

3 Faroe Bank Cod

Summary

The total reported landings in 2013 were the lowest recorded since 1965 (36 tonnes).

The spring index suggests that since 2013 the stock is increasing but it is however well below levels of those in the 1996-2002 period. Nevertheless both the summer and spring index suggest the stock is well below average while there is no indication of strong incoming year classes.

The results of an exploratory production model based on both surveys indicate a good agreement in the stock biomass index in recent years whereas the observed survey-based exploitation rates correlates reasonably well with estimated fishing mortalities. However the model failed to pick up the large increases in stock biomass observed in the 1996-2003 period. Correlation between modelled F 's and summer survey based exploitation rates is $R=0.90$. The exploitation ratio sharply increased in 2011 as a consequence of the increase in landings and it decreased afterwards reflecting the fall of catches observed since 2012.

3.1 State of the stock – historical and compared to what is now.

Total nominal catches of the Faroe Bank cod from 1987 to 2013 as officially reported to ICES are given in Table 3.1 and since 1965 in Figure 3.1. UK catches reported to be taken on the Faroe Bank are all assumed to be taken on the Faroe Plateau and are therefore not used in the assessment. Landings have been highly variable from 1965 to the mid-1980s, reflecting the opportunistic nature of the cod fishery on the Bank, with peak landings slightly exceeding 5 000t in 1973 and 2003. The trend of landings has been smoother since 1987, declining from about 3 500t in 1987 to only 330 t in 1992 before increasing to 3 600t in 1997. In 2013 landings were estimated at 36t which is the lowest ever recorded since 1965 (Figure 3.7.1). Longline fishing effort increased substantially in 2003 and although it decreased in 2004 and 2005 the latter remains the second highest fishing effort observed since 1988 (Figure 3.1). From 2005 to 2007 the effort has been reduced substantially. In the 2010/2011 and 2011/2012 fishing years a total of 61 and 100 fishing-days were allocated to the Bank. No days were allocated in the 2012/2013 fishing year.

The Faroese groundfish surveys (spring and summer) cover the Faroe Bank and cod is mainly taken within the 200 m depth contour. The catches of cod per trawl hour in depths shallower than 200 meter are shown in Figure 3.2.

The spring survey was initiated in 1983 and discontinued in 1996, 2004 and 2005. The summer survey has been carried out since 1996. The CPUE of the spring survey was low during 1988 to 1995 varying between 73 and 95 kg per tow. Although noisy, the survey suggests higher, possibly increasing biomass during 1995 - 2003. The 2013 and the 2014 spring point estimates suggest that the stock is rising but it is however well below the average of that of the period 1996–2002. The 2013 summer index is estimated at 17 kg per tow, which is the lowest value in the series. There are conflicting signals between both indices in recent years. The agreement between the summer and spring index is good during 1996 to 2001 and since 2006, but they diverged in 2002 and 2003 and since 2012. Both indexes have remained well below average since 2004.

The figure of length distributions (figures 3.3 and 3.5) show in general good recruitment of 1 year old in the summer survey from 2000 – 2002 (lengths 26 – 45 cm), corresponding to good recruitment of 2 years old in the spring surveys from 2001 to 2003 (40 – 60 cm). The spring index shows poor recruitment from 2006 to 2014 reflecting the weak year classes observed in the summer survey since 2004. Age-disaggregated indices confirm the pattern observed in the length composition (figure 3.4 and figure 3.6)

A way to estimate recruitment strength is by simply counting the number of fish in length groups in the surveys. In the spring index, recruitment was estimated as total number of fish below 60 cm (2-year old) and in the summer index as number of fish below 45 cm (1-year old). According to the summer index the recruitment of 1 year old was good from 2000 to 2003, while the recruitment has been relatively poor since 2004 (Figure 3.7) The spring recruitment index in 2014 shows no sign of incoming year classes. Correlation between the spring and summer survey recruitment indices is fairly good ($r=0.85$). Correlation between numbers of 1-year and 2-years old cod in the age-disaggregated summer and spring surveys respectively is estimated at $r=0.79$.

The group tried the ASPIC (Prager 1992) stock production model for the stock. The model requires catch data and corresponding effort or CPUE data that are reasonable indices of the stock biomass.

ASPIC requires starting guesses for r , the intrinsic rate of increase, MSY, $B1/B_{msy}$ ratio and q , catchability coefficients. No sensitivity analysis was performed to explore the stability of parameter estimation.

The program was run with the time-series from 1983-2013 including spring survey and 1996-2013 summer CPUE's separately. The result of the runs are presented in tables 3.2 and 3.3 For both runs the model seemed to follow reasonably well survey trends in periods of low stock abundances but it failed to pick up the large increases observed in the 1996-2003 period (figures 3.8 and 3.9).

However estimates of $r=0.072$ and $F_{msy}=0.036$ (using the fall survey series) seem spurious given that the Faroe Bank cod is the fastest growing cod stock in the Atlantic.

The ratio of landings to the survey indices provides an exploitation ratio, which can be used as a proxy to relative changes in fishing mortality. For the summer survey, the results suggest that fishing mortality has been reasonably stable during 1996 to 2002, but that it increased steeply in 2003, consistent with the 160% increase in longline fishing days in that year (Figure 3.1). The exploitation ratio has decreased since 2006 but increased in 2011 due to the increase in catches and decreased again afterwards reflecting the fall of catches observed since 2011.

3.2 Comparison with previous assessment and forecast

The status of the stock remains almost unchanged with respect to last year's assessment. Both the spring and the summer indexes suggest the stock is well below average while there are no indications of incoming recruitment. The spring index suggests an increasing stock biomass since 2013 which it is however not picked up by the summer survey. The exploratory production model performed in 2013 and 2014 confirms the poor status of the stock.

3.3 Management plans and evaluations (Could just be a reference to the year when the plan was agreed/evaluated. Include proposed/agreed management plan.)

None

3.4 Management considerations

The landing estimates are uncertain because since 1996 vessels are allowed to fish both on the Plateau and on Faroe Bank during the same trip, rendering landings from both areas uncertain. Given the relative size of the two fisheries, this is a bigger problem for Faroe Bank cod than for Faroe Plateau cod, but the magnitude remains unquantified for both. The ability to provide advice depends on the reliability of input data. If the cod landings from Faroe Bank are not known, it is difficult to provide advice. If the fishery management agency intends to manage the two fisheries to protect the productive capacity of each individual unit, then it is necessary to identify the catch removed from each stock. Simple measures should make it possible to identify if the catch is originating from the Bank or from the Plateau e.g. by storing in different section of the hold and/or by tagging of the different boxes.

Consistent with the advice given in 2013 the WG suggests the closure of the fishery until the recovery of the stock is confirmed. The reopening of the fishery should not be considered until both surveys indicate a biomass at or above the average that of the period 1996-2002.

3.5 Regulations and their effects

In 1990, the decreasing trends in cod landings from Faroe Bank lead ACFM to advise the Faroese authorities to close the bank to all fishing. This advice was followed for depths shallower than 200 meters. In 1992 and 1993 longliners and jiggers were allowed to participate in an experimental fishery inside the 200 meters depth contour. For the quota year 1 September 1995 to 31 August 1996 a fixed quota of 1 050 t was set. The new management regime with fishing days was introduced on 1 June 1996 allowing longliners and jiggers to fish inside the 200 m contour. The trawlers are allowed to fish outside the 200 m contour.

A total fishing ban during the spawning period (1 March to 1 May) has been enforced since 2005. In 2009, fishing was restricted to all fishing gears from 1 January to 31 August. However, in the 2010/2011 and 2011/2012 fishing years a total of 61 and 100 fishing-days were allocated to the Bank to jiggers in the shallow waters of the Bank. No days were allocated in the 2013/2014 fishing year.

3.6 Changes in fishing technology and fishing patterns

None

Changes in the environment

Table 3.1. Faroe Bank (sub-division Vb2) cod. Nominal catches (tonnes) by countries 1986-2012 as officially reported to ICES. From 1992 the catches by Faroe Islands and Norway are used in the assessment.

	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Faroe Islands	1836	3409	2966	1270	289	297	122	264	717	561	2051	3459	3092	1001
Norway	6	23	94	128	72	38	32	2	8	40	55	135	147	88
UK (E/W/NI)	-	-	-	-	2 ¹	1 ¹	74 ²	186 ²	56 ²	43 ²	126 ²	61 ²	27 ²	-
UK (Scotland)	63 ³	47 ³	37 ³	14 ³	205 ³	90 ³	176 ³	118 ³	227 ³	551 ³	382 ³	277 ³	265 ³	51 ³
Total	1905	3479	3097	1412	568	426	404	570	1008	1195	2614	3932	3531	210
Used in assessment					289	297	154	266	725	601	2106	3594	3239	0
														1089
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Faroe Islands		1094	1840	5957	3607	1270	1005	471	231	81	111	393	115	38
Norway	49	51	25	72	18	37	10	7	1	4	1		0	
Greenland	-	-	-	-	-	-	-	-	-	-	-	-	1	
UK (E/W/NI)	18 ³	50 ³	42 ³	15 ³	15 ³	24 ³	1 ³							
UK (Scotland)	245 ³	288 ³	218 ³	254 ³	244 ³	1129 ³	278 ³	53	32	38	54			
Total	312	1483	2125	6298	3884	2460	1294	531	264	123	166	393	116	38
Correction of Faroese catches in Vb2		-65	-109	-353	-214	-75	-60	-28	-14	-5	-7	-23	-7	-2
Used in assessment	1194	1080	1756	5676	3411	1232	955	450	218	80	105	370	108	36
¹ Preliminary														
² Included in Vb1.														
³ Reported as Vb.														

