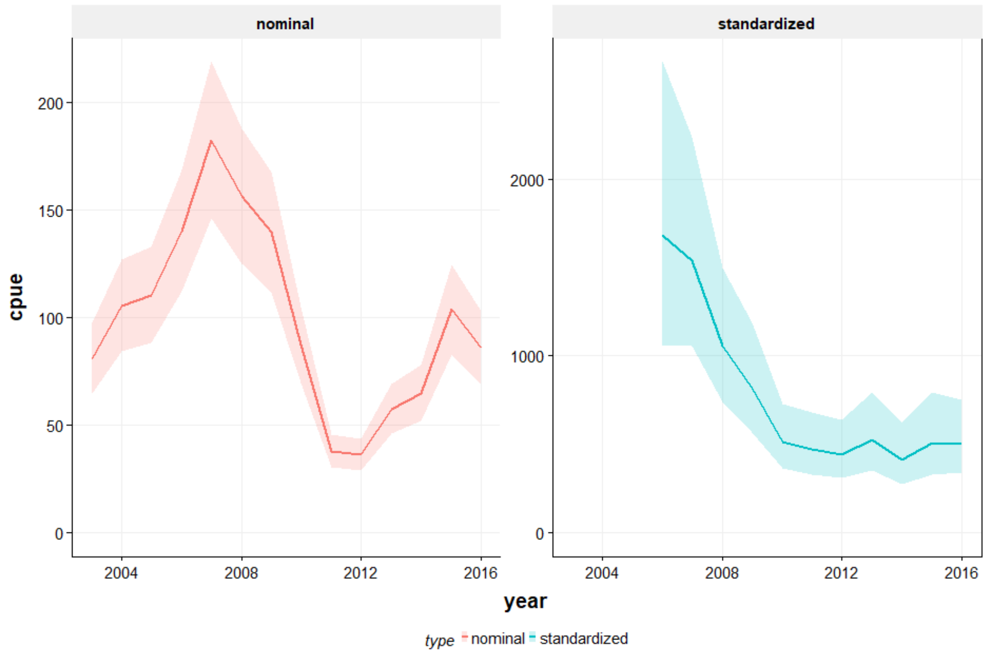


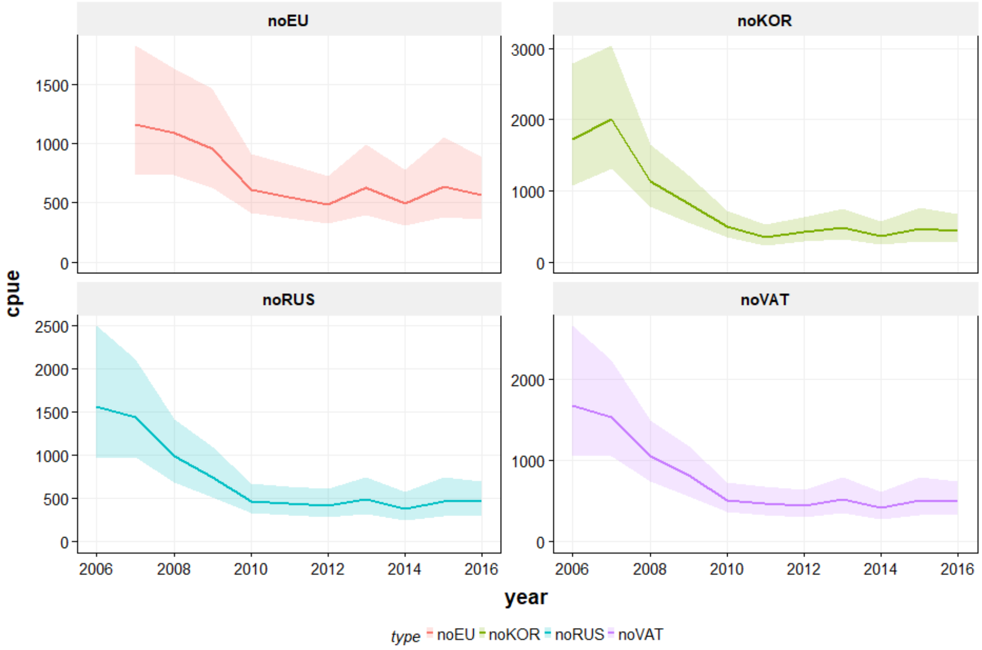
Figure 3.3. Jack mackerel, comparison of the nominal CPUE (as used in the 2017 assessment) and the new standardized CPUE series (catch per week).

"New standardized CPUE series"

year	cpue	upr	lwr
2006	1679	2663	1058
2007	1536	2234	1056
2008	1054	1496	742
2009	819	1187	565
2010	516	731	364
2011	473	679	329
2012	445	640	309
2013	527	791	351
2014	415	619	278
2015	509	795	326
2016	504	750	339

Leave one out analysis: without EU

The leave-one-out analysis shows that the signal of standardized CPUE is largely similar if data of one of the contracting parties is left out. Notably when the EU data is left out, the pattern and the variance is somewhat different from the other situations.



4 Discussion and conclusions

The nominal CPUE of the offshore fleet fishing for Jack mackerel has so far beenused as a tuning index for the assessment. The index consists of the nominal average catch per fishing day for the fleets of EU, Vanuatu and Korea. China has standardized their CPUE series in 2013. The nominal CPUE series of Russia is also being used in the assessment.

This working document described the work aimed to standardizing the CPUE series of EU, Korea, vanuatu and Russia based on the haul-by-haul data contained in the SPRFMO database. Permission to utilize that information was granted by the delegations of Korea, Vanuatu and Russia while the analysis was carried out by scientists from the EU delegation.

The final model for standardizing the CPUE of these fleets models the catch by week and takes into account of the vessel, month, sea surface temperature anomaly and a smooth interaction between latitude and longitude with an off-set of log effort (in number of days per week). The new standardized CPUE series starts in 2006 as this is the first year for which haul by haul information was available to carry out this analysis.

A 'leave-one-out analysis' was carried out by removing the data of one of the contracting parties from the analysis to explore the sensitivity of the results to the data being used. The conclusion from that analysis is that there is some sensitivity, especially when not using the EU data in the analysis.

5 Acknowledgements

We would like to acknowledge the permission granted by the delegations of Russia, Vanuatu and Korea to utilize their haul-by-haul data for the analysis of standardized CPUE of the offshore fleet fishing for Jack mackerel. Sharing access to vessel data has made it possible to improve the indicator that can be used in the assessment.

6 References

Li, G., X. Zou, X. Chen, Y. Zhou and M. Zhang (2013). "Standardization of CPUE for Chilean jack mackerel (Trachurus murphyi) from Chinese trawl fleets in the high seas of the Southeast Pacific Ocean." Journal of Ocean University of China 12(3): 441-451.

SPRFMO (2011) Report of the Jack Mackerel Subgroup. Tenth Science Working Group of SPRFMO, 19 – 23 September 2011, Port Vila, Vanuatu.