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Northwest Atlantic Fisheries Organization

Serial No. N4580 **NAFO SCR Doc. 01/190**

SCIENTIFIC COUNCIL MEETING – November 2001

Sensitivity Analyses of Virtual Population Analysis of the Stock of Division 3M Shrimp Using XSA and ADAPT

by

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Abstract

A Virtual Population Analysis (VPA) was performed on the stock of northern shrimp in NAFO Division 3M. This analysis extends previous work, which applied extended survivors analysis (XSA) to calibrate the VPA based on catch at age data from 1993 through 1999. In the present analysis, several formulations of the VPA were calibrated using XSA and ADAPT methods applied to the catch at age from 1993 through 2000. Results suggest that both VPA calibration methods produce similar trends in fishing mortality and stock biomass, although the magnitude of these estimates differ.

Introduction

In 2000, a Virtual Population Analysis (VPA) was conducted on the stock of northern shrimp in Div. 3M (Ratz and Skuladottir, 2000). At that time, Extended Survivors Analysis (XSA) was employed to calibrate the VPA based on catch at age data from 1993 through 1999. Results suggested that fishing mortality peaked and biomass declined in 1996, coincident with a substantial increase in landings.

The present analysis extends the previous work by incorporating an additional set of tuning indices derived from the EU research vessel survey in Division 3M (Skuladottir, 2001) combined with updated indices from the Faeroese 3M survey (Nicolajsen, 2001) and recalculated CPUE indices at age from the Icelandic commercial shrimp fishery (Skuladottir, 2001). In addition to the XSA calibration method (Shepherd, 1999), the present analysis employs the ADAPT method (Gavaris, 1988) to calibrate the VPA.

The two methods employ different approaches to estimate survivors in the terminal year of each cohort analyzed by the VPA. XSA focuses on the relationship between CPUE and population abundance taking into account year-class strength at the youngest ages. Within this context, XSA estimates fleet-specific catchability coefficients (q), which relate population numbers at age to indices of abundance at age. ADAPT employs an objective function which minimizes the deviation between observed and predicted indices of abundance. The latter are derived from VPA estimates population numbers at age and age-specific estimates of q.

Methods

Sensitivity of the VPA was evaluated using XSA and ADAPT. Three tuning fleets were available: Icelandic commercial CPUE at age in numbers, Faeroese survey population estimates, and EU survey indices of abundance at age. Various combinations of fleets and ages were evaluated. The catch-at-age was derived by applying Canadian length frequency samples from 1993-1995, and Canadian, Icelandic and Greenlandic samples from 1994-2000 as described by Ratz and Skuladottir (2000). The XSA settings and formulation were as described by Ratz and Skuladittir (2000). Natural mortality was set as M= 0.2.The ADAPT formulation was specified to match the XSA formulation as closely as possible.

Four formulations of the XSA were run to explore sensitivity of the model to F shrinkage and various combinations of input data. The formulation which produced the most consistent results was then employed in the ADAPT analysis for evaluation of model comparability.

Results

XSA Results. Several XSA formulations were examined. The initial XSA analysis was run without F shrinkage. The remaining analyses applied F shrinkage to all but the youngest ages. The residuals on age 2 from the Icelandic commercial CPUE were extremely high and this series was down-weighted in the estimation of survivors at age 2. Subsequent analyses were run without age 2 in the commercial CPUE tuning series.

In each analysis, each tuning fleet estimated survivors and F at age at similar magnitudes whether or not F shrinkage was applied. The analysis, which included Icelandic commercial CPUE ages 3-6, Faeroes survey ages 2-4 and EU survey ages 2-6 was judged to be the preferred formulation. An additional analysis, which used the Faeroese small mesh bag results (Nicolajsen and Brynjolfsson, 2001) as the age 2 tuning index, yielded results similar to the preferred formulation.

Diagnostics from the preferred XSA analysis are presented in Table 1, and summary VPA results are displayed in Fig. 1. Average (ages 3-6) fishing mortality (F) is estimated to have increased from 1993 to a peak in 1996. This was followed by a decline and subsequent increase through 2000. Total stock biomass declined from an initial high level in 1993 to a minimum in 1996, followed by a subsequent increase through 1999 and 2000. The 1993 and 1996 year-classes were estimated to be the largest in the series, followed by the 1997 year-class. The 1991 and 1998 year-classes were the lowest

ADAPT Results. Results from the ADAPT calibration are presented in Tables 2 and 3, and Fig. 2. Trends in population biomass and fully recruited fishing mortality are similar to those derived from the XSA analysis. However, estimates of fishing mortality are consistently higher than those obtained from the XSA analysis, particularly at ages 5 and 6 and in the most recent years. Trends in recruitment are also similar, indicating strong 1993 and 1996 year-classes and weak 1991 and 1998 year-classes.

Discussion

Although trends in the estimates of F, biomass and recruitment derived from XSA and ADAPT calibration methods are generally similar, differences in magnitude persist throughout the time series, and are most noticeable in the most recent years. At present it is not possible to determine the causes or to reconcile these differences. There do not appear to be any substantial patterns in residuals from either model (Table 1, Fig. 3-6), although the coefficients of variation on the parameter estimates (N and q) derived by ADAPT are rather high. The XSA results are internally consistent among fleets at all ages and the internal and external standard errors on the weighted predicted survivors are relatively low.

Thus, further evaluation of both VPA calibration approaches is required in order to explain the major differences.

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Table 1. Results from 3M shrimp VPA using Extended Survivors Analysis (XSA)

Catch at Age: 1993-2000
F Shrinkage Applied

3 Tuning Fleets:

Icelandic CPUE: Ages 3-6; 1993-2000
Faeroese Survey: Ages 2-4
EU Survey: Ages 2-6

Table 1 (Continued).