Table 3.2. Faroe Bank (sub-division Vb2) cod. Surplus production model output using the summer index.

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ASPIC -- A Surplus-Production Model Including Covariates (Ver. 3.82)

FIT Mode

Author: Michael H. Prager; NOAA/NMFS/S.E. Fisheries Science Center

ASPIC User's Manual

101 Pivers Island Road; Beaufort, North Carolina 28516 USA

is available gratis

from the author.

Ref: Prager, M. H. 1994. A suite of extensions to a nonequilibrium

surplus-production model. Fishery Bulletin 92: 374-389.

CONTROL PARAMETERS USED (FROM INPUT FILE)

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Number of years analyzed:      49      Number of bootstrap trials:      0
Number of data series:        1      Lower bound on MSY:              5.000E+02
Objective function computed:   in effort  Upper bound on MSY:              1.000E+09
Relative conv. criterion (simplex): 1.000E-08  Lower bound on r:                7.000E-02
Relative conv. criterion (restart): 3.000E-08  Upper bound on r:                2.500E+00
Relative conv. criterion (effort): 1.000E-04  Random number seed:              2010417
Maximum F allowed in fitting:   8.000      Monte Carlo search mode, trials: 1 10000

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PROGRAM STATUS INFORMATION (NON-BOOTSTRAPPED ANALYSIS)

code 0

Normal convergence.

GOODNESS-OF-FIT AND WEIGHTING FOR NON-BOOTSTRAPPED ANALYSIS

Loss component number and title	Weighted SSE	Weighted N	Current MSE	Suggested weight	R-squared weight	in CPUE
Loss(-1) SSE in yield	0.000E+00					
Loss(0) Penalty for B1R > 2	9.283E-05	1	N/A	1.000E-01	N/A	
Loss(1) Survey CPUE Summer	2.393E+00	18	1.496E-01	1.000E+00	1.000E+00	0.766
TOTAL OBJECTIVE FUNCTION:	2.39352046E+00					

NOTE: B1-ratio constraint term contributing to loss. Sensitivity analysis advised.

Number of restarts required for convergence: 8
 Est. B-ratio coverage index (0 worst, 2 best): 1.9319 < These two measures are defined in Prager
 Est. B-ratio nearness index (0 worst, 1 best): 1.0000 < et al. (1996), Trans. A.F.S. 125:729

MODEL PARAMETER ESTIMATES (NON-BOOTSTRAPPED)

Parameter	Estimate	Starting guess	Estimated	User guess
B1R Starting biomass ratio, year 1965	2.062E+00	1.000E+00	1	1
MSY Maximum sustainable yield	1.002E+03	3.000E+03	1	1
r Intrinsic rate of increase	7.227E-02	8.000E-01	1	1
..... Catchability coefficients by fishery:				
q(1) Survey CPUE Summer	1.661E-02	1.000E-02	1	1

MANAGEMENT PARAMETER ESTIMATES (NON-BOOTSTRAPPED)

Parameter	Estimate	Formula	Related quantity
MSY Maximum sustainable yield	1.002E+03	Kr/4	
K Maximum stock biomass	5.543E+04		
Bmsy Stock biomass at MSY	2.772E+04	K/2	
Fmsy Fishing mortality at MSY	3.614E-02	r/2	
F(0.1) Management benchmark	3.252E-02	0.9*Fmsy	
Y(0.1) Equilibrium yield at F(0.1)	9.916E+02	0.99*MSY	
B-ratio Ratio of B(2014) to Bmsy	7.264E-02		
F-ratio Ratio of F(2013) to Fmsy	5.076E-01		
F01-mult Ratio of F(0.1) to F(2013)	1.773E+00		
Y-ratio Proportion of MSY avail in 2014	1.400E-01	2*Br-Br^2	Ye(2014) = 1.402E+02
..... Fishing effort at MSY in units of each fishery:			
fmsy(1) Survey CPUE Summer	2.176E+00	r/2q(1)	f(0.1) = 1.958E+00

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ESTIMATED POPULATION TRAJECTORY (NON-BOOTSTRAPPED)

Obs or ID	Year	Estimated total F mort	Estimated starting biomass	Estimated average biomass	Observed total yield	Model total surplus yield	Estimated F mort production	Ratio of biomass to Fmsy	Ratio of biomass to Bmsy
1	1965	0.042	5.715E+04	5.594E+04	2.341E+03	2.341E+03	-3.729E+01	1.158E+00	2.062E+00
2	1966	0.035	5.477E+04	5.386E+04	1.909E+03	1.909E+03	1.104E+02	9.809E-01	1.976E+00
3	1967	0.030	5.297E+04	5.229E+04	1.569E+03	1.569E+03	2.145E+02	8.304E-01	1.911E+00
4	1968	0.078	5.162E+04	4.983E+04	3.871E+03	3.871E+03	3.630E+02	2.150E+00	1.862E+00
5	1969	0.052	4.811E+04	4.712E+04	2.457E+03	2.457E+03	5.103E+02	1.443E+00	1.736E+00
6	1970	0.067	4.617E+04	4.495E+04	3.002E+03	3.002E+03	6.139E+02	1.848E+00	1.666E+00
7	1971	0.048	4.378E+04	4.307E+04	2.079E+03	2.079E+03	6.939E+02	1.336E+00	1.579E+00
8	1972	0.052	4.239E+04	4.167E+04	2.168E+03	2.168E+03	7.475E+02	1.440E+00	1.529E+00
9	1973	0.132	4.097E+04	3.878E+04	5.101E+03	5.101E+03	8.399E+02	3.640E+00	1.478E+00
10	1974	0.057	3.671E+04	3.612E+04	2.068E+03	2.068E+03	9.093E+02	1.584E+00	1.324E+00
11	1975	0.058	3.555E+04	3.499E+04	2.036E+03	2.036E+03	9.324E+02	1.610E+00	1.283E+00
12	1976	0.067	3.445E+04	3.379E+04	2.258E+03	2.258E+03	9.533E+02	1.849E+00	1.243E+00
13	1977	0.029	3.314E+04	3.315E+04	9.590E+02	9.590E+02	9.631E+02	8.006E-01	1.196E+00
14	1978	0.139	3.315E+04	3.141E+04	4.379E+03	4.379E+03	9.825E+02	3.858E+00	1.196E+00
15	1979	0.044	2.975E+04	2.960E+04	1.306E+03	1.306E+03	9.969E+02	1.221E+00	1.073E+00
16	1980	0.041	2.944E+04	2.934E+04	1.203E+03	1.203E+03	9.981E+02	1.135E+00	1.062E+00
17	1981	0.042	2.924E+04	2.912E+04	1.229E+03	1.229E+03	9.990E+02	1.168E+00	1.055E+00
18	1982	0.077	2.901E+04	2.841E+04	2.184E+03	2.184E+03	1.001E+03	2.127E+00	1.047E+00
19	1983	0.084	2.782E+04	2.717E+04	2.284E+03	2.284E+03	1.001E+03	2.326E+00	1.004E+00
20	1984	0.084	2.654E+04	2.594E+04	2.189E+03	2.189E+03	9.973E+02	2.335E+00	9.576E-01
21	1985	0.120	2.535E+04	2.437E+04	2.913E+03	2.913E+03	9.865E+02	3.308E+00	9.146E-01
22	1986	0.080	2.342E+04	2.299E+04	1.836E+03	1.836E+03	9.723E+02	2.210E+00	8.451E-01
23	1987	0.160	2.256E+04	2.130E+04	3.409E+03	3.409E+03	9.472E+02	4.429E+00	8.139E-01
24	1988	0.156	2.010E+04	1.904E+04	2.966E+03	2.966E+03	9.030E+02	4.310E+00	7.251E-01
25	1989	0.071	1.803E+04	1.784E+04	1.270E+03	1.270E+03	8.742E+02	1.971E+00	6.507E-01
26	1990	0.016	1.764E+04	1.793E+04	2.890E+02	2.890E+02	8.767E+02	4.460E-01	6.364E-01
27	1991	0.016	1.823E+04	1.852E+04	2.970E+02	2.970E+02	8.913E+02	4.437E-01	6.576E-01
28	1992	0.008	1.882E+04	1.920E+04	1.540E+02	1.540E+02	9.068E+02	2.220E-01	6.790E-01
29	1993	0.013	1.957E+04	1.990E+04	2.660E+02	2.660E+02	9.218E+02	3.699E-01	7.062E-01
30	1994	0.036	2.023E+04	2.033E+04	7.250E+02	7.250E+02	9.304E+02	9.867E-01	7.298E-01
31	1995	0.029	2.043E+04	2.060E+04	6.010E+02	6.010E+02	9.355E+02	8.073E-01	7.373E-01
32	1996	0.104	2.077E+04	2.017E+04	2.106E+03	2.106E+03	9.271E+02	2.889E+00	7.493E-01
33	1997	0.198	1.959E+04	1.820E+04	3.594E+03	3.594E+03	8.825E+02	5.466E+00	7.068E-01
34	1998	0.207	1.688E+04	1.563E+04	3.239E+03	3.239E+03	8.104E+02	5.735E+00	6.090E-01
35	1999	0.076	1.445E+04	1.429E+04	1.089E+03	1.089E+03	7.664E+02	2.109E+00	5.213E-01
36	2000	0.086	1.413E+04	1.391E+04	1.194E+03	1.194E+03	7.528E+02	2.376E+00	5.097E-01

