Northwest Atlantic Fisheries Organization

Serial No. N6585 **NAFO SCR Doc. 16/39**

SCIENTIFIC COUNCIL MEETING – JUNE 2016

Standardized Catch Rate Indices for Greenland Halibut in SA2+3KLMNO

By
D. Power

Science Branch, Department of Fisheries and Oceans
P. O. Box 5667, St. John's, Newfoundland, Canada A1C 5X1

Abstract

Catch and effort data were analysed with a multiplicative model to derive a standardized catch rate index for the directed Greenland halibut otter trawl fishery in NAFO SA2+3KLMNO. Since 2005, the index increased rapidly and peaked at the highest rate in the series in 2008, an increase of about 250%, then declined 60% thereafter by 2010. The catch rate remained stable to 2013 then almost doubled in 2014 and remained at this level in 2015. It is difficult to accept that this index is reflective of stock dynamics, particularly since the recent scale of the CPUE relative to the entire series and rapid changes in trend are unprecedented.

Introduction

Catch and effort data from directed Greenland halibut otter trawl fisheries, standardized with a multiplicative model, have been presented as information for the assessment of this resource in SA2+ Div. 3KLMNO since 2001. Based on differences in trends in the catch rate models between CANADIAN and NON-CANADIAN fleets for the years since 1992, separate standardizations were conducted since 2004 (Power, 2004). This may be related to the fact that Canadian fleets fish within the 200 mile limit and all other fleets operate in the NAFO regulatory, outside the 200 mile limit.

Materials and Methods

Catch and effort data from the Canadian otter trawl fishery directed for Greenland halibut during the period 1975 to 2002 were obtained from the NAFO STATLANT 21B database and combined with data from 2003-2015 from Canada (N) logbook (ZIFF) records. The catch/effort data were analysed with a multiplicative model (Gavaris, 1980) to derive a standardized catch rate index based on an hours-fished measure of effort. Ln (CPUE) was the dependent variable in the model. Independent variables (category types) were: (1) a combination country-gear-tonnage-class category type (CGT), (2) month, (3) NAFO Division and (4) Year. Consistent with previous catch rate standardizations (e.g. Power, 2004), individual observations with catch less than or equal to 10 tons or effort less than 10 hours were eliminated prior to analysis. Subsequently, within each dependent variable, categories with arbitrarily less than five observations were also eliminated, with the exception of the variable "year", which is the purpose of the standardization. The advantage of running the Gavaris model is the derived standardized index is retransformed into the original units of fishing effort and can be computed for any chosen combination of the main factors.

After the selection criteria were applied, the percentage of otter trawl catch with hours fished effort utilized in the analysis ranged from 9.5% in 1976 to 99.1% in 2007, and averaged 92% since 2007. In recent years, there was sufficient data available from the tonnage class 4 trawlers, and, the tonnage class 7 trawlers utilizing twin trawls for inclusion in the standardization. The twin trawls were introduced in 2003 but have accounted for less than 11% of the otter trawl catch.

Residual plots (not shown) did not indicate model misspecification. The model resulted in a significant regression ($P < 0.05$) explaining 67% of the variation in catch rates (Table 1). Based on the regression coefficients, over the entire time series, catch rates were better in late summer and higher in Div. 2H. The divisional coefficients also suggest catch rate decreases from north to south. The fishing power of the large trawlers (TC 7) is the highest with no significant difference between single and twin trawls.

The standardized catch rate series (Table 2, Fig. 1) shows much between-year variability. CPUE more than doubled from 1976 to 1978 then showed a period of stability to 1984. CPUE declined by about two-thirds to 1992 although there were some sporadic increases over this period. The 1992 value was near the lowest in the series then was relatively stable to 2005. Within a five year period, the index increased rapidly and peaked at the highest rate in the series in 2008, an increase of about 250%, then declined 60% thereafter by 2010. The catch rate remained stable to 2013 then almost doubled in 2014 and remained at this level in 2015.