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Lowestoft VPA Version 3.1

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Extended Survivors Analysis

3M Shrimp:  November 2001.

CPUE data from file c:\nafo\nov2001\3mshrimp\update\shrtun1.dat

Catch data for   8 years. 1993 to 2000. Ages  2 to   6.

     Fleet,            First, Last, First, Last, Alpha,  Beta
                  ,    year, year,  age ,  age
ICEFLSTA           ,   1993, 2000,   3,     6,   .000,  1.000
FAESUR             ,   1997, 2000,   2,     4,   .500,   .600
EUSUR              ,   1993, 2000,   2,     6,   .600,   .700


Time series weights :

     Tapered time weighting applied
     Power =    3 over  20 years


Catchability analysis :

     Catchability dependent on stock size for ages <    3

        Regression type = C
        Minimum of   5 points used for regression
        Survivor estimates shrunk to the population mean for ages <  3


     Catchability independent of age for ages >=    4


Terminal population estimation :

     Survivor estimates shrunk towards the mean F
     of the final   5 years or the   4 oldest ages.

     S.E. of the mean to which the estimates  are shrunk =    .500

     Minimum standard error for population
     estimates derived from each fleet =    .300

     Prior weighting not applied


Tuning had not converged after   80 iterations


Total absolute residual between iterations
79 and  80 =     .00027

Final year F values

Age          ,      2,      3,      4,      5,      6
Iteration 79,  .0307,  .2961,  .3968,  .4745,  .2506
Iteration 80,  .0307,  .2961,  .3968,  .4747,  .2507


Regression weights
      ,  .877,  .921,  .954,  .976,  .990,  .997, 1.000, 1.000


Fishing mortalities
   Age,  1993,  1994,  1995,  1996,  1997,  1998,  1999,  2000

     2,  .096,  .091,  .192,  .038,  .018,  .014,  .018,  .031
     3,  .257,  .562,  .401,  .520,  .166,  .165,  .128,  .296
     4,  .081,  .171,  .280,  .761,  .345,  .367,  .291,  .397
     5,  .214,  .212,  .668,  .845,  .320,  .199,  .591,  .475
     6,  .175,  .244,  .455,  .510,  .218,  .177,  .359,  .251
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Table 1 (Continued).

XSA population numbers (Thousands)

YEAR	AGE 2	3	4	5	6
1993	4.46E+06	3.37E+06	5.31E+06	4.83E+06	6.39E+06
1994	8.21E+06	3.32E+06	2.13E+06	4.01E+06	3.20E+06
1995	1.93E+07	6.13E+06	1.55E+06	1.47E+06	2.66E+06
1996	1.48E+07	1.30E+07	3.36E+06	9.59E+05	6.18E+05
1997	1.75E+07	1.17E+07	6.35E+06	1.29E+06	3.37E+05
1998	1.98E+07	1.41E+07	8.11E+06	3.68E+06	7.65E+05
1999	1.84E+07	1.60E+07	9.77E+06	4.60E+06	2.47E+06
2000	7.61E+06	1.48E+07	1.15E+07	5.98E+06	2.09E+06

Estimated population abundance at 1st Jan 2001

, 0.00E+00, 6.04E+06, 9.02E+06, 6.34E+06, 3.04E+06,

Taper weighted geometric mean of the VPA populations:

, 1.25E+07, 8.99E+06, 4.99E+06, 2.77E+06, 1.57E+06,

Standard error of the weighted Log(VPA populations) :

, .5486, .6551, .7290, .7105, .9798,

Log catchability residuals.

Fleet : ICEFLSTA

Age	1993	1994	1995	1996	1997	1998	1999	2000
2	No data for this fleet at this age							
3	.40	.89	.35	.02	-.35	-.24	-.87	-.07
4	-.83	-.37	-.08	.33	.30	.49	-.12	.15
5	.15	-.16	.79	.43	.23	-.12	.58	.33
6	-.05	-.02	.40	-.07	-.15	-.24	.09	-.31

Mean log catchability and standard error of ages with catchability independent of year-class strength and constant w.r.t. time

Age	3	4	5	6
Mean Log q	-13.0294	-12.9582	-12.9582	-12.9582
S.E(Log q)	.5343	.4238	.4446	.2257

Regression statistics :

Ages with q independent of year-class strength and constant w.r.t. time.

Age	Slope	t-value	Intercept	RSquare	No Pts	Reg s.e	Mean Q
3	3.29	-3.918	6.19	.34	8	.99	-13.03
4	.87	.665	13.29	.81	8	.38	-12.96
5	1.20	-.925	12.25	.79	8	.39	-12.68
6	.92	.957	13.10	.96	8	.20	-13.00

Fleet : FAESUR

Age	1993	1994	1995	1996	1997	1998	1999	2000
2	99.99	99.99	99.99	99.99	1.05	-.48	-.38	-.18
3	99.99	99.99	99.99	99.99	.30	-.09	-.23	.02
4	99.99	99.99	99.99	99.99	-.29	.21	-.12	.20
5	No data for this fleet at this age							
6	No data for this fleet at this age							

Table 1 (Continued).

Mean log catchability and standard error of ages with catchability independent of year-class strength and constant w.r.t. time

Age ,	3,	4
Mean Log q,	-13.6244,	-13.5777,
S.E(Log q),	.2251,	.2490,

Regression statistics :

Ages with q dependent on year-class strength

Age,	Slope ,	t-value ,	Intercept,	RSquare,	No Pts,	Reg s.e,	Mean Log q
2,	.90,	.102,	15.57,	.33,	4,	.78,	-15.46,

Ages with q independent of year-class strength and constant w.r.t. time.