37	2001	0.080	1.369E+04	1.351E+04	1.080E+03	1.080E+03	7.385E+02	2.211E+00	4.938E-01
38	2002	0.137	1.334E+04	1.281E+04	1.756E+03	1.756E+03	7.119E+02	3.792E+00	4.815E-01
39	2003	0.597	1.230E+04	9.514E+03	5.676E+03	5.676E+03	5.668E+02	1.651E+01	4.438E-01
40	2004	0.618	7.192E+03	5.524E+03	3.411E+03	3.411E+03	3.583E+02	1.709E+01	2.595E-01
41	2005	0.340	4.139E+03	3.623E+03	1.232E+03	1.232E+03	2.446E+02	9.411E+00	1.493E-01
42	2006	0.347	3.152E+03	2.751E+03	9.550E+02	9.550E+02	1.888E+02	9.608E+00	1.137E-01
43	2007	0.201	2.385E+03	2.235E+03	4.500E+02	4.500E+02	1.550E+02	5.573E+00	8.606E-02
44	2008	0.106	2.090E+03	2.053E+03	2.180E+02	2.180E+02	1.428E+02	2.939E+00	7.542E-02
45	2009	0.039	2.015E+03	2.046E+03	8.000E+01	8.000E+01	1.424E+02	1.082E+00	7.271E-02
46	2010	0.050	2.078E+03	2.098E+03	1.050E+02	1.050E+02	1.459E+02	1.385E+00	7.496E-02
47	2011	0.185	2.119E+03	2.001E+03	3.700E+02	3.700E+02	1.394E+02	5.117E+00	7.643E-02
48	2012	0.057	1.888E+03	1.900E+03	1.080E+02	1.080E+02	1.326E+02	1.573E+00	6.811E-02
49	2013	0.018	1.913E+03	1.963E+03	3.600E+01	3.600E+01	1.368E+02	5.076E-01	6.900E-02
50	2014		2.013E+03				7.264E-02		

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RESULTS FOR DATA SERIES # 1 (NON-BOOTSTRAPPED)

Survey CPUE Summer

Data type CC: CPUE-catch series

Series weight: 1.000

Obs	Year	CPUE	Estimated CPUE	Estim F	Observed yield	Model yield	Resid in log scale	Resid in yield	
1	1965	*	9.290E+02	0.0418	2.341E+03	2.341E+03	0.00000	0.000E+00	
2	1966	*	8.945E+02	0.0354	1.909E+03	1.909E+03	0.00000	0.000E+00	
3	1967	*	8.684E+02	0.0300	1.569E+03	1.569E+03	0.00000	0.000E+00	
4	1968	*	8.275E+02	0.0777	3.871E+03	3.871E+03	0.00000	0.000E+00	
5	1969	*	7.826E+02	0.0521	2.457E+03	2.457E+03	0.00000	0.000E+00	
6	1970	*	7.465E+02	0.0668	3.002E+03	3.002E+03	0.00000	0.000E+00	
7	1971	*	7.154E+02	0.0483	2.079E+03	2.079E+03	0.00000	0.000E+00	
8	1972	*	6.921E+02	0.0520	2.168E+03	2.168E+03	0.00000	0.000E+00	
9	1973	*	6.441E+02	0.1315	5.101E+03	5.101E+03	0.00000	0.000E+00	
10	1974	*	5.999E+02	0.0572	2.068E+03	2.068E+03	0.00000	0.000E+00	
11	1975	*	5.812E+02	0.0582	2.036E+03	2.036E+03	0.00000	0.000E+00	
12	1976	*	5.611E+02	0.0668	2.258E+03	2.258E+03	0.00000	0.000E+00	
13	1977	*	5.505E+02	0.0289	9.590E+02	9.590E+02	0.00000	0.000E+00	
14	1978	*	5.216E+02	0.1394	4.379E+03	4.379E+03	0.00000	0.000E+00	
15	1979	*	4.915E+02	0.0441	1.306E+03	1.306E+03	0.00000	0.000E+00	
16	1980	*	4.873E+02	0.0410	1.203E+03	1.203E+03	0.00000	0.000E+00	
17	1981	*	4.836E+02	0.0422	1.229E+03	1.229E+03	0.00000	0.000E+00	
18	1982	*	4.718E+02	0.0769	2.184E+03	2.184E+03	0.00000	0.000E+00	
19	1983	*	4.513E+02	0.0841	2.284E+03	2.284E+03	0.00000	0.000E+00	
20	1984	*	4.308E+02	0.0844	2.189E+03	2.189E+03	0.00000	0.000E+00	
21	1985	*	4.047E+02	0.1195	2.913E+03	2.913E+03	0.00000	0.000E+00	
22	1986	*	3.818E+02	0.0799	1.836E+03	1.836E+03	0.00000	0.000E+00	
23	1987	*	3.537E+02	0.1601	3.409E+03	3.409E+03	0.00000	0.000E+00	
24	1988	*	3.163E+02	0.1558	2.966E+03	2.966E+03	0.00000	0.000E+00	
25	1989	*	2.962E+02	0.0712	1.270E+03	1.270E+03	0.00000	0.000E+00	
26	1990	*	2.978E+02	0.0161	2.890E+02	2.890E+02	0.00000	0.000E+00	
27	1991	*	3.076E+02	0.0160	2.970E+02	2.970E+02	0.00000	0.000E+00	
28	1992	*	3.188E+02	0.0080	1.540E+02	1.540E+02	0.00000	0.000E+00	
29	1993	*	3.305E+02	0.0134	2.660E+02	2.660E+02	0.00000	0.000E+00	
30	1994	*	3.377E+02	0.0357	7.250E+02	7.250E+02	0.00000	0.000E+00	
31	1995	*	3.422E+02	0.0292	6.010E+02	6.010E+02	0.00000	0.000E+00	
32	1996		3.105E+02	3.350E+02	0.1044	2.106E+03	2.106E+03	0.07594	0.000E+00
33	1997		4.492E+02	3.022E+02	0.1975	3.594E+03	3.594E+03	-0.39632	0.000E+00
34	1998		3.871E+02	2.596E+02	0.2072	3.239E+03	3.239E+03	-0.39959	0.000E+00
35	1999		1.495E+02	2.373E+02	0.0762	1.089E+03	1.089E+03	0.46170	0.000E+00

36	2000	1.199E+02	2.309E+02	0.0859	1.194E+03	1.194E+03	0.65544	0.000E+00
37	2001	2.626E+02	2.244E+02	0.0799	1.080E+03	1.080E+03	-0.15696	0.000E+00
38	2002	3.472E+02	2.128E+02	0.1370	1.756E+03	1.756E+03	-0.48934	0.000E+00
39	2003	1.618E+02	1.580E+02	0.5966	5.676E+03	5.676E+03	-0.02354	0.000E+00
40	2004	7.304E+01	9.173E+01	0.6175	3.411E+03	3.411E+03	0.22789	0.000E+00
41	2005	6.188E+01	6.016E+01	0.3401	1.232E+03	1.232E+03	-0.02812	0.000E+00
42	2006	2.927E+01	4.568E+01	0.3472	9.550E+02	9.550E+02	0.44501	0.000E+00
43	2007	3.331E+01	3.711E+01	0.2014	4.500E+02	4.500E+02	0.10799	0.000E+00
44	2008	3.117E+01	3.409E+01	0.1062	2.180E+02	2.180E+02	0.08938	0.000E+00
45	2009	4.927E+01	3.398E+01	0.0391	8.000E+01	8.000E+01	-0.37137	0.000E+00
46	2010	4.164E+01	3.484E+01	0.0500	1.050E+02	1.050E+02	-0.17822	0.000E+00
47	2011	5.854E+01	3.323E+01	0.1849	3.700E+02	3.700E+02	-0.56623	0.000E+00
48	2012	3.425E+01	3.156E+01	0.0568	1.080E+02	1.080E+02	-0.08196	0.000E+00
49	2013	1.737E+01	3.259E+01	0.0183	3.600E+01	3.600E+01	0.62935	0.000E+00

* Asterisk indicates missing value(s).

Table 3.3. Faroe Bank (sub-division Vb2) cod. Surplus production model output using the spring index.

Faroe Bank Cod RV

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04 Apr 2014 at 13:42.20

ASPIC -- A Surplus-Production Model Including Covariates (Ver. 3.82)

FIT Mode

Author: Michael H. Prager; NOAA/NMFS/S.E. Fisheries Science Center

ASPIC User's Manual

101 Pivers Island Road; Beaufort, North Carolina 28516 USA

is available gratis

from the author.