The same dataset after the data selection criteria was applied was also modelled with a SAS Version 9.3 PROC GLM (SAS, 2011). The AVOVA results and parameter estimates (Table 3), diagnostics (Fig. 2) and CPUE series (Table 4, Fig. 3) in regard to the trend by year are comparable and for convenience only the GLM model results will be produced at future assessments. For further comparative purposes, both the Gavaris and GLM modelled CPUE, and the unstandardized CPUE (sum of catch divided by sum of effort for each year) are provided on the same graph to evaluate trends (Fig. 4). The Gavaris and GLM CPUE trends are virtually indistinguishable and compared to the trend of the unstandardized CPUE (all scaled to their mean values) the effect of the model is quite dramatic before and after 2004.

It is difficult to accept that this index is reflective of stock dynamics, particularly since the recent scale and rapid changes in trend are unprecedented. It would be important to investigate a finer scale disaggregation of the data set for a long a series as possible in an attempt to understand the nature of the rapid changes in the recent period compared to the past.

References

Gavaris, S. 1980. Use of a multiplicative model to estimate catch rate and effort from commercial data. Can. J. Fish. Aquat. Sci. 37:2272-2275.

Power, D. 2004. Standardized Catch Rate Indices for Greenland Halibut in SA2+3KLMNO. NAFO SCR. Doc. 04/37, Serial No. N4988, 15p.

SAS (2011). The data analysis for this paper was generated using SAS/STAT software, Version 9.3 of the SAS System for Windows. Copyright © 2011 SAS Institute Inc. SAS and all other SAS Institute Inc. product or service names are registered trademarks or trademarks of SAS Institute Inc., Cary, NC, USA.

Table 1. ANOVA results and regression coefficients from a multiplicative model utilized to derive a standardized CPUE index for Greenland halibut in NAFO Div. 2HJ3KL. Analysis is based on HOURS FISHED from the Canadian ottertrawl fleet (2015 based on preliminary data). (Gavaris Model)

REGRESSION OF MULTIPLICATIVE MODEL
MULTIPLE R............ 0.820
MULTIPLE R SQUARED..... 0.673

ANALYSIS OF VARIANCE

SOURCE OF VARIATION	DF	SUMS OF SQUARES	MEAN SQUARE	F-VALUE
INTERCEPT	1	2.08E2	2.08E2	
REGRESSION	59	1.66E2	2.81E0	13.546
Cntry|Gear|TC	6	2.50E1	4.17E0	20.108
Month	11	9.94E0	9.04E-1	4.357
Division	3	1.21E1	4.04E0	19.456
Year	39	5.15E1	1.32E0	6.365
RESIDUALS	388	8.05E1	2.07E-1	
TOTAL	448	4.54E2		

REGRESSION COEFFICIENTS

CATEGORY	CODE	VAR #	REG. COEF	STD. ERR	NO. OBS
Cntry|Gear|TC	3125	INT	-1.159	0.339	448
Month	9				
Division	22				
Year	76				
1	3123	1	-0.638	0.117	25
	3124	2	-0.134	0.220	5
	3126	3	0.111	0.125	19
	3127	4	0.493	0.098	98
	3857	5	0.659	0.119	31
	27125	6	0.108	0.111	25
2	1	7	-0.077	0.140	18
	2	8	0.056	0.145	18
	3	9	-0.062	0.129	26
	4	10	0.085	0.114	42
	5	11	0.227	0.114	42
	6	12	0.275	0.103	62
	7	13	0.096	0.097	70
	8	14	0.102	0.095	55
	10	15	-0.182	0.126	23
	11	16	-0.433	0.130	23
	12	17	-0.023	0.126	24
3	23	18	-0.102	0.093	153
	31	19	-0.465	0.096	169
	32	20	-0.525	0.103	82
4	77	21	0.310	0.385	5
	78	22	0.886	0.369	8
	79	23	0.844	0.422	3
	80	24	1.076	0.354	13
	81	25	0.810	0.356	14
	82	26	0.894	0.362	10
	83	27	0.883	0.348	18
	84	28	1.014	0.354	12
	85	29	0.600	0.355	12
	86	30	0.339	0.375	7
	87	31	0.858	0.386	5
	88	32	0.015	0.402	4
	89	33	0.477	0.377	6
	90	34	0.487	0.354	12
	91	35	0.131	0.348	16
	92	36	0.100	0.346	20
	93	37	0.218	0.357	14
	94	38	0.313	0.401	4
	95	39	0.446	0.461	2
	96	40	0.278	0.366	8
	97	41	0.615	0.371	7
	98	42	0.241	0.462	2
	99	43	0.118	0.465	2
	100	44	0.433	0.364	9
	101	45	0.662	0.350	17
	102	46	0.233	0.359	11
	103	47	0.175	0.341	28
	104	48	0.182	0.345	20
	105	49	0.246	0.347	23
	106	50	0.920	0.367	10
	107	51	1.384	0.381	7
	108	52	1.517	0.388	6
	109	53	1.335	0.364	11
	110	54	0.673	0.351	20
	111	55	0.740	0.355	18
	112	56	0.576	0.354	19
	113	57	0.717	0.357	17
	114	58	1.241	0.361	15
	115	59	1.175	0.369	11

