Northwest Atlantic Fisheries Organization

Serial No. N5680 **NAFO SCR Doc. 09/41**

SC WG ON GREENLAND HALIBUT ASSESSMENT METHODS – JUNE 2009

GLM standardisation of recent commercial CPUE data for Greenland halibut for Canada, Portugal and Spain which allows for finer spatial stratification

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April 2009

Summary

Updated CPUE data for the Canadian, Portugese and Spanish fleets are standardised using GLMs with an overdispersed Poisson error structure, and allowing for finer spatial stratification than the Division level to correct for possible redistribution of fishing towards higher density areas. Results for standardisations without year-interactions do show the recent increases evident in the nominal CPUE data; these results are independent of the extent of spatial stratification, and are broadly compatible with previous standardisation exercises, except for now showing a higher rate of recent increase in the Canadian case. However, the introduction of either Division or depth interaction terms with year in the standardisation does reduce the extent of the recent rate of increase.

Introduction

There has been considerable debate on the reliability of commercial CPUE as an index of abundance for the Greenland halibut population in NAFO Subarea 2 and Divisions 3KLMNO. There have been large increases recently in the nominal CPUE, but counter suggestion to inferences that this indicates a substantial increase in abundance has been that this rather reflects a displacement of fishing effort towards areas where halibut density is greater.

The primary purpose of this paper is to GLM-standardise the Canadian, Portuguese and Spanish commercial CPUE data on a finer spatial scale than has been the case in the past (Brodie *et al*. (2008), Fernández *et al*. (2007) and Vargas *et al.* (2008)) as a means to correct, to the extent possible, for any such effect. Furthermore year interactions with spatial co-variates are introduced to allow for the possibility of distributional shifts in the population over time could similarly have biased trends in CPUE as an index of abundance.

Methods

Past GLM standardisations for this halibut resource (e.g. Brodie *et al*., 2008) have generally been conducted assuming that CPUE is log-normally distributed. However, this approach has the disadvantage of necessitating the addition of some small constant k to the CPUE before taking logarithms, to cater for instances of zero catch. Furthermore, the results of such models were found to be sensitive to the value selected for k, and furthermore to exhibit deviations from the desired linearity in QQ plots.

For these reasons, the standardisations carried out in this paper have assumed an overdispersed Poisson distribution. Note that instances of a zero catch are not problematic for this approach. Figs 1-3 show diagnostic plots for the fits of Model 3 (see Appendix A) without interactions to the data sets for each of the three nations contributing. All are reasonably satisfactory in terms of QQ plots, and with the possible exception of the Portuguese data do not provide any obvious indications of heteroscedasticity..

Appendix A details the basis used to select the data considered in the standardisation exercises, the finer (than Division) spatial stratification considered, and the five alternative GLM standardisations computed for each nation’s data set. The first three of these include single factors only, but the final two include interactions between year and either latitude or depth factors to allow for the possibility of resource distribution shifts over time. Further analyses could consider both interactions together, but this has not been attempted as yet given that a coarse approach was required to calculate the open ocean areas for the depth strata.

For the Canadian data, model 3 has also been run excluding the 2008 data to investigate the effect of these data on the recent trend obtained. This run is referred to as 3b.

Results and Discussion

Results of the various standardisations carried out are reported in Tables 1, 2 and 3 for the commercial data from Canada, Spain and Portugal respectively. These results are plotted in Fig. 4, where they are also compared to the earlier GLM standardisations of Brodie *et al*. (2008), Fernández *et al*. (2007) and Vargas *et al.* (2008).

The three standardisations excluding interactions give very similar results, independent of the coarser or finer scale used for spatial factors, which suggests that CPUE trends have not been biased by recent concentration of fishing effort in areas of higher density. The trends obtained are also very similar to those of previous standardisations, except in the Canadian case where this analysis indicates a higher recent rate of increase (this is not a consequence of the addition of the 2008 data).