Ref: Prager, M. H. 1994. A suite of extensions to a nonequilibrium surplus-production model. Fishery Bulletin 92: 374-389.

CONTROL PARAMETERS USED (FROM INPUT FILE)

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-----
Number of years analyzed:      49      Number of bootstrap trials:      0
Number of data series:        1      Lower bound on MSY:              5.000E+02
Objective function computed:   in effort  Upper bound on MSY:              1.000E+09
Relative conv. criterion (simplex): 1.000E-08  Lower bound on r:                7.000E-02
Relative conv. criterion (restart): 3.000E-08  Upper bound on r:                2.500E+00
Relative conv. criterion (effort): 1.000E-04  Random number seed:              2010417
Maximum F allowed in fitting:   8.000    Monte Carlo search mode, trials: 1 10000

```

PROGRAM STATUS INFORMATION (NON-BOOTSTRAPPED ANALYSIS)

code 0

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Normal convergence.

```

GOODNESS-OF-FIT AND WEIGHTING FOR NON-BOOTSTRAPPED ANALYSIS

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                Weighted   Weighted   Current   Suggested   R-squared
Loss component number and title      SSE   N      MSE   weight   weight   in CPUE

Loss(-1) SSE in yield                0.000E+00
Loss(0) Penalty for B1R > 2          2.825E-02   1     N/A   1.000E-01   N/A
Loss(1) Survey CPUE Spring          1.822E+01  28   7.009E-01  1.000E+00  1.000E+00  0.199
TOTAL OBJECTIVE FUNCTION:                1.82514209E+01

```

NOTE: B1-ratio constraint term contributing to loss. Sensitivity analysis advised.