Age,	Slope ,	t-value ,	Intercept,	RSquare,	No Pts,	Reg s.e,	Mean Q
3,	-1.73,	-3.658,	21.35,	.48,	4,	.17,	-13.62,
4,	.62,	1.107,	14.48,	.81,	4,	.15,	-13.58,

Fleet : EUSUR

Age ,	1993,	1994,	1995,	1996,	1997,	1998,	1999,	2000
2 ,	.10,	-.51,	-.03,	.03,	-.56,	.51,	.06,	.36
3 ,	.75,	-1.98,	.25,	.32,	-.87,	1.10,	.52,	-.14
4 ,	-.32,	-.75,	-.28,	-.04,	.08,	.62,	.52,	.06
5 ,	.08,	-1.03,	.61,	1.21,	.54,	-.15,	-.05,	.22
6 ,	.18,	-.02,	.07,	.64,	.08,	1.36,	-2.29,	-.41

Mean log catchability and standard error of ages with catchability independent of year-class strength and constant w.r.t. time

Age ,	3,	4,	5,	6
Mean Log q,	-12.3731,	-11.8840,	-11.8840,	-11.8840,
S.E(Log q),	.9831,	.4484,	.6823,	1.0702,

Regression statistics :

Ages with q dependent on year-class strength

Age,	Slope ,	t-value ,	Intercept,	RSquare,	No Pts,	Reg s.e,	Mean Log q
2,	.30,	2.424,	16.05,	.68,	8,	.41,	-15.39,

Ages with q independent of year-class strength and constant w.r.t. time.

Age,	Slope ,	t-value ,	Intercept,	RSquare,	No Pts,	Reg s.e,	Mean Q
3,	.63,	1.014,	13.72,	.57,	8,	.62,	-12.37,
4,	.69,	2.634,	12.99,	.93,	8,	.22,	-11.88,
5,	2.95,	-2.478,	5.59,	.22,	8,	1.45,	-11.70,
6,	1.67,	-.944,	10.39,	.26,	8,	1.80,	-11.94,

1

Terminal year survivor and F summaries :

Age 2 Catchability dependent on age and year-class strength

Year-class = 1998

Fleet,		Estimated,	Int,	Ext,	Var,	N,	Scaled,	Estimated
,		Survivors,	s.e,	s.e,	Ratio,	,	Weights,	F
ICEFLSTA	,	1.,	.000,	.000,	.00,	0,	.000,	.000
FAESUR	,	5056779.,	.794,	.000,	.00,	1,	.119,	.037
EUSUR	,	8637950.,	.435,	.000,	.00,	1,	.394,	.022
P shrinkage mean	,	8992504.,	.66,,,,				.179,	.021
F shrinkage mean	,	3254618.,	.50,,,,				.308,	.056

Table 1 (Continued).

Weighted prediction :

Survivors, at end of year,	Int, s.e,	Ext, s.e,	N, ,	Var, Ratio,	F
6044916.,	.28,	.29,	4,	1.058,	.031

Age 3 Catchability constant w.r.t. time and dependent on age

Year-class = 1997

Fleet, ,		Estimated, Survivors,	Int, s.e,	Ext, s.e,	Var, Ratio,	N, ,	Scaled, Weights,	Estimated F
ICEFLSTA	,	8420874.,	.568,	.000,	.00,	1,	.115,	.314
FAESUR	,	8750230.,	.281,	.133,	.47,	2,	.470,	.304
EUSUR	,	9304628.,	.411,	.075,	.18,	2,	.216,	.288
F shrinkage mean	,	9722385.,	.50,,,,				.199,	.277

Weighted prediction :

Survivors, at end of year,	Int, s.e,	Ext, s.e,	N, ,	Var, Ratio,	F
9015414.,	.20,	.05,	6,	.248,	.296

Age 4 Catchability constant w.r.t. time and dependent on age

Year-class = 1996

Fleet, ,		Estimated, Survivors,	Int, s.e,	Ext, s.e,	Var, Ratio,	N, ,	Scaled, Weights,	Estimated F
ICEFLSTA	,	5134002.,	.354,	.488,	1.38,	2,	.172,	.471
FAESUR	,	6159269.,	.205,	.167,	.81,	3,	.499,	.407
EUSUR	,	8470013.,	.326,	.159,	.49,	3,	.197,	.311
F shrinkage mean	,	6070642.,	.50,,,,				.133,	.411

Weighted prediction :

Survivors, at end of year,	Int, s.e,	Ext, s.e,	N, ,	Var, Ratio,	F
6343502.,	.15,	.11,	9,	.754,	.397

Age 5 Catchability constant w.r.t. time and age (fixed at the value for age) 4

Year-class = 1995

Fleet, ,		Estimated, Survivors,	Int, s.e,	Ext, s.e,	Var, Ratio,	N, ,	Scaled, Weights,	Estimated F
ICEFLSTA	,	3218965.,	.288,	.175,	.61,	3,	.242,	.454
FAESUR	,	2924137.,	.206,	.196,	.95,	3,	.390,	.490
EUSUR	,	3393656.,	.289,	.310,	1.07,	4,	.215,	.435
F shrinkage mean	,	2656037.,	.50,,,,				.154,	.529

Weighted prediction :

Survivors, at end of year,	Int, s.e,	Ext, s.e,	N, ,	Var, Ratio,	F
3044873.,	.14,	.11,	11,	.736,	.475