The introduction of interactions to these standardisations does however make a difference, indicating reduced recent rates of increase. This suggests that the recent increase in nominal CPUE is in part a reflection of a changed distribution of the halibut population, and does not entirely reflect an increase in abundance.

Acknowledgments

Scientific colleagues from Canada, Portugal and Spain are thanked for providing the data upon which the analyses of this paper were based.

References

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Fernández C, González F and González D. 2007. Standardized CPUE indices for Greenland Halibut in NAFO Regulatory Area of Divisions 3LMNO based on Spanish commercial catch rates. NAFO SRC Doc 07/31, Ser. No. N5383.

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Table 1: Standardised CPUE for the Canadian data, all normalised to 1 in 2003.

	1	2	3	3b	4	5
1998	0.77	0.77	0.70	0.70	1.05	0.83
1999	1.05	1.04	0.93	0.94	1.19	0.81
2000	1.58	1.55	1.50	1.50	1.56	1.47
2001	1.74	1.72	1.70	1.69	1.45	1.17
2002	1.40	1.38	1.36	1.36	1.27	1.44
2003	1.00	1.00	1.00	1.00	1.00	1.00
2004	1.13	1.14	1.10	1.10	1.37	0.76
2005	1.22	1.21	1.14	1.13	1.27	1.26
2006	3.07	3.05	2.73	2.70	1.94	2.28
2007	3.25	3.33	3.27	3.22	3.00	2.41
2008	4.24	4.34	4.16		3.00	2.49

Table 2: Standardised CPUE for the Spanish data, all normalised to 1 for 2000.

	1	2	3	4	5
1992	1.08	1.09	1.07	0.88	0.99
1993	0.93	0.94	0.92	0.81	0.95
1994	0.81	0.81	0.80	0.84	0.92
1995	1.04	1.06	1.08	0.78	0.97
1996	1.14	1.15	1.11	0.83	0.86
1997	1.05	1.06	1.04	0.87	1.09
1998	0.92	0.93	0.89	0.71	0.87
1999	0.64	0.66	0.67	0.70	0.65
2000	1.00	1.00	1.00	1.00	1.00
2001	0.91	0.91	0.90	0.85	0.97
2002	1.25	1.26	1.25	0.90	0.92
2003	0.86	0.88	0.89	0.70	0.96
2004	0.69	0.70	0.69	0.79	0.66
2005	0.82	0.82	0.81	0.88	0.69
2006	1.04	1.05	1.05	0.89	0.94
2007	2.20	2.21	2.18	1.26	1.89
2008	1.84	1.86	1.85	1.15	1.62

Table 3: Standardised CPUE for the Portuguese data, all normalised to 1 for 1998.

	1	2	3	4	5
1998	1.00	1.00	1.00	1.00	1.00
1999	1.13	1.12	1.12	0.90	1.20
2000	1.09	1.07	1.07	0.90	1.11
2001	0.88	0.87	0.87	0.84	0.73
2002	0.85	0.84	0.84	0.86	0.86
2003	0.83	0.81	0.81	0.88	0.88
2004	0.52	0.51	0.51	0.71	0.53
2005	0.95	0.92	0.90	0.95	0.91
2006	1.26	1.27	1.24	0.89	1.33
2007	1.50	1.51	1.48	1.12	0.96