```

Number of restarts required for convergence:      16
Est. B-ratio coverage index (0 worst, 2 best):    1.9118      < These two measures are defined in Prager
Est. B-ratio nearness index (0 worst, 1 best):    1.0000      < et al. (1996), Trans. A.F.S. 125:729

```

MODEL PARAMETER ESTIMATES (NON-BOOTSTRAPPED)

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Parameter	Estimate	Starting guess	Estimated	User guess
B1R Starting biomass ratio, year 1965	3.403E+00	1.000E+00	1	1
MSY Maximum sustainable yield	2.164E+03	3.000E+03	1	1
r Intrinsic rate of increase	6.203E-01	8.000E-01	1	1
..... Catchability coefficients by fishery:				
q(1) Survey CPUE Spring	3.942E-02	1.000E-02	1	1

MANAGEMENT PARAMETER ESTIMATES (NON-BOOTSTRAPPED)

Parameter	Estimate	Formula	Related quantity
MSY Maximum sustainable yield	2.164E+03		$Kr/4$
K Maximum stock biomass	1.396E+04		
Bmsy Stock biomass at MSY	6.978E+03		$K/2$
Fmsy Fishing mortality at MSY	3.101E-01		$r/2$
F(0.1) Management benchmark	2.791E-01		$0.9 \cdot Fmsy$
Y(0.1) Equilibrium yield at F(0.1)	2.142E+03		$0.99 \cdot MSY$
B-ratio Ratio of B(2014) to Bmsy	9.742E-01		
F-ratio Ratio of F(2013) to Fmsy	2.016E-02		
F01-mult Ratio of F(0.1) to F(2013)	4.464E+01		
Y-ratio Proportion of MSY avail in 2014	9.993E-01	$2 \cdot Br - Br^2$	$Ye(2014) = 2.163E+03$
..... Fishing effort at MSY in units of each fishery:			
fmsy(1) Survey CPUE Spring	7.867E+00	$r/2q(1)$	$f(0.1) = 7.080E+00$

Faroe Bank Cod RV

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ESTIMATED POPULATION TRAJECTORY (NON-BOOTSTRAPPED)

Obs or ID	Year	Estimated total F mort	Estimated starting biomass	Estimated average biomass	Observed total yield	Model total surplus yield	Estimated F mort production	Ratio of biomass to Fmsy	Ratio of biomass to Bmsy
1	1965	0.121	2.375E+04	1.941E+04	2.341E+03	2.341E+03	-4.885E+03	3.890E-01	3.403E+00
2	1966	0.127	1.652E+04	1.502E+04	1.909E+03	1.909E+03	-7.323E+02	4.099E-01	2.367E+00
3	1967	0.119	1.388E+04	1.324E+04	1.569E+03	1.569E+03	4.174E+02	3.822E-01	1.989E+00
4	1968	0.343	1.273E+04	1.129E+04	3.871E+03	3.871E+03	1.313E+03	1.105E+00	1.824E+00
5	1969	0.250	1.017E+04	9.815E+03	2.457E+03	2.457E+03	1.805E+03	8.072E-01	1.457E+00
6	1970	0.335	9.516E+03	8.964E+03	3.002E+03	3.002E+03	1.985E+03	1.080E+00	1.364E+00
7	1971	0.245	8.499E+03	8.490E+03	2.079E+03	2.079E+03	2.062E+03	7.896E-01	1.218E+00
8	1972	0.257	8.482E+03	8.430E+03	2.168E+03	2.168E+03	2.070E+03	8.292E-01	1.216E+00
9	1973	0.759	8.385E+03	6.717E+03	5.101E+03	5.101E+03	2.129E+03	2.449E+00	1.202E+00
10	1974	0.383	5.413E+03	5.406E+03	2.068E+03	2.068E+03	2.054E+03	1.234E+00	7.757E-01
11	1975	0.376	5.399E+03	5.409E+03	2.036E+03	2.036E+03	2.055E+03	1.214E+00	7.737E-01
12	1976	0.426	5.418E+03	5.303E+03	2.258E+03	2.258E+03	2.039E+03	1.373E+00	7.764E-01
13	1977	0.166	5.199E+03	5.772E+03	9.590E+02	9.590E+02	2.095E+03	5.357E-01	7.450E-01
14	1978	0.878	6.335E+03	4.988E+03	4.379E+03	4.379E+03	1.967E+03	2.830E+00	9.078E-01
15	1979	0.312	3.923E+03	4.180E+03	1.306E+03	1.306E+03	1.815E+03	1.007E+00	5.621E-01