Table 1 (Continued).

```
1
 Age  6   Catchability constant w.r.t. time and age (fixed at the value for age)  4

 Year-class = 1994

 Fleet,                   Estimated,    Int,       Ext,    Var,     N, Scaled,  Estimated
     ,                    Survivors,    s.e,       s.e,   Ratio,     , Weights,    F
 ICEFLSTA           ,    1223217.,   .223,      .217,    .97,    4,  .473,     .270
 FAESUR             ,    1716253.,   .214,      .044,    .21,    2,  .225,     .200
 EUSUR              ,    1447704.,   .298,      .211,    .71,    5,  .155,     .233

   F shrinkage mean  ,   1077827.,    .50,,,,                          .147,     .301

 Weighted prediction :

 Survivors,        Int,      Ext,    N,    Var,     F
 at end of year,   s.e,      s.e,     ,   Ratio,
   1329811.,       .14,      .11,   12,    .726,   .251
```

Table 2. ADAPT estimates of population numbers(biased), fishing mortality and biomass

Bias popnum	2	3	4	5	6	
1993	3,893,565	2774867	3000205	2161405	1904555	13734596
1994	7101366	2854875	1651704	2121337	1015684	14744966
1995	15264301	5230838	1183404	1078709	1116230	23873481
1996	11269883	9754973	2640938	661687	306590	24634072
1997	12813871	8775392	3722756	722869	106269	26141157
1998	16045038	10237282	5730346	1552407	306960	33872033
1999	12451697	12905292	6641281	2674324	732575	35405169
2000	4192053	9924071	8997997	3439468	547280	27100868
2001	9426100	3244446	5048075	4309908	999321	23027849

F	2	3	4	5	6	Mean 3-6
1993	0.11	0.32	0.15	0.56	0.76	0.44
1994	0.11	0.68	0.23	0.44	1.10	0.61
1995	0.25	0.48	0.38	1.06	1.85	0.94
1996	0.05	0.76	1.10	1.63	1.53	1.26
1997	0.02	0.23	0.67	0.66	0.94	0.63
1998	0.02	0.23	0.56	0.55	0.51	0.46
1999	0.03	0.16	0.46	1.39	3.41	1.35
2000	0.06	0.48	0.54	1.04	1.72	0.94

Biomass	2	3	4	5	6	sum	sum/10^3
1993	10792963	14498682	24565677	22567225	21310062	93734608	93735
1994	18293118	14268666	11728747	21383076	12070391	77743999	77744
1995	29994351	25756648	7647154	10367470	12099935	85865557	85866
1996	24342948	47340883	24386423	7648443	4514234	108232932	108233
1997	41017203	36242370	29655474	7684816	1531013	116130876	116131
1998	27966502	39065470	38204217	15733645	3503330	124473163	124473
1999	20408332	39606340	42444424	22707685	8102281	133269062	133269
2000	5089152	29514186	45943773	29661968	5912809	116121889	116122
2001	9312987	9678182	26179316	35043860	10213056	90427402	90427

Table 3. ADAPT estimates of population number and catchabilities .
Parameters are in linear scale.

Year	Age	Estmate Abundance	STD. Err	Relative error	Bias	Relative Bias
---------	---------	---------	---------	---------	---------	---------
1993	6	1.90E+06	1.90E+06	0.997	1.29E+06	0.675
1994	6	1.02E+06	7.55E+05	0.744	5.15E+05	0.508
1995	6	1.12E+06	4.77E+05	0.427	4.09E+05	0.366
1996	6	3.07E+05	1.70E+05	0.554	1.38E+05	0.452
1997	6	1.06E+05	9.03E+04	0.85	6.19E+04	0.583
1998	6	3.07E+05	3.06E+05	0.996	1.56E+05	0.508
1999	6	7.33E+05	8.81E+04	0.12	8.33E+04	0.114
2000	6	5.47E+05	2.64E+05	0.482	2.30E+05	0.421
2001	3	3.24E+06	1.90E+06	0.587	7.49E+05	0.231
2001	4	5.05E+06	2.86E+06	0.567	1.08E+06	0.215
2001	5	4.31E+06	2.37E+06	0.55	9.95E+05	0.231
2001	6	9.99E+05	9.51E+05	0.952	5.71E+05	0.572
		Catchabilities				
Icelandic	2	4.19E-06	1.41E-06	0.336	6.17E-09	0.001
	3	2.69E-05	9.00E-06	0.334	-2.88E-07	-0.011
	4	3.24E-05	1.16E-05	0.358	-1.30E-06	-0.04
	5	6.41E-05	3.26E-05	0.509	-2.29E-06	-0.036
	6	1.03E-04	1.47E-04	1.421	1.34E-04	1.3
Faroese	2	2.80E-05	1.38E-05	0.494	1.34E-06	0.048
	3	1.68E-04	8.01E-05	0.476	6.78E-06	0.04
	4	2.00E-04	9.43E-05	0.472	5.59E-06	0.028
	2	2.61E-06	8.76E-07	0.336	3.67E-09	0.001
EU	3	5.62E-05	1.89E-05	0.336	-6.57E-07	-0.012
	4	1.05E-04	3.81E-05	0.363	-4.35E-06	-0.041
	5	1.90E-04	1.02E-04	0.535	-5.35E-06	-0.028
	6	3.79E-04	5.97E-04	1.574	6.18E-04	1.628