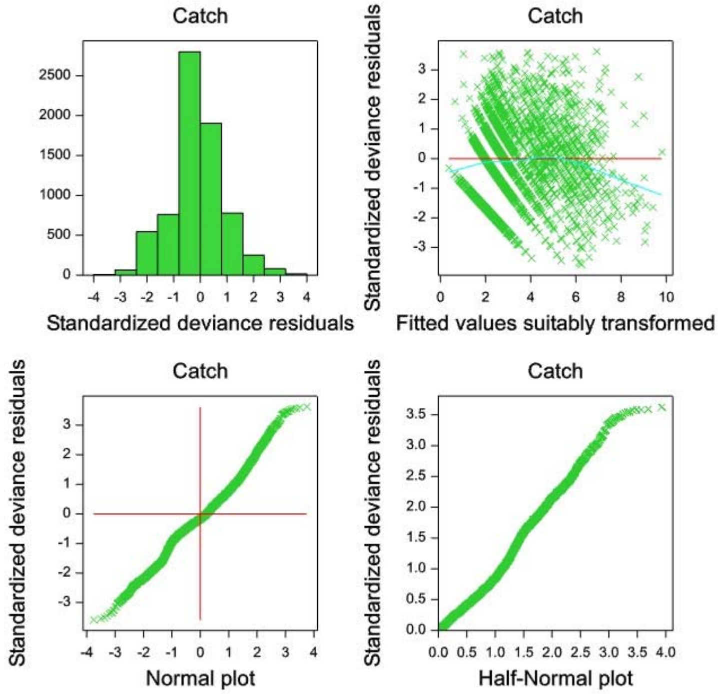

Fig. 1: Diagnostic plots for Canadian catch data for model 3.

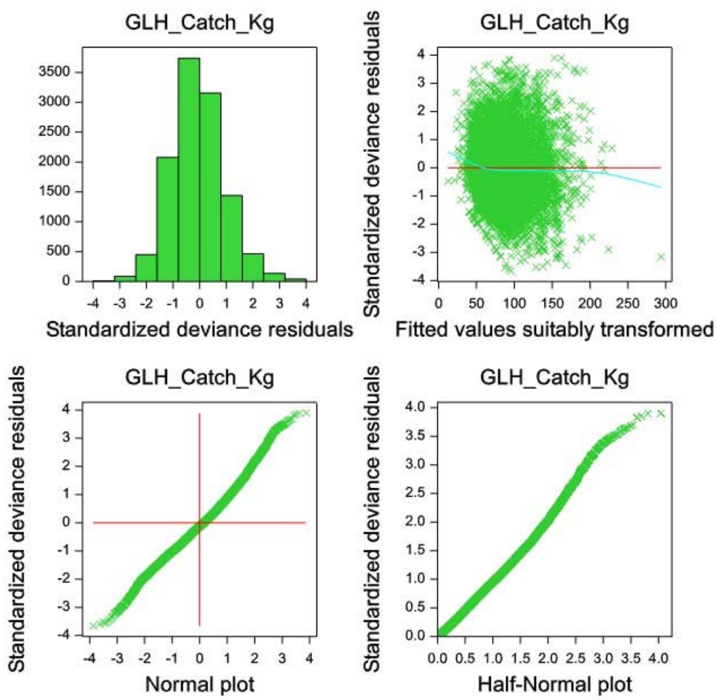

Fig. 2: Diagnostic plots for Spanish catch data for model 3.

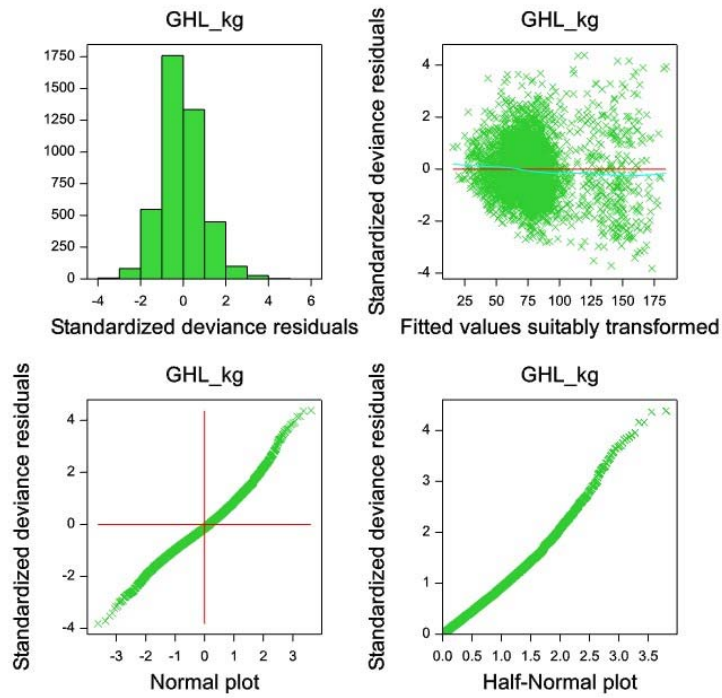

Fig. 3: Diagnostic plots for Portuguese catch data for model 3.