16	1980	0.250	4.432E+03	4.810E+03	1.203E+03	1.203E+03	1.953E+03	8.064E-01	6.351E-01
17	1981	0.219	5.182E+03	5.614E+03	1.229E+03	1.229E+03	2.079E+03	7.059E-01	7.426E-01
18	1982	0.364	6.032E+03	5.999E+03	2.184E+03	2.184E+03	2.122E+03	1.174E+00	8.644E-01
19	1983	0.389	5.969E+03	5.878E+03	2.284E+03	2.284E+03	2.110E+03	1.253E+00	8.554E-01
20	1984	0.381	5.795E+03	5.747E+03	2.189E+03	2.189E+03	2.097E+03	1.228E+00	8.305E-01
21	1985	0.557	5.703E+03	5.230E+03	2.913E+03	2.913E+03	2.025E+03	1.796E+00	8.173E-01
22	1986	0.376	4.815E+03	4.884E+03	1.836E+03	1.836E+03	1.969E+03	1.212E+00	6.901E-01
23	1987	0.841	4.949E+03	4.052E+03	3.409E+03	3.409E+03	1.774E+03	2.713E+00	7.092E-01
24	1988	1.296	3.314E+03	2.288E+03	2.966E+03	2.966E+03	1.175E+03	4.180E+00	4.749E-01
25	1989	1.058	1.522E+03	1.200E+03	1.270E+03	1.270E+03	6.790E+02	3.413E+00	2.181E-01
26	1990	0.265	9.312E+02	1.091E+03	2.890E+02	2.890E+02	6.235E+02	8.539E-01	1.334E-01
27	1991	0.195	1.266E+03	1.525E+03	2.970E+02	2.970E+02	8.413E+02	6.281E-01	1.814E-01
28	1992	0.067	1.810E+03	2.296E+03	1.540E+02	1.540E+02	1.186E+03	2.163E-01	2.594E-01
29	1993	0.076	2.842E+03	3.491E+03	2.660E+02	2.660E+02	1.617E+03	2.457E-01	4.073E-01
30	1994	0.151	4.193E+03	4.800E+03	7.250E+02	7.250E+02	1.948E+03	4.870E-01	6.009E-01
31	1995	0.097	5.416E+03	6.182E+03	6.010E+02	6.010E+02	2.127E+03	3.135E-01	7.761E-01
32	1996	0.302	6.942E+03	6.972E+03	2.106E+03	2.106E+03	2.164E+03	9.739E-01	9.949E-01
33	1997	0.579	7.000E+03	6.206E+03	3.594E+03	3.594E+03	2.130E+03	1.867E+00	1.003E+00
34	1998	0.669	5.536E+03	4.843E+03	3.239E+03	3.239E+03	1.956E+03	2.156E+00	7.933E-01
35	1999	0.233	4.252E+03	4.673E+03	1.089E+03	1.089E+03	1.925E+03	7.515E-01	6.094E-01
36	2000	0.216	5.089E+03	5.532E+03	1.194E+03	1.194E+03	2.068E+03	6.959E-01	7.293E-01

37	2001	0.166	5.963E+03	6.509E+03	1.080E+03	1.080E+03	2.150E+03	5.350E-01	8.546E-01
38	2002	0.242	7.033E+03	7.244E+03	1.756E+03	1.756E+03	2.160E+03	7.816E-01	1.008E+00
39	2003	1.068	7.438E+03	5.316E+03	5.676E+03	5.676E+03	1.993E+03	3.443E+00	1.066E+00
40	2004	1.360	3.754E+03	2.508E+03	3.411E+03	3.411E+03	1.259E+03	4.386E+00	5.380E-01
41	2005	0.915	1.602E+03	1.347E+03	1.232E+03	1.232E+03	7.540E+02	2.949E+00	2.296E-01
42	2006	1.081	1.124E+03	8.834E+02	9.550E+02	9.550E+02	5.126E+02	3.486E+00	1.611E-01
43	2007	0.695	6.820E+02	6.479E+02	4.500E+02	4.500E+02	3.832E+02	2.240E+00	9.774E-02
44	2008	0.306	6.152E+02	7.113E+02	2.180E+02	2.180E+02	4.186E+02	9.882E-01	8.816E-02
45	2009	0.076	8.158E+02	1.059E+03	8.000E+01	8.000E+01	6.061E+02	2.436E-01	1.169E-01
46	2010	0.061	1.342E+03	1.730E+03	1.050E+02	1.050E+02	9.375E+02	1.957E-01	1.923E-01
47	2011	0.141	2.174E+03	2.630E+03	3.700E+02	3.700E+02	1.321E+03	4.536E-01	3.116E-01
48	2012	0.028	3.125E+03	3.905E+03	1.080E+02	1.080E+02	1.735E+03	8.917E-02	4.478E-01
49	2013	0.006	4.752E+03	5.757E+03	3.600E+01	3.600E+01	2.082E+03	2.016E-02	6.809E-01
50	2014		6.798E+03				9.742E-01		

Faroe Bank Cod RV

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RESULTS FOR DATA SERIES # 1 (NON-BOOTSTRAPPED)