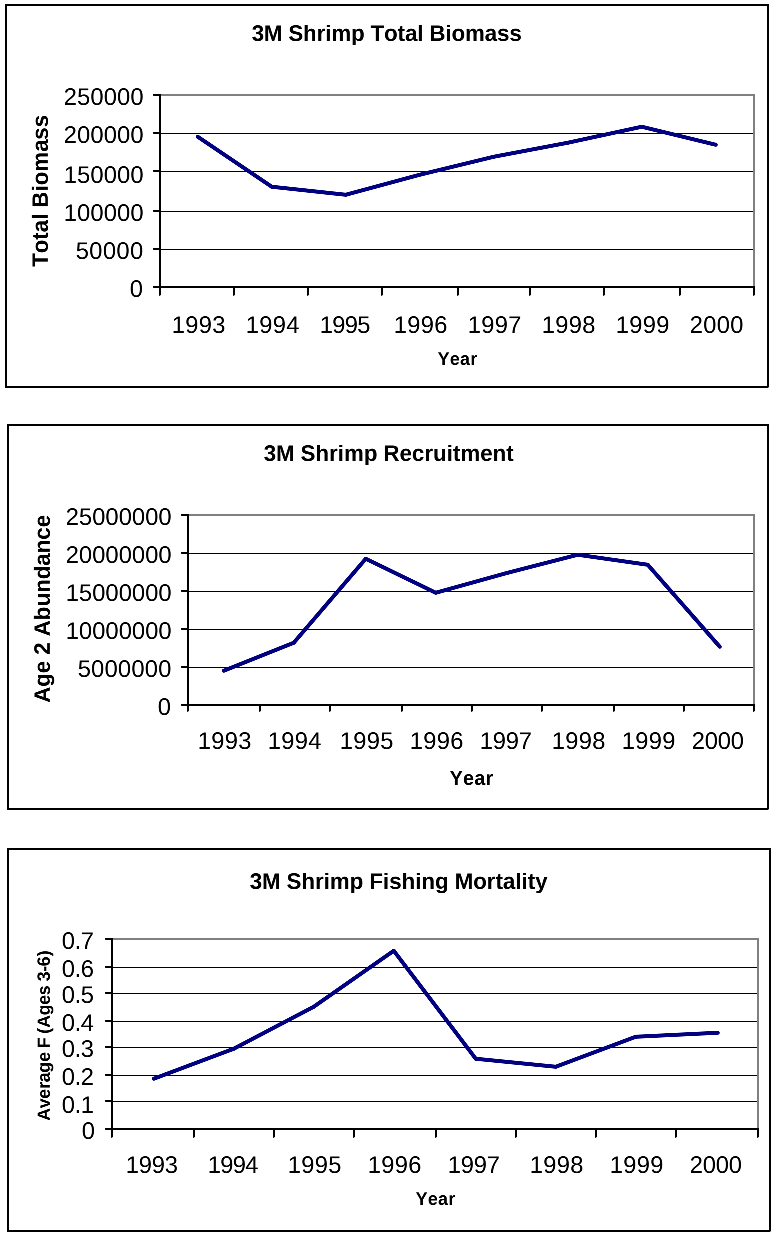

Fig 1. XSA estimates of total biomass, recruitment numbers at age 2 and average F(ages3-6) for shrimp in NAFO Div. 3M

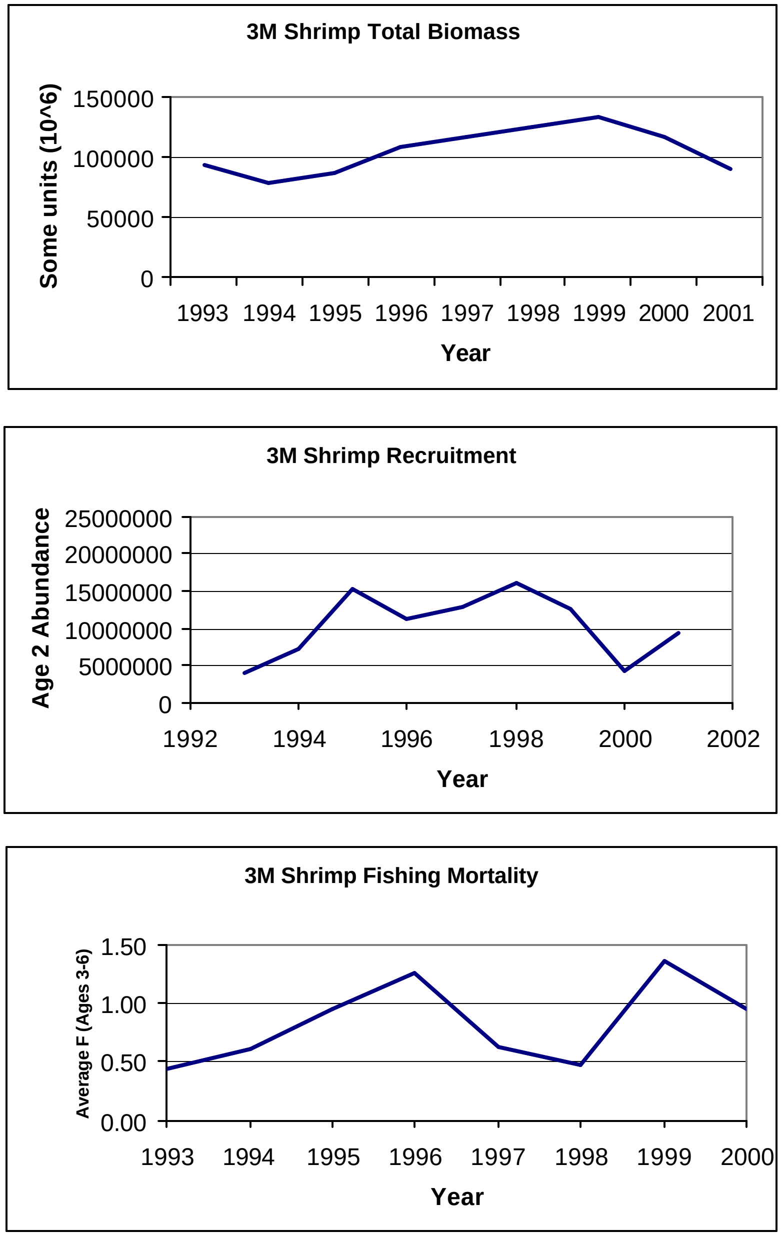

Fig 2. ADAPT estimates of total biomass, recruitment numbers at age 2 and average F(ages3-6) for shrimp in NAFO Div. 3M.