LEGEND FOR ANOVA RESULTS:
CGT CODES: All are Stern Trawlers

3123 =	Can(NFLD)	Otter Trawl	TC 3
3124 =	"	"	TC 4
3125 =	"	"	TC 5
3126 =	"	"	TC 6
3127 =	"	"	TC 7
3857 =	"	Twin Otter Trawl	TC 7
27125 =	Can(M)	Otter Trawl	TC 5

DIVISION CODES:
22 = 2H, 23 = 2J, 31 = 3K, 32 = 3L

Table 2. Standardized CPUE for Greenland halibut in NAFO 2HJ3KL based on a multiplicative model based utilizing HOURS FISHED as a measure of effort. Results are from the CANADIAN OTTERTRAWL fleet (2015 based on preliminary data). (Gavaris Model)

	PREDICTED CATCH RATE						
	LN TRANSFORM		RETRANSFORMED				% OF CATCH IN
YEAR	MEAN	S.E.	MEAN	S.E.	CATCH	EFFORT	THIS ANALYSIS
1976	-1.1589	0.1152	0.329	0.109	767	2334	9.5
1977	-0.8485	0.0543	0.462	0.106	2866	6200	20.9
1978	-0.2726	0.0400	0.828	0.164	3951	4771	30.0
1979	-0.3149	0.0853	0.776	0.222	5183	6680	35.4
1980	-0.0833	0.0304	1.005	0.174	3946	3925	42.9
1981	-0.3492	0.0292	0.771	0.131	6155	7981	59.2
1982	-0.2649	0.0279	0.840	0.139	8143	9699	73.4
1983	-0.2762	0.0212	0.833	0.121	7085	8506	87.4
1984	-0.1449	0.0241	0.948	0.146	6070	6400	90.4
1985	-0.5586	0.0255	0.627	0.099	4847	7735	91.0
1986	-0.8195	0.0405	0.479	0.096	1896	3957	74.1
1987	-0.3006	0.0521	0.800	0.181	2465	3080	85.6
1988	-1.1443	0.0661	0.342	0.087	629	1848	38.8
1989	-0.6818	0.0463	0.548	0.117	988	1802	21.2
1990	-0.6721	0.0277	0.559	0.093	2402	4299	75.9
1991	-1.0276	0.0267	0.392	0.064	3254	8305	70.0
1992	-1.0591	0.0229	0.380	0.057	2502	6578	50.2
1993	-0.9409	0.0317	0.426	0.075	1034	2426	86.8
1994	-0.8458	0.0651	0.461	0.116	575	1247	96.5
1995	-0.6931	0.1152	0.524	0.173	632	1207	56.2
1996	-0.8812	0.0379	0.451	0.087	1043	2312	81.0
1997	-0.9175	0.0423	0.631	0.129	1017	1612	94.7
1998	-0.8172	0.1177	0.418	0.139	46	110	63.0
1999	-1.0407	0.1198	0.369	0.124	81	219	81.5
2000	-0.7259	0.0367	0.527	0.100	1285	2438	99.3
2001	-0.4967	0.0268	0.666	0.109	1833	2751	99.2
2002	-0.9256	0.0322	0.433	0.077	1784	4123	98.7
2003	-0.9843	0.0160	0.411	0.052	3710	9020	89.9
2004	-0.9769	0.0201	0.414	0.058	1832	4430	98.5
2005	-0.9130	0.0268	0.439	0.072	2218	5049	98.1
2006	-0.2393	0.0391	0.856	0.168	2356	2721	94.8
2007	-0.2247	0.0534	1.352	0.309	1866	1380	99.1
2008	0.3585	0.0587	1.542	0.369	2430	1576	93.0
2009	0.1759	0.0406	1.296	0.259	2456	1895	98.9
2010	-0.4861	0.0324	0.671	0.120	3276	4879	98.4
2011	-0.4186	0.0333	0.718	0.130	2418	3368	88.6
2012	-0.5825	0.0313	0.610	0.107	2924	4793	74.8
2013	-0.4419	0.0327	0.702	0.126	3056	4355	89.4
2014	0.0818	0.0358	1.183	0.222	3713	3139	93.1
2015	0.0160	0.0418	1.104	0.224	3601	3261	99.0