Survey CPUE Spring

Data type CC: CPUE-catch series

Series weight: 1.000

Obs	Year	Observed CPUE	Estimated CPUE	Estim F	Observed yield	Model yield	Resid in log scale	Resid in yield	
1	1965	*	7.650E+02	0.1206	2.341E+03	2.341E+03	0.00000	0.000E+00	
2	1966	*	5.919E+02	0.1271	1.909E+03	1.909E+03	0.00000	0.000E+00	
3	1967	*	5.219E+02	0.1185	1.569E+03	1.569E+03	0.00000	0.000E+00	
4	1968	*	4.452E+02	0.3428	3.871E+03	3.871E+03	0.00000	0.000E+00	
5	1969	*	3.869E+02	0.2503	2.457E+03	2.457E+03	0.00000	0.000E+00	
6	1970	*	3.534E+02	0.3349	3.002E+03	3.002E+03	0.00000	0.000E+00	
7	1971	*	3.347E+02	0.2449	2.079E+03	2.079E+03	0.00000	0.000E+00	
8	1972	*	3.323E+02	0.2572	2.168E+03	2.168E+03	0.00000	0.000E+00	
9	1973	*	2.648E+02	0.7594	5.101E+03	5.101E+03	0.00000	0.000E+00	
10	1974	*	2.131E+02	0.3826	2.068E+03	2.068E+03	0.00000	0.000E+00	
11	1975	*	2.132E+02	0.3764	2.036E+03	2.036E+03	0.00000	0.000E+00	
12	1976	*	2.091E+02	0.4258	2.258E+03	2.258E+03	0.00000	0.000E+00	
13	1977	*	2.276E+02	0.1661	9.590E+02	9.590E+02	0.00000	0.000E+00	
14	1978	*	1.967E+02	0.8778	4.379E+03	4.379E+03	0.00000	0.000E+00	
15	1979	*	1.648E+02	0.3125	1.306E+03	1.306E+03	0.00000	0.000E+00	
16	1980	*	1.896E+02	0.2501	1.203E+03	1.203E+03	0.00000	0.000E+00	
17	1981	*	2.213E+02	0.2189	1.229E+03	1.229E+03	0.00000	0.000E+00	
18	1982	*	2.365E+02	0.3641	2.184E+03	2.184E+03	0.00000	0.000E+00	
19	1983		7.899E+01	2.317E+02	0.3886	2.284E+03	2.284E+03	1.07622	0.000E+00
20	1984		1.752E+02	2.266E+02	0.3809	2.189E+03	2.189E+03	0.25703	0.000E+00
21	1985		1.735E+02	2.062E+02	0.5570	2.913E+03	2.913E+03	0.17264	0.000E+00
22	1986		2.661E+02	1.925E+02	0.3759	1.836E+03	1.836E+03	-0.32352	0.000E+00
23	1987		1.640E+02	1.597E+02	0.8413	3.409E+03	3.409E+03	-0.02653	0.000E+00
24	1988		7.311E+01	9.019E+01	1.2965	2.966E+03	2.966E+03	0.20994	0.000E+00
25	1989		3.655E+01	4.730E+01	1.0584	1.270E+03	1.270E+03	0.25791	0.000E+00
26	1990		2.324E+01	4.302E+01	0.2648	2.890E+02	2.890E+02	0.61577	0.000E+00
27	1991		5.097E+01	6.011E+01	0.1948	2.970E+02	2.970E+02	0.16492	0.000E+00
28	1992		2.843E+01	9.052E+01	0.0671	1.540E+02	1.540E+02	1.15809	0.000E+00
29	1993		2.576E+01	1.376E+02	0.0762	2.660E+02	2.660E+02	1.67576	0.000E+00
30	1994		8.674E+01	1.892E+02	0.1510	7.250E+02	7.250E+02	0.78003	0.000E+00
31	1995		9.017E+01	2.437E+02	0.0972	6.010E+02	6.010E+02	0.99430	0.000E+00
32	1996	*	2.749E+02	0.3020	2.106E+03	2.106E+03	0.00000	0.000E+00	
33	1997		5.934E+02	2.446E+02	0.5791	3.594E+03	3.594E+03	-0.88609	0.000E+00
34	1998		6.074E+02	1.909E+02	0.6688	3.239E+03	3.239E+03	-1.15732	0.000E+00
35	1999		4.210E+02	1.842E+02	0.2331	1.089E+03	1.089E+03	-0.82660	0.000E+00
36	2000		3.645E+02	2.181E+02	0.2158	1.194E+03	1.194E+03	-0.51363	0.000E+00

37	2001	1.022E+03	2.566E+02	0.1659	1.080E+03	1.080E+03	-1.38228	0.000E+00
38	2002	4.439E+02	2.856E+02	0.2424	1.756E+03	1.756E+03	-0.44101	0.000E+00
39	2003	8.671E+02	2.096E+02	1.0677	5.676E+03	5.676E+03	-1.42009	0.000E+00