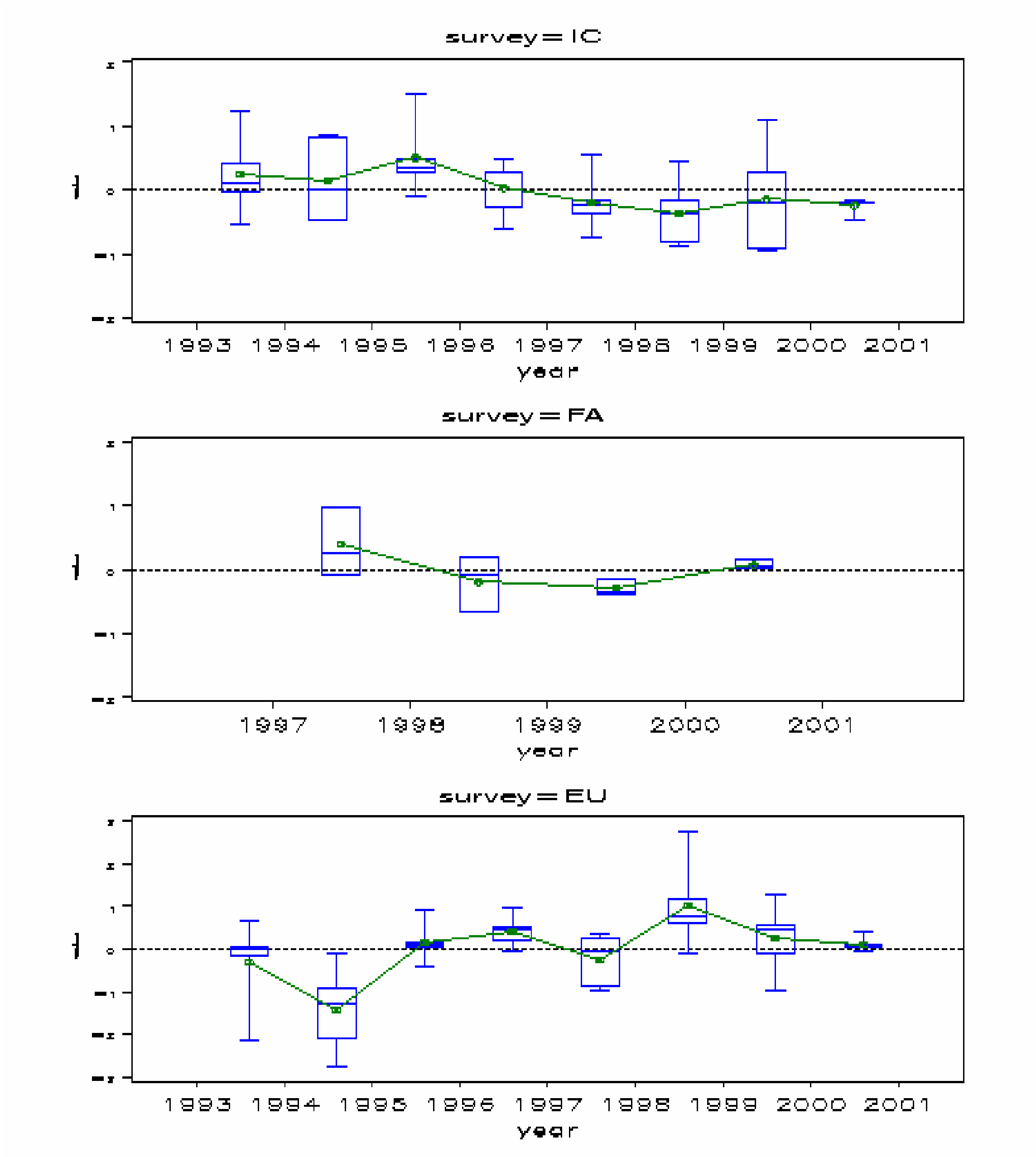

Fig. 3. Box whisker plots of log residuals from ADAPT for the three tuning indices. The box represents the 25th and 75th percentiles, the bar represents the median, and the star is the mean with the extreme values represented by the whiskers.