AVERAGE C.V. FOR THE RETRANSFORMED MEAN: 0.203

Table 3. ANOVA results and regression coefficients from a GLM model utilized to derive a standardized CPUE index for Greenland halibut in NAFO Div. 2HJ3KL. Analysis is based on HOURS FISHED from the Canadian ottertrawl fleet (2015 based on preliminary data). (SAS GLM)

```
                               The GLM Procedure
                            Class Level Information

Class       Levels  Values

MO              12  1 2 3 4 5 6 7 8 10 11 12 90
DIV              4  23 31 32 220
CGT              7  3123 3124 3126 3127 3857 27125 31250
YEAR            40  77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96
                    97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112
                    113 114 115 760

                    Number of Observations Read         448
                    Number of Observations Used         448

Dependent Variable: LNCPUE
                                          Sum of
 Source                      DF          Squares    Mean Square    F Value    Pr > F
 Model                       59      165.7698745      2.8096589      13.55    <.0001
 Error                      388       80.4791664      0.2074205

 Corrected Total            447      246.2490409

              R-Square     Coeff Var      Root MSE    LNCPUE Mean
              0.673180     -66.91186      0.455434      -0.680648

Source                      DF     Type III SS    Mean Square   F Value    Pr > F

 CGT                         6     25.02495443     4.17082574     20.11    <.0001
 YEAR                       39     51.48827526     1.32021219      6.36    <.0001
 MO                         11      9.94096452     0.90372405      4.36    <.0001
 DIV                         3     12.10687783     4.03562594     19.46    <.0001

                                               Standard
   Parameter              Estimate                Error    t Value    Pr > |t|

   Intercept          -1.158925871 B      0.33942950      -3.41      0.0007
   CGT       3123     -0.638197151 B      0.11662511      -5.47      <.0001
   CGT       3124     -0.133745768 B      0.22030614      -0.61      0.5441
   CGT       3126      0.110687601 B      0.12465227       0.89      0.3751
   CGT       3127      0.492889202 B      0.09761534       5.05      <.0001
   CGT       3857      0.659346346 B      0.11901412       5.54      <.0001
   CGT       27125     0.107743985 B      0.11057216       0.97      0.3305
   CGT       31250     0.000000000 B       .               .          .
   YEAR      77        0.310450174 B      0.38496776       0.81      0.4205
                                               Standard
   Parameter              Estimate                Error    t Value    Pr > |t|

   YEAR      78        0.886305185 B      0.36927354       2.40      0.0169
   YEAR      79        0.843985649 B      0.42176008       2.00      0.0461
   YEAR      80        1.075595439 B      0.35416754       3.04      0.0026
   YEAR      81        0.809749462 B      0.35574736       2.28      0.0234
   YEAR      82        0.894064365 B      0.36205392       2.47      0.0140
   YEAR      83        0.882764695 B      0.34763884       2.54      0.0115
   YEAR      84        1.014015788 B      0.35427171       2.86      0.0044
   YEAR      85        0.600365511 B      0.35549439       1.69      0.0921
   YEAR      86        0.339411926 B      0.37507287       0.90      0.3661
   YEAR      87        0.858294283 B      0.38616584       2.22      0.0268
```