40	2004	*	9.886E+01	1.3602	3.411E+03	3.411E+03	0.00000	0.000E+00
41	2005	*	5.310E+01	0.9146	1.232E+03	1.232E+03	0.00000	0.000E+00
42	2006	6.051E+01	3.483E+01	1.0810	9.550E+02	9.550E+02	-0.55242	0.000E+00
43	2007	5.206E+01	2.554E+01	0.6946	4.500E+02	4.500E+02	-0.71213	0.000E+00
44	2008	6.402E+01	2.804E+01	0.3065	2.180E+02	2.180E+02	-0.82554	0.000E+00
45	2009	5.550E+01	4.175E+01	0.0755	8.000E+01	8.000E+01	-0.28463	0.000E+00
46	2010	5.808E+01	6.820E+01	0.0607	1.050E+02	1.050E+02	0.16063	0.000E+00
47	2011	1.224E+02	1.037E+02	0.1407	3.700E+02	3.700E+02	-0.16591	0.000E+00
48	2012	4.454E+01	1.539E+02	0.0277	1.080E+02	1.080E+02	1.24021	0.000E+00
49	2013	1.390E+02	2.270E+02	0.0063	3.600E+01	3.600E+01	0.49046	0.000E+00

* Asterisk indicates missing value(s).

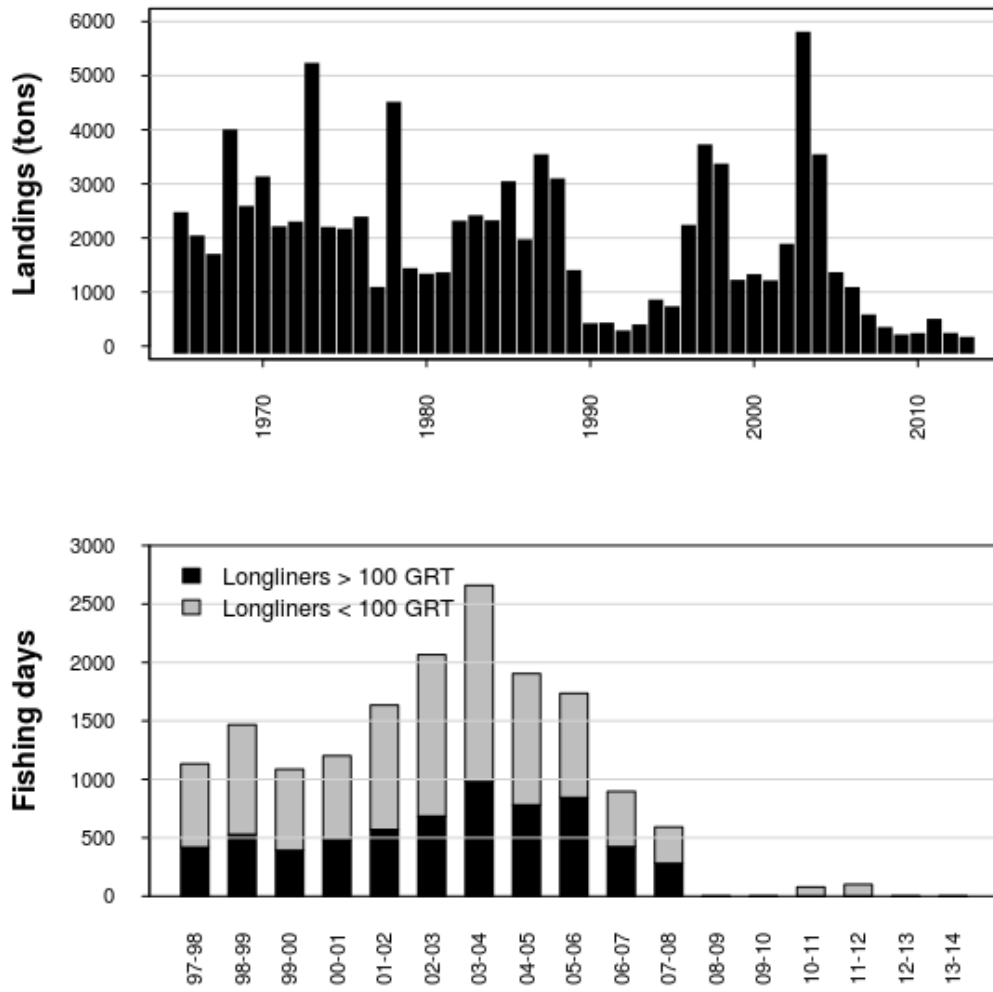


Figure 3.1. Faroe Bank (sub-division Vb2) cod. Reported landings 1965-2013. Since 1992 only catches from Faroese and Norwegian vessels are considered to be taken on Faroe Bank. Lower plot: fishing days (fishing year) 1997-2014 for long line gear type in the Faroe Bank.

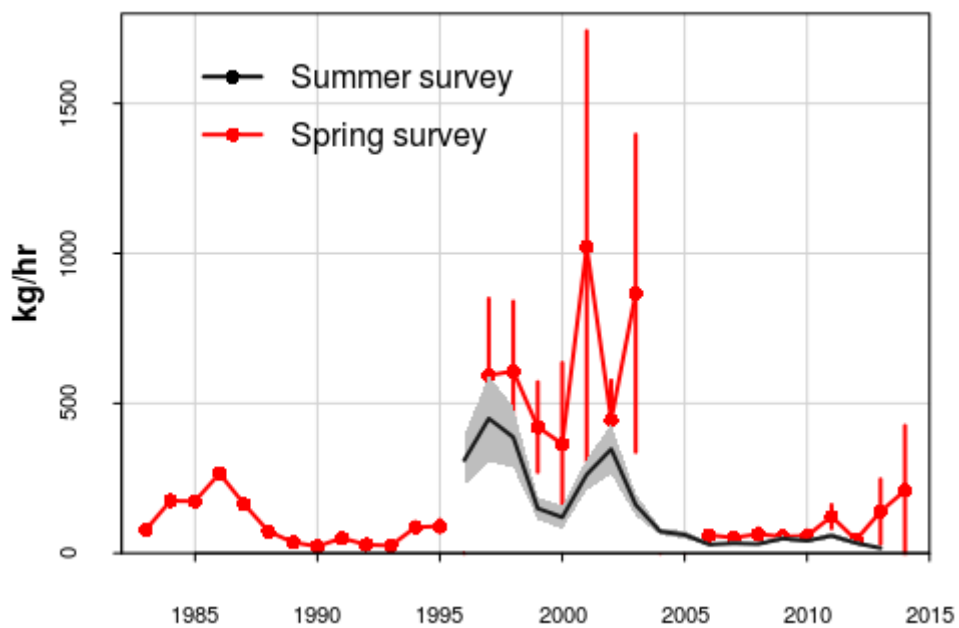


Figure 3.2. Faroe Bank (subdivision Vb2) cod. Catch per unit of effort in the spring groundfish survey (1983-2014) and summer survey (1996-2013). Vertical bars and shaded areas show the standard error in the estimation of indexes.

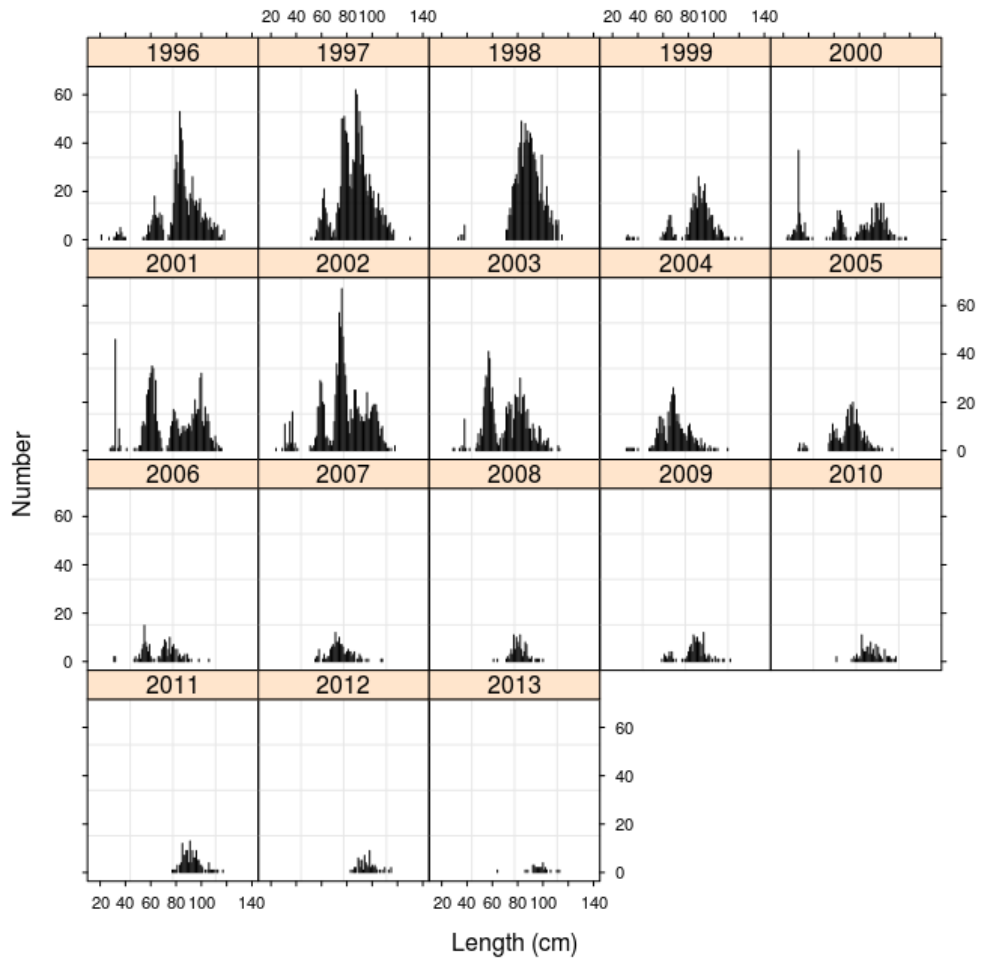


Figure 3.3. Faroe Bank (sub-division Vb2) cod. Length distributions in summer survey (1996-2012)

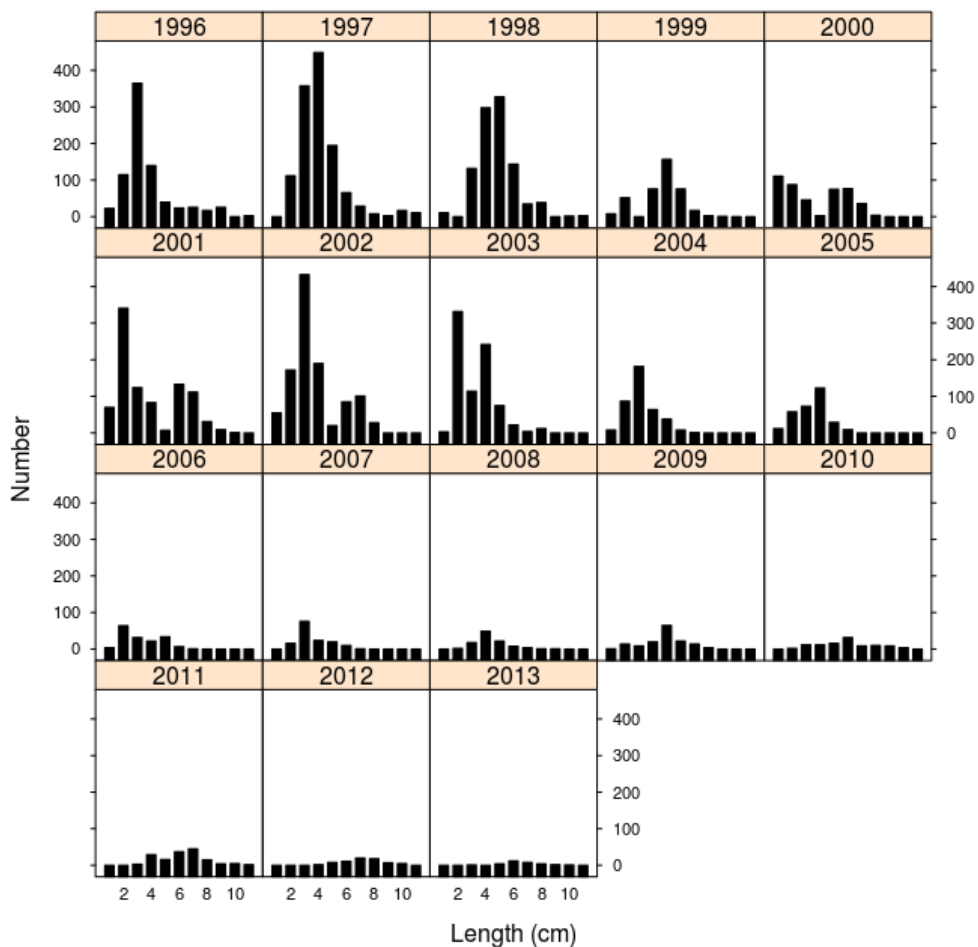


Figure 3.4. Faroe Bank (sub-division Vb2) cod. Age-disaggregated indices in the summer survey (ages 1-11)(1996-2013)

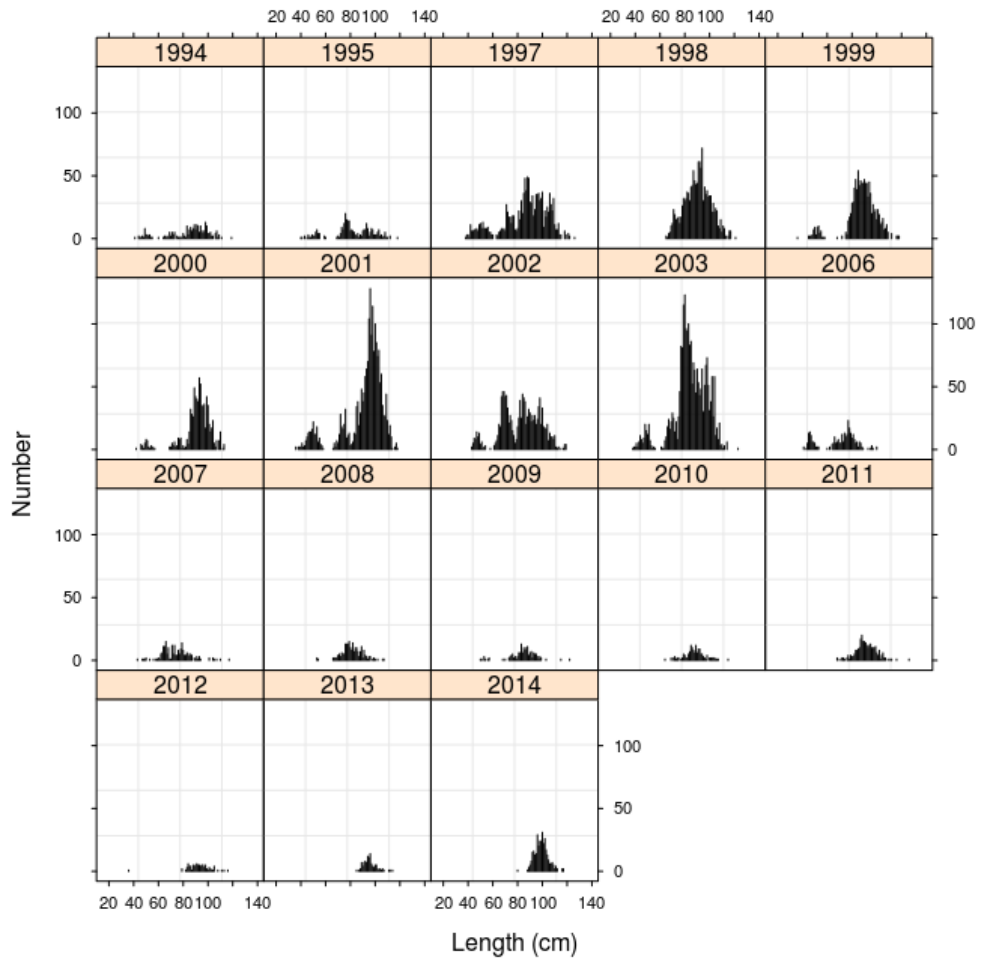


Figure 3.5. Faroe Bank (sub-division Vb2) cod. Length distributions in spring survey (1994-2014). No surveys were conducted in 1996, 2004 and 2005.

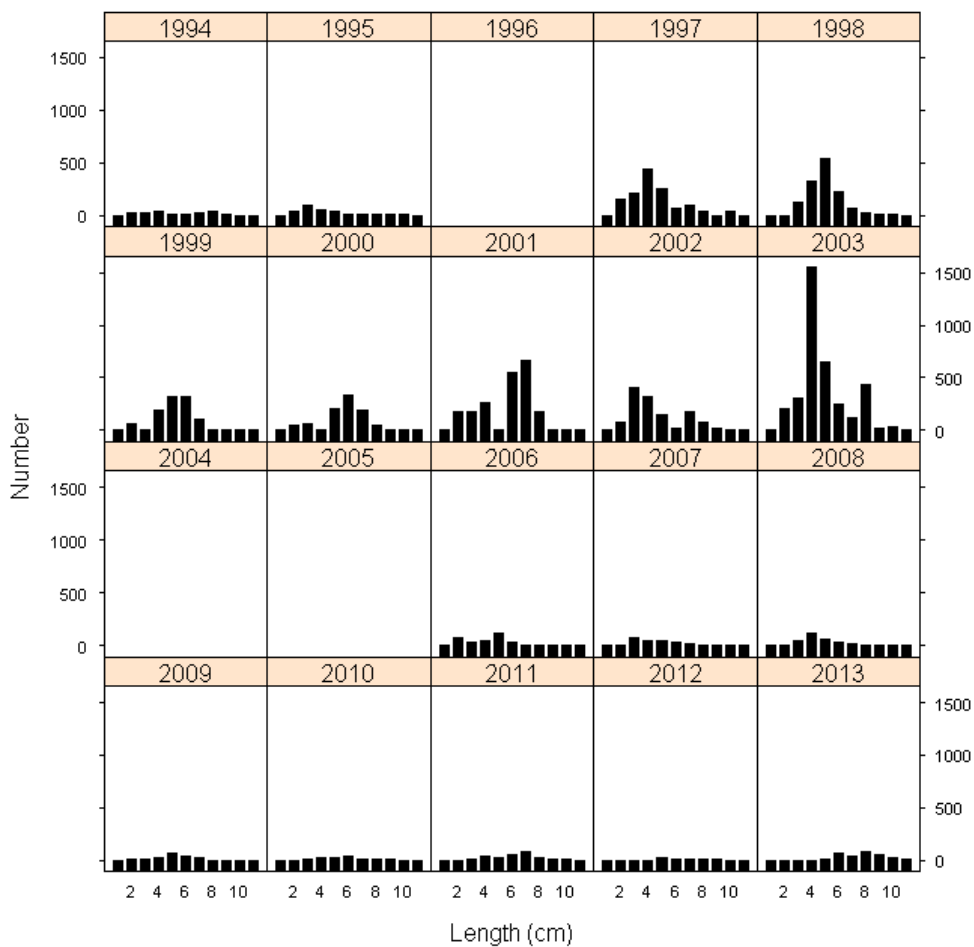


Figure 3.6. Faroe Bank (sub-division Vb2) cod. Age-disaggregated indices in the spring survey (ages 1-11) (1994-2013). No surveys were conducted in 1996, 2004 and 2005.

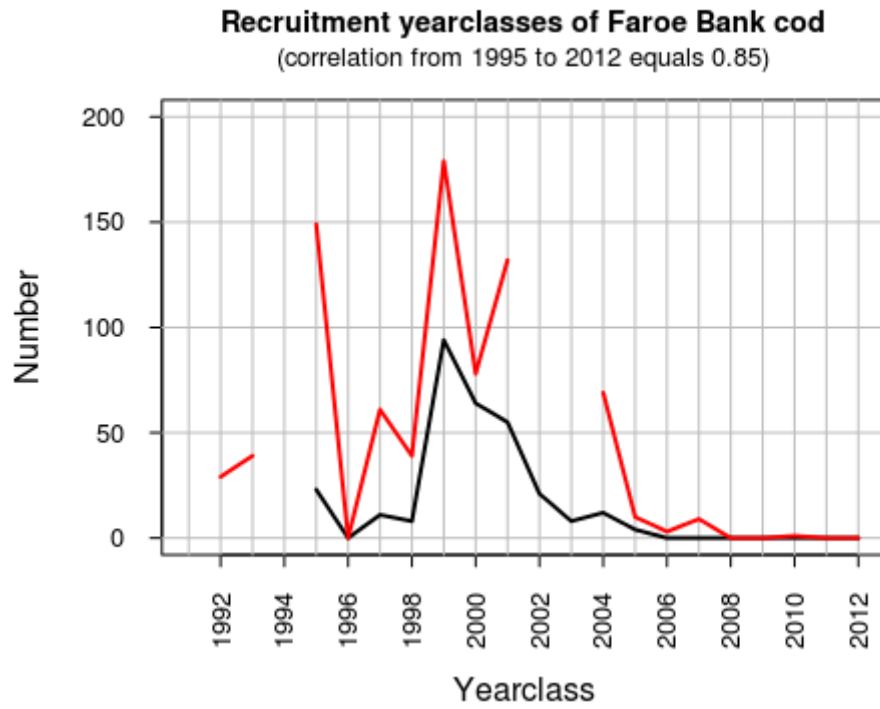


Figure 3.7. Faroe Bank (sub-division Vb2) cod. Correlation between recruitment year classes in both survey indices.

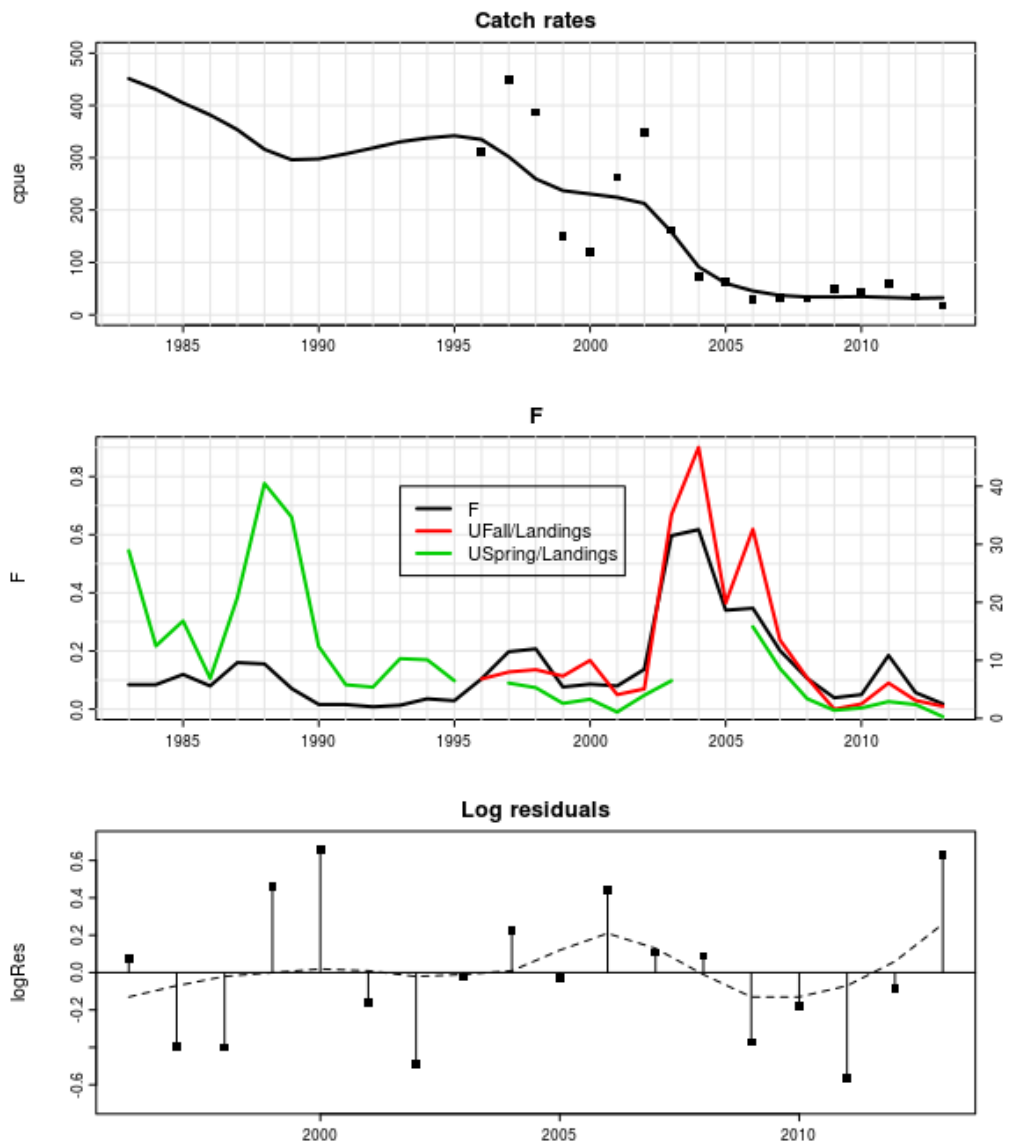


Figure 3.8. Results from the surplus production model using the summer index. Observed (points) and expected catch rates (kg/hour) (top panel). Estimated fishing mortality (black line) and exploitation ratios (ratio of spring index to landings)(green line) (ratio of summer index to landings)(red line)(middle panel). Model residuals in log scale (bottom panel)

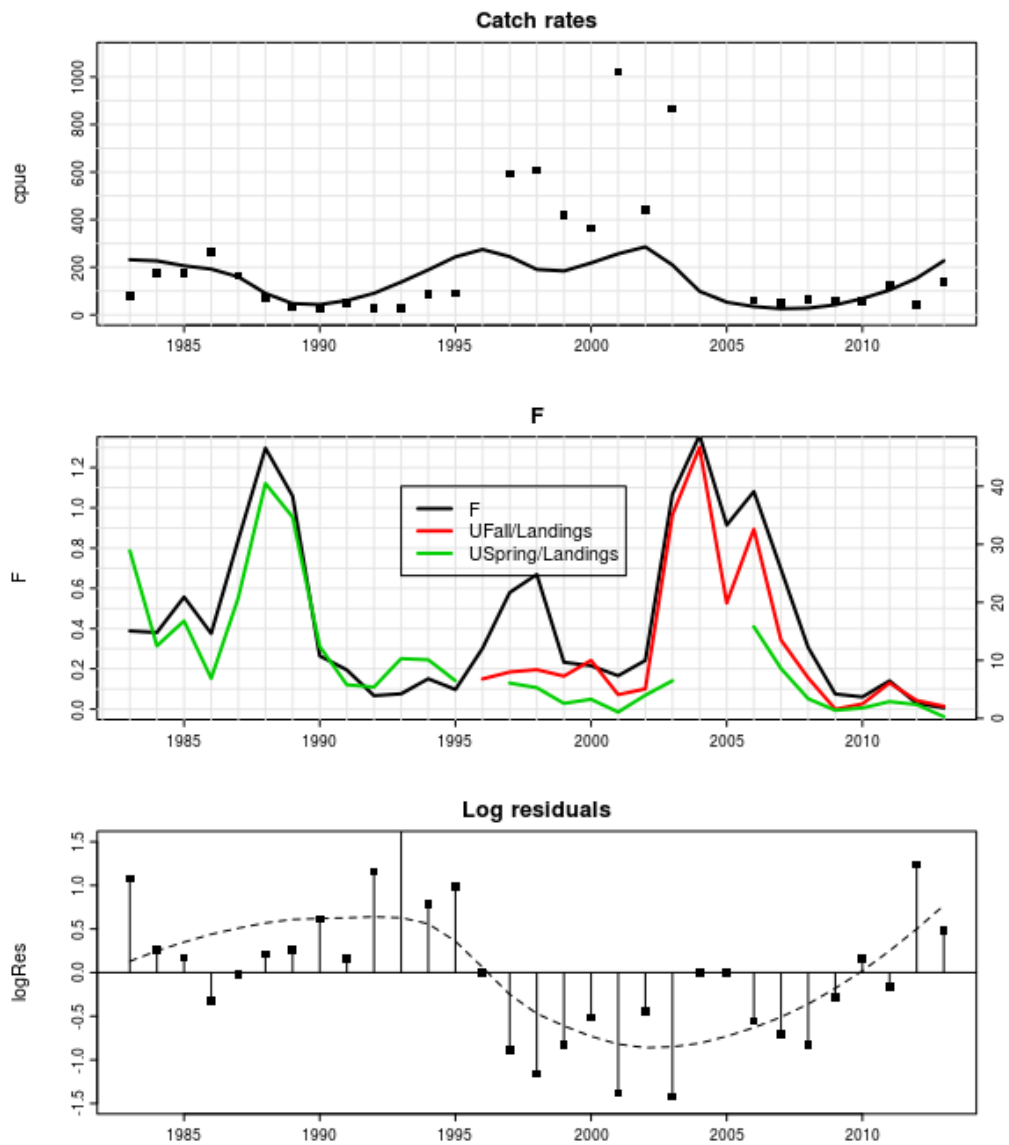


Figure 3.9. Results from the surplus production model using the spring index. Observed (points) and expected catch rates (kg/hour) (top panel). Estimated fishing mortality (black line) and exploitation ratios (ratio of spring index to landings)(green line) (ratio of summer index to landings)(red line)(middle panel). Model residuals in log scale (bottom panel)