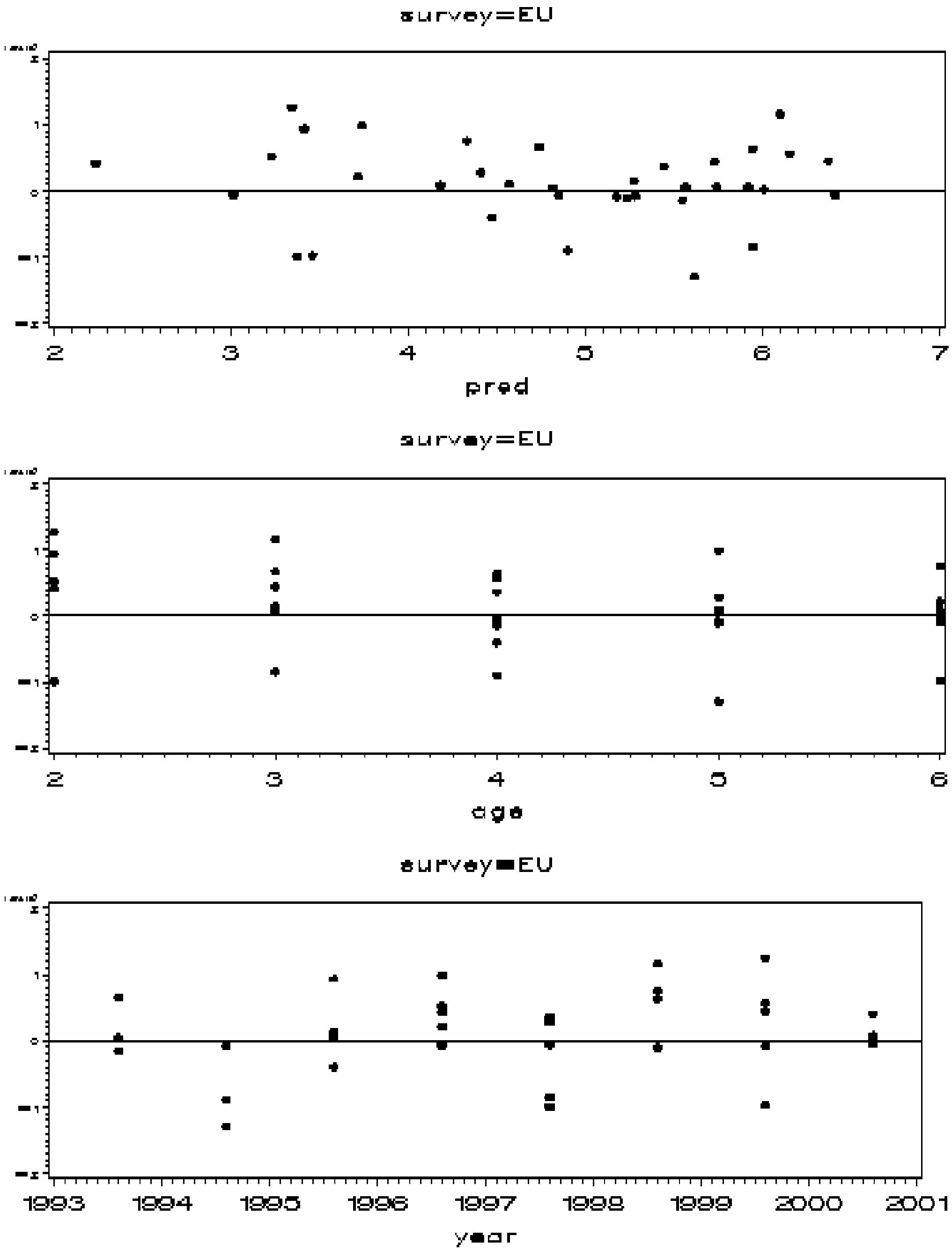

Fig. 4. Log residuals vs. log predicted values (top), age (middle) and year (bottom panel) for the EU survey.