Table 3 (continued)

Parameter		Estimate		Standard Error	t Value	Pr > |t|
YEAR	88	0.014672682	B	0.40206559	0.04	0.9709
YEAR	89	0.477122589	B	0.37749225	1.26	0.2070
YEAR	90	0.486857693	B	0.35394396	1.38	0.1698
YEAR	91	0.131367107	B	0.34833452	0.38	0.7063
YEAR	92	0.099783323	B	0.34585169	0.29	0.7731
YEAR	93	0.217980454	B	0.35663264	0.61	0.5414
YEAR	94	0.313155106	B	0.40116047	0.78	0.4355
YEAR	95	0.465779165	B	0.46062026	1.01	0.3126
YEAR	96	0.277775405	B	0.36581574	0.76	0.4481
YEAR	97	0.615251577	B	0.37130720	1.66	0.0983
YEAR	98	0.241396089	B	0.46220205	0.52	0.6018
YEAR	99	0.118188825	B	0.46466631	0.25	0.7994
YEAR	100	0.432981768	B	0.36409522	1.19	0.2351
YEAR	101	0.662205333	B	0.35031012	1.89	0.0595
YEAR	102	0.233351618	B	0.35851579	0.65	0.5155
YEAR	103	0.174597205	B	0.34081672	0.51	0.6087
YEAR	104	0.182055334	B	0.34500479	0.53	0.5980
YEAR	105	0.245904906	B	0.34658903	0.71	0.4784
YEAR	106	0.919643810	B	0.36659589	2.51	0.0125
YEAR	107	1.383581106	B	0.38144972	3.63	0.0003
YEAR	108	1.517386432	B	0.38820827	3.91	0.0001
YEAR	109	1.334783400	B	0.36437351	3.66	0.0003
YEAR	110	0.672803052	B	0.35117875	1.92	0.0561
YEAR	111	0.740284616	B	0.35541347	2.08	0.0379
YEAR	112	0.576394101	B	0.35397653	1.63	0.1043
YEAR	113	0.717072995	B	0.35663199	2.01	0.0451
YEAR	114	1.240753794	B	0.36059317	3.44	0.0006
YEAR	115	1.174952488	B	0.36912310	3.18	0.0016
YEAR	760	0.000000000	B	.	.	.
MO	1	-0.077435695	B	0.13995004	-0.55	0.5804
MO	2	0.056252867	B	0.14548904	0.39	0.6992
MO	3	-0.062073638	B	0.12926127	-0.48	0.6313
MO	4	0.084689950	B	0.11379291	0.74	0.4572
MO	5	0.226538579	B	0.11380190	1.99	0.0472
MO	6	0.275322508	B	0.10269582	2.68	0.0077
MO	7	0.096189213	B	0.09677227	0.99	0.3209
MO	8	0.101682891	B	0.09485975	1.07	0.2844
MO	10	-0.182089944	B	0.12599711	-1.45	0.1492
MO	11	-0.433254225	B	0.12973703	-3.34	0.0009
MO	12	-0.023419717	B	0.12630499	-0.19	0.8530
MO	90	0.000000000	B	.	.	.
DIV	23	-0.101743624	B	0.09312389	-1.09	0.2753
DIV	31	-0.464879026	B	0.09563988	-4.86	<.0001
DIV	32	-0.524596348	B	0.10343039	-5.07	<.0001
DIV	220	0.000000000	B	.	.	.

NOTE: The X'X matrix has been found to be singular, and a generalized inverse was used to solve the normal equations. Terms whose estimates are followed by the letter 'B' are not uniquely estimable.

Table 4. Standardized CPUE for Greenland halibut in NAFO 2HJ3KL based on a general linear model utilizing HOURS FISHED as a measure of effort. Results are from the CANADIAN OTTERTRAWL fleet (2015 based on preliminary data). (SAS GLM).