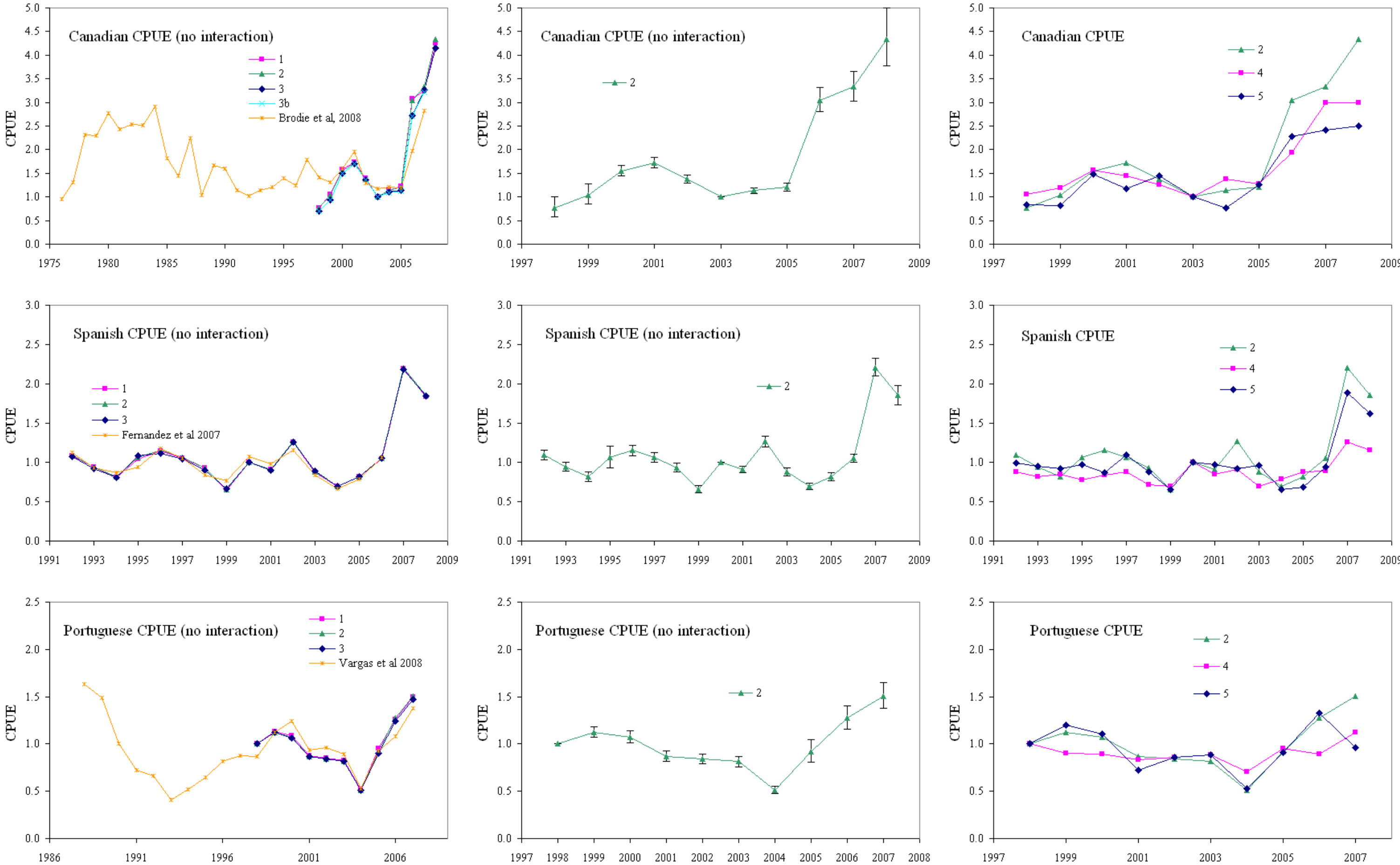

Fig. 4: Standardised CPUE without interactions (left and middle columns) and including two variants with interactions (right column). The middle column plots give the 90% CIs relative to the year for which the series concerned is normalised to 1. For the past Portuguese Vargas *et al.* (2008) series plotted, the average of the 3L, 3M and 3O series which they provide has been used.