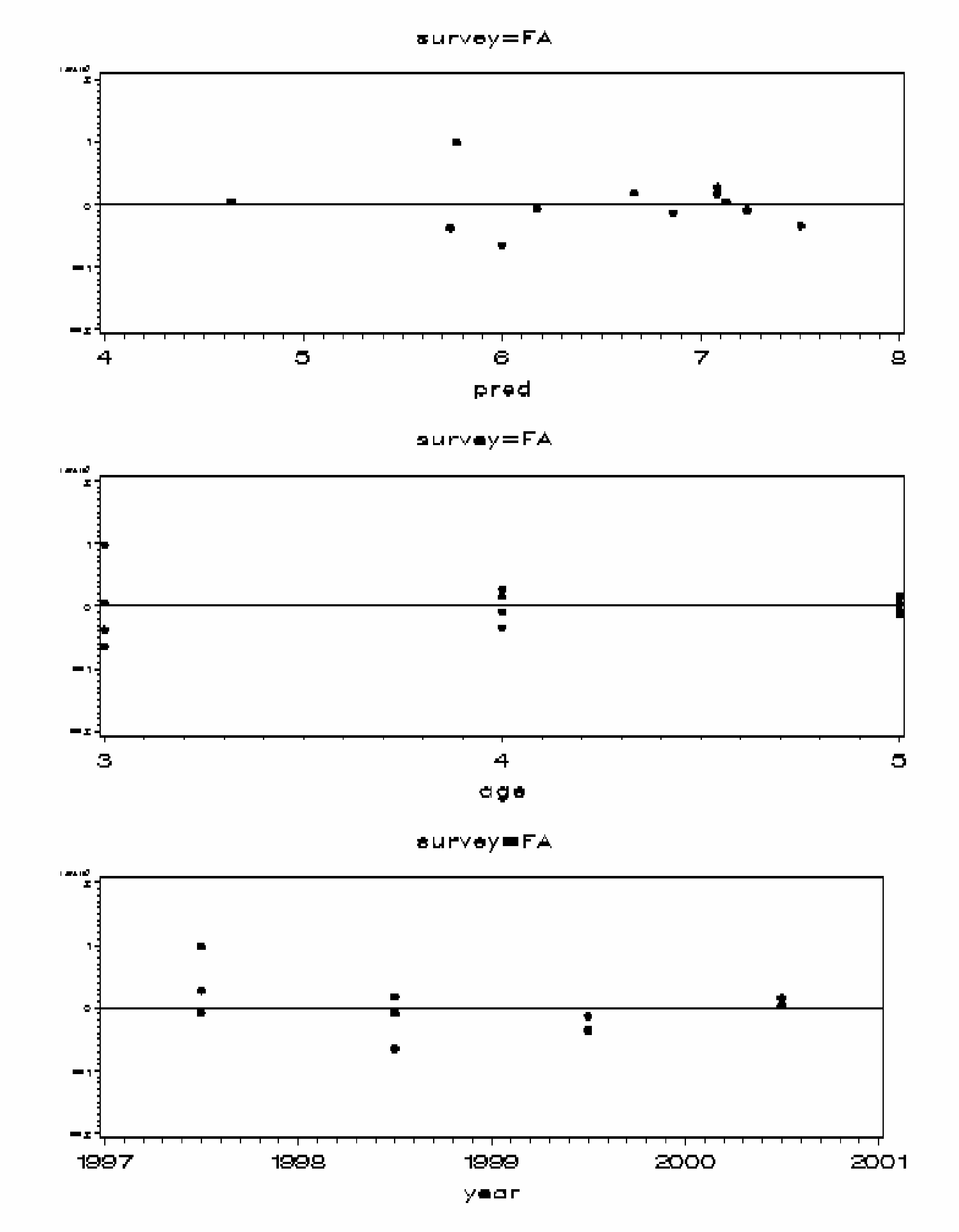

Fig. 5. Log residuals vs. log predicted values (top), age (middle) and year (bottom panel) for the Faroese survey.

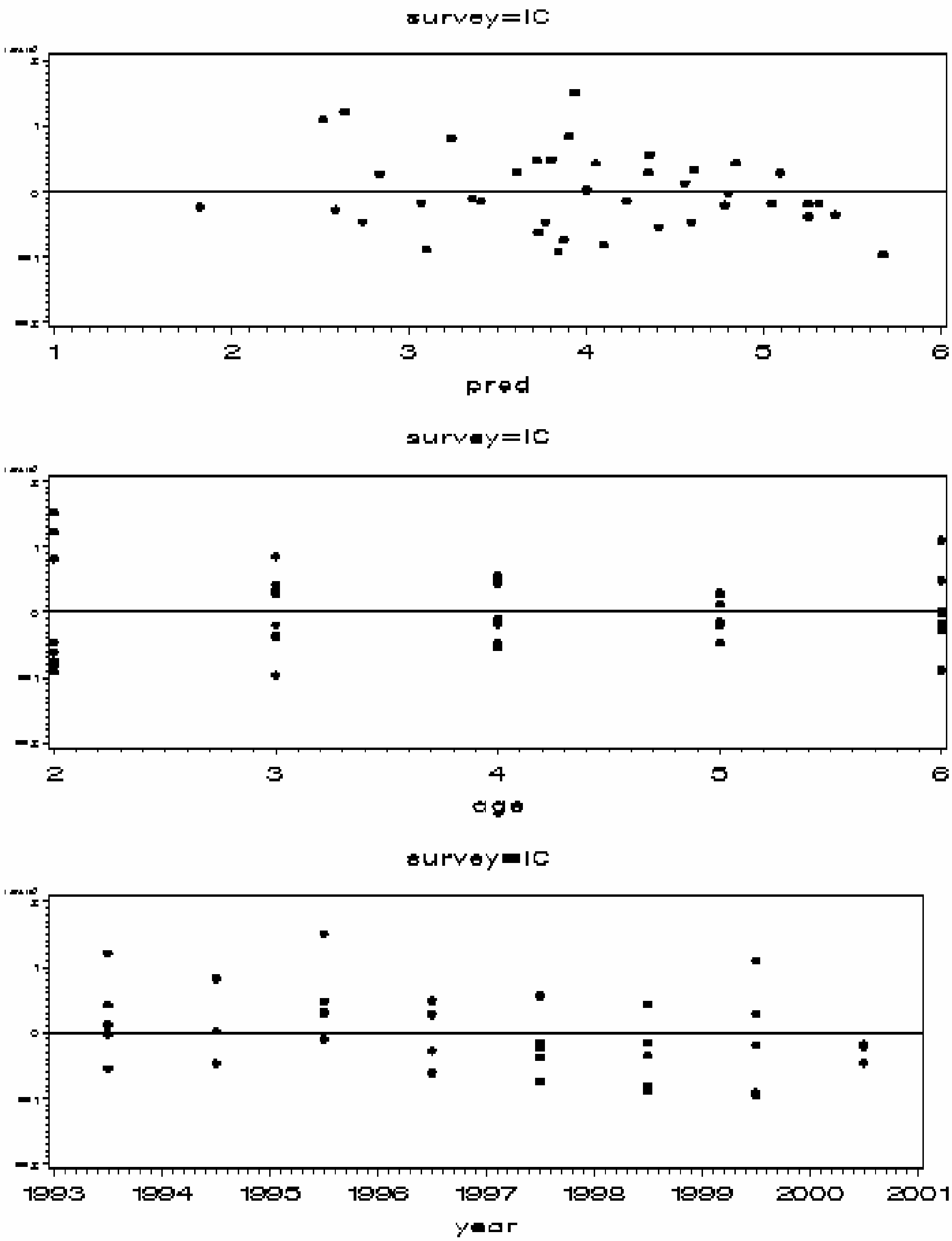

Fig. 6. Log residuals vs. log predicted values (top), age (middle) and year (bottom panel) for the Icelandic CPUE series-at-age.