The GLM Procedure
Least Squares Means

YEAR	LNCPUE LSMEAN	Standard Error	Pr > |t|
77	-1.03054818	0.21706676	<.0001
78	-0.45469317	0.17425884	0.0094
79	-0.49701271	0.27598025	0.0725
80	-0.26540292	0.13888841	0.0568
81	-0.53124890	0.13355811	<.0001
82	-0.44693399	0.16399100	0.0067
83	-0.45823366	0.12934102	0.0004
84	-0.32698257	0.15069337	0.0306
85	-0.74063285	0.15393236	<.0001
86	-1.00158643	0.18475539	<.0001
87	-0.48270407	0.22042743	0.0291
88	-1.32632568	0.24174350	<.0001
89	-0.86387577	0.20211730	<.0001
90	-0.85414066	0.14612805	<.0001
91	-1.20963125	0.12601635	<.0001
92	-1.24121503	0.11518658	<.0001
93	-1.12301790	0.14023978	<.0001
94	-1.02784325	0.24349812	<.0001
95	-0.87521919	0.33673653	0.0097
96	-1.06322295	0.17596661	<.0001
97	-0.72574678	0.18838956	0.0001
98	-1.09960227	0.33181147	0.0010
99	-1.22280953	0.33391000	0.0003
100	-0.90801659	0.16650285	<.0001
101	-0.67879302	0.12674833	<.0001
102	-1.10764674	0.15205147	<.0001
103	-1.16640115	0.10051545	<.0001
104	-1.15894302	0.11717467	<.0001
105	-1.09509345	0.11119389	<.0001
106	-0.42135455	0.16352682	0.0103
107	0.04258275	0.19015399	0.8229
108	0.17638807	0.20312833	0.3857
109	-0.00621496	0.15480311	0.9680
110	-0.66819531	0.12655020	<.0001
111	-0.60071374	0.12601379	<.0001
112	-0.76460426	0.12297843	<.0001
113	-0.62392536	0.12806079	<.0001
114	-0.10024456	0.13659231	0.4635
115	-0.16604587	0.15508446	0.2850
760	-1.34099836	0.33455391	<.0001

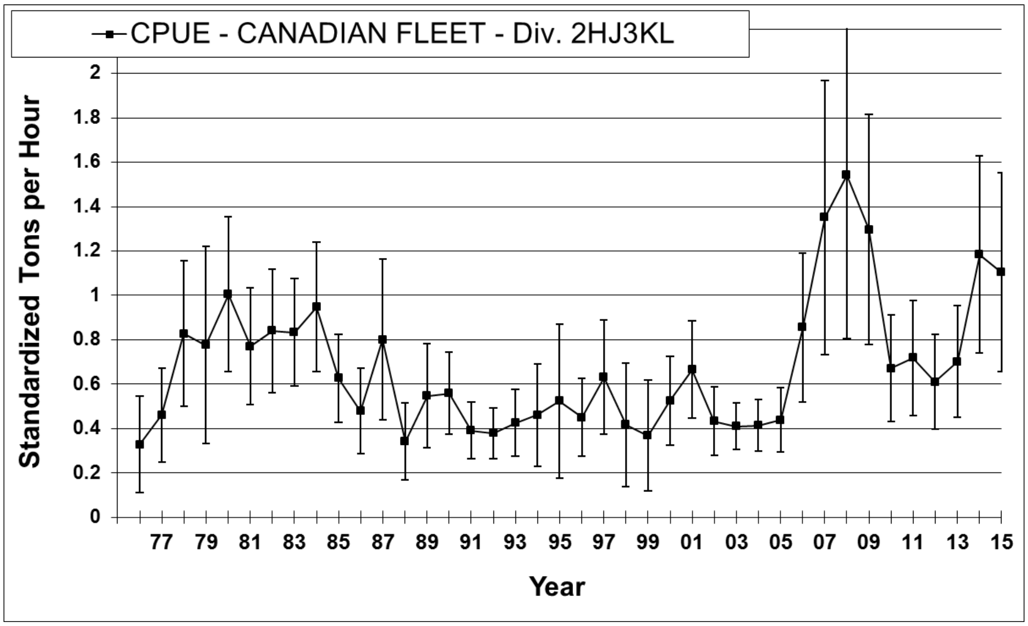

Fig. 1. Standardized Mean CPUE ± 2 standard errors for Greenland Halibut in Div. 2HJ3KL utilizing effort in HOURS fished from the CANADIAN OTTERTRAWL FLEET. (GAVARIS model)