APPENDIX A

The following General Linear Models (GLMs) were then fitted to the Canadian, Portuguese and Spanish catch (C) and effort (E) data:

Model 1:

$$\overline{\mathrm{E}}(C) = E^* \exp[\mu + \alpha_{Year} + \beta_{Month} + \gamma_{Vessel} + \delta_{Division}] \tag{1}$$

Model 2:

$$\overline{\mathrm{E}}(C) = E^* \exp[\mu + \alpha_{Year} + \beta_{Month} + \gamma_{Vessel} + \delta_{Division} + \phi_{Depth}] \tag{2}$$

Model 3:

$$\overline{\mathrm{E}}(C) = E^* \exp[\mu + \alpha_{Year} + \beta_{Month} + \gamma_{Vessel} + \theta_{Lat} + \phi_{Depth}] \tag{3}$$

Model 4:

$$\overline{\mathrm{E}}(C) = E^* \exp[\mu + \alpha_{Year} + \beta_{Month} + \gamma_{Vessel} + \delta_{Division} + \phi_{Depth} + \lambda_{DivisionxYear}] \tag{4}$$

Model 5:

$$\overline{\mathrm{E}}(C) = E^* \exp[\mu + \alpha_{Year} + \beta_{Month} + \gamma_{Vessel} + \theta_{Lat} + \phi_{Depth} + \eta_{DepthxYear}] \tag{5}$$

where:

$\overline{\mathrm{E}}(C)$ is the expected catch, where C is assumed to have an over-dispersion Poisson distribution,
E^* is the offset denoting effort,
μ is the intercept,
α_{Year} is the year effect,
β_{Month} is the month effect,
γ_{Vessel} is the vessel effect,
$\delta_{Division}$ is the division effect,
ϕ_{Depth} is the depth effect,
θ_{Lat} is the latitude effect,
$\lambda_{DivisionxYear}$ is the division x year interaction, and
$\eta_{DepthxYear}$ is the depth x year interaction.

Table A1 lists the factor levels for the Canadian, Spanish and Portuguese data. The depth and latitude strata have been determined as fine as possible subject to maintaining reasonable sample sizes for each spatial cell. The Canadian Vessel factor levels have been chosen to correspond to the Brodie *et al*. (2008) levels except that here, level "3125" also includes level "27125" of Brodie *et al.* (2008).

The analyses for each country have been based on mobile gear, directed at Greenland halibut/turbot.

For Canada, entries from Divisions 2G and 3O have been omitted because of the low sample sizes (13 and 7 respectively). In the Canadian data, prior to 1998 the depth was recorded in one category only: "251 fathoms and over" (except for one entry in 1997). The Canadian analyses have therefore omitted all data prior to 1998.

For the Spanish and Portuguese data, where both the start and end latitudes, dates and depths are available, the start latitude, date and depth of each trawl have been used.

Records with large residuals have also been excluded from the analyses. Any record with a residual greater than 3.5 or less than -3.5 after the initial Model 3 fit was excluded (29, 60 and 34 records were excluded for Canada, Spain and Portugal respectively).

Table A1 summarises details the factors used for the GLMs carried out for each national data set.

Table A1: Description of the factor levels for the Canadian, Spanish and Portuguese data. For the Division and Depth factors, the values in parentheses represent the size of the corresponding open ocean area in n.m^2.