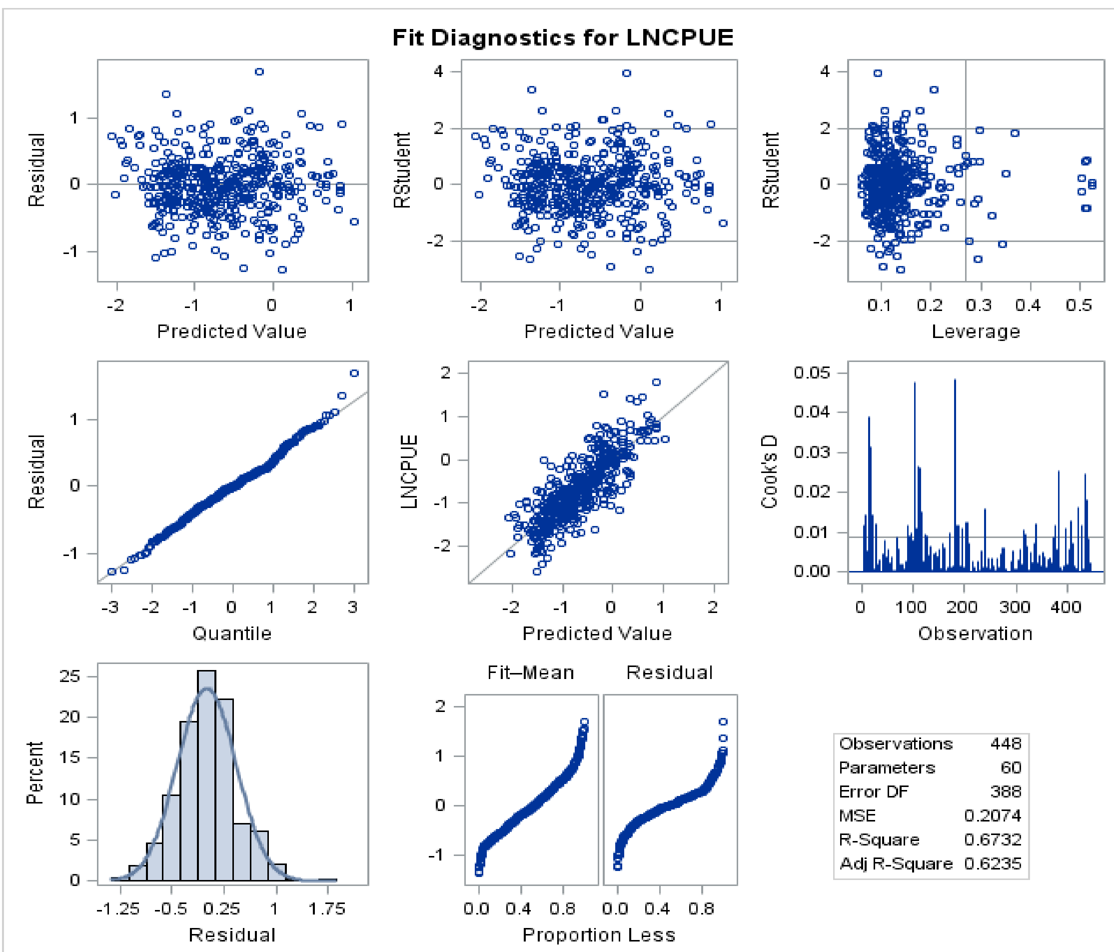

Fig. 2. Diagnostic plots from SAS PROC GLM

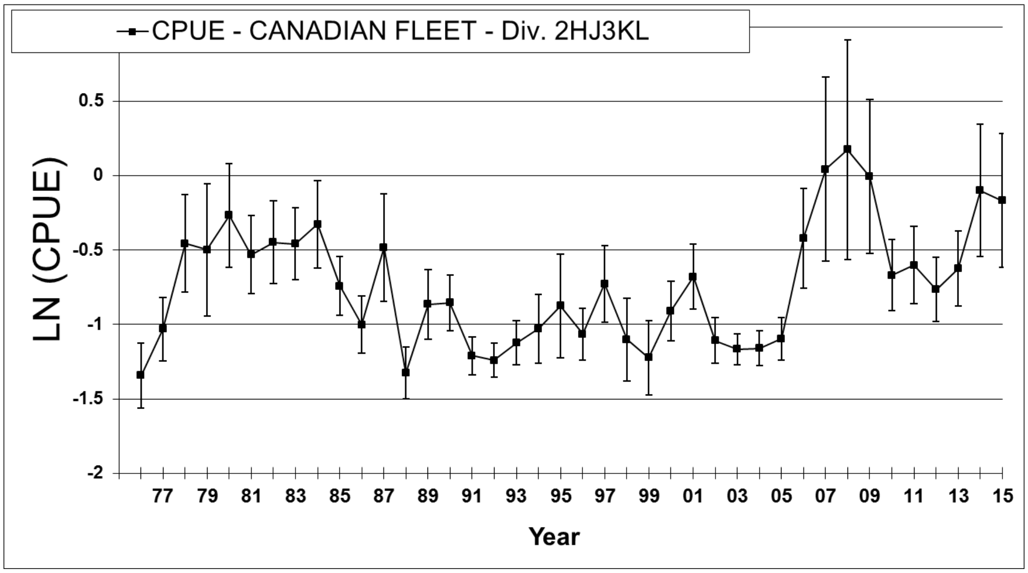

Fig. 3. Standardized Mean CPUE ± 2 standard errors for Greenland Halibut in Div. 2HJ3KL utilizing effort in HOURS fished from