	Canada		Spain		Portugal	
α_{Year}	1998-2008		1992-2008		1998-2007	
β_{Month}	12 months		12 months		12 months	
γ_{Vessel}	6 "CGT" levels:		58 vessels,		4 vessels,	
	"3123": Otter Trawl, 50-149t		each treated as a separate factor		each treated as a separate factor	
	"3124": Otter Trawl, 150-499t					
	"3125": Otter Trawl, 500-999t					
	"3126": Otter Trawl, 1000-1999t					
	"3127": Otter Trawl, >2000t					
	"3857": Twin Otter Trawl, >2000t					
$\delta_{Division}$	4 levels:		4 levels:		4 levels:	
	2H	(11776)	3L	(46338)	3L	(46338)
	2J	(25272)	3M	(17051)	3M	(17051)
	3K	(37051)	3N	(19523)	3N	(19523)
	3L	(46338)	3O	(20176)	3O	(20176)
ϕ_{Depth}	6 levels (in fathoms):		6 levels (in fathoms):		6 levels (in fathoms):	
	<400	(95986)	<800	(89989)	<800	(89994)
	400-449	(3748)	800-899	(1767)	800-849	(887)
	450-499	(3748)	900-999	(1955)	850-899	(887)
	500-549	(1136)	1000-1099	(1993)	900-949	(948)
	550-599	(939)	1100-1199	(2566)	950-999	(1017)
	600+	(14880)	>1200	(4817)	>1000	(9356)
θ_{Lat}	7 levels:		6 levels:		6 levels:	
	"2Hb": Div.2H, N of 56°30'N		"3Lb": Div.3L, N of 47°40'		"3Lb": Div.3L, N of 47°40'	
	"2Hc": Div.2H, S of 56°30'N		"3Ld": Div.3L, S of 47°40'		"3Ld": Div.3L, S of 47°40'	
	"2Ja": Div.2J, N of 53°50'N		"3Ma": Div.3M		"3Ma": Div.3M	
	"2Jc": Div.2J, S of 53°50'N		"3Nb": Div.3N, N of 44°30'		"3Nb": Div.3N, N of 44°30'	
	"3Kb": Div.3K, N of 50°50'N		"3Nd": Div.3N, S of 44°30'		"3Nd": Div.3N, S of 44°30'	
	"3Kd": Div.3K, S of 50°50'N		"3Od": Div.3O, S of 44°30'		"3Od": Div.3O, S of 44°30'	
	"3La": Div.3L					

CPUE time series

For the models without interactions, the CPUE time series are obtained directly from the year factors estimated:

$$CPUE_y = e^{\alpha_{Year}} \tag{A1}$$

The introduction of interactions with year requires that the standardized CPUE (assumed to provide an index of local density) be integrated over area to determine an index of abundance:

$$CPUE_y = \sum_{Division}\left[\exp\left(\alpha_{Year} + \delta_{Division} + \lambda_{DivisionxYear}\right)\frac{A_{Division}}{A_{Total}}\right] \tag{A2}$$

for the model with Division*Year interactions, and

$$CPUE_y = \sum_{Depth}\left[\exp\left(\alpha_{Year} + \phi_{Depth} + \eta_{DepthxYear}\right)\frac{A_{Depth}}{A_{Total}}\right] \quad \text{(A3)}$$

for the model with Depth*Year interactions, where:

$A_{Division} / A_{Depth}$ is the size of the open ocean area of the Division/Depth stratum, and

A_{Total} is the total size of the area considered (it is not strictly necessary to divide by A_{Total}, but this keeps the units and size of the standardised CPUE index comparable with those of the basic CPUE data).

Area sizes were available at the level of the NAFO strata for each Division. For $A_{Division}$, the sum of the areas of all the NAFO strata in a particular Division has simply been used. The NAFO strata are sorted into depth categories; however these categories do not correspond to the ones chosen for these analyses. To compute A_{Depth} For each of the depth categories used, the known areas for certain depth categories were divided in proportion to the depth range in each of the strata used.

In cases where a DivisionxYear or DepthxYear cell is empty of data so that the interaction term cannot computed, the average of the two closest cells has been used.