the CANADIAN OTTERTRAWL FLEET. (SAS GLM)

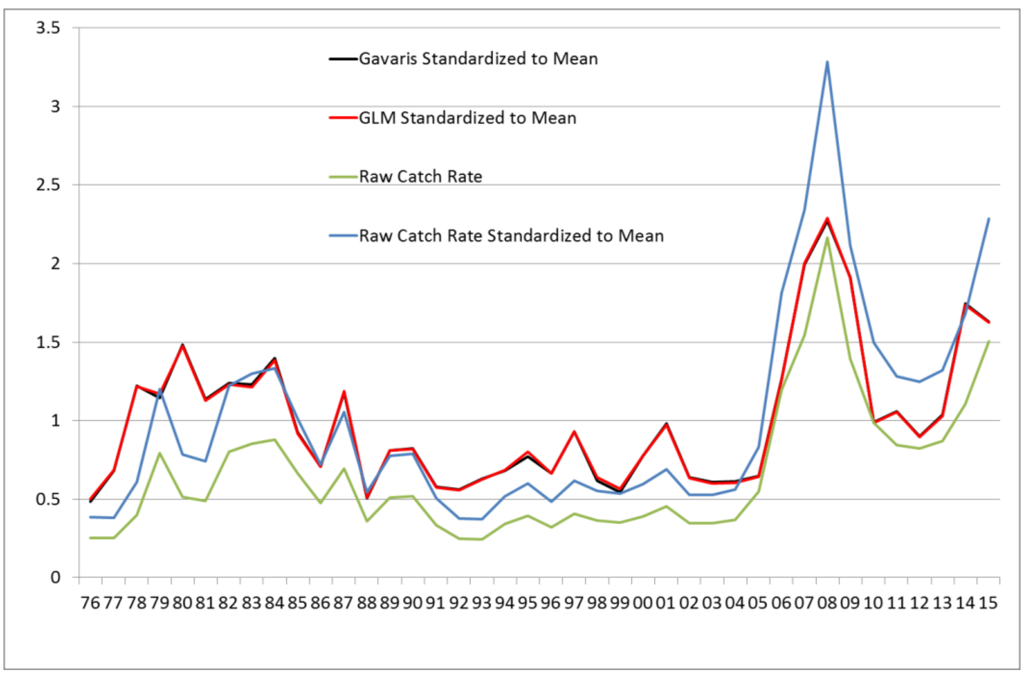

Fig. 4. Comparison of trends between Gavaris model, a GLM model and unstandardized CPUE (scaled to their respective series mean) for Greenland Halibut in Div. 2HJ3KL.