2016 年のミナミマグロのコア船データおよび CPUE の更新

Update of the core vessel data and CPUE for southern bluefin tuna in 2016

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要旨

本文書は、CCSBT の管理方式に用いられるミナミマグロの資源指数であるコア船 CPUE についてまとめたものである。データ準備、GLM を用いた CPUE 標準化、エリア重み付けについて記述する。データは 2015 年までに更新した。2015 年の指数は、ベース GLM モデルによる W0.8 及び W0.5 において、この 10 年間の平均より高く、2014 年より大きく増加した。

Summary

This paper summarizes the core vessel CPUE which is an abundance index of southern bluefin tuna used for the Management Procedure in CCSBT. It describes data preparation, CPUE standardization using GLM and area weighting. The data were updated up to 2015. The index values in 2015, W0.8 and W0.5 by the base GLM model, are higher than the average in the last 10 years, and much higher than those in 2014.

Introduction

Stock management of southern bluefin tuna *Thunnus maccoyii* in CCSBT entered a new era with the agreement and implementation of Management Procedure (MP) in 2011. The adapted MP in CCSBT determines TAC by the pre-specified rule using longline CPUE and aerial survey index, so that those indices should be evaluated with high transparency. However, because shot-by-shot data for Japanese longline is critically important intellectual property for fishermen, Japanese government is not able to open it for CCSBT scientists. Therefore, we describe the data preparation and indices made in detail in the present paper and try to ensure transparency and evaluation.

Data preparation

The dataset used was made from shot-by-shot records of Japanese longline from Japan (1986-2015), from Australia (RTMP data; 1989-2005) and from New Zealand (Joint venture; 1990-2015). Data from Japan were based on logbook data, except that RTMP data were used for the most recent years if logbook data were not yet available and RTMP data of the vessel were available. Note that data of operations especially for non-SBT targeting will be added to the dataset one or two years later after logbook data become available.

Dataset was limited within CCSBT statistical areas between Area 4 and Area 9 and months between April and September. CPUE was defined as the number of SBT for age 4 and older caught per 1000 hooks. Proportion of age 4+ by 5x5 degree square and month was calculated from the CCSBT catch-at-age database including catch-at-age data made by Japan for 2014 and 2015.

Vessels which caught a large number of SBT (called "core vessels") were selected with x (top rank of SBT catch in a year) = 56 and y (number of years in the top ranks) = 3. A subset of vessels with a total data records of 179,520 was extracted from entire vessels (Table 1). The number of core vessels chosen ranged from 35 to 105 in each year.

For reference, the number of area operated in terms of 5x5-degree / month, 1x1-degree / month and the number of 1x1-degree squares in 5x5-degree square are shown in Fig. 1 for all operations and operations with positive SBT (age 4+) catch.

Following corrections were made to the dataset before CPUE standardization: deleted records for operations in south of 50 degree South; combined Area 5 and Area 6 into Area 56; and deleted records for operations with extremely high CPUE (>120) as outliers. The shot-by-shot data were aggregated into 5x5 degrees and month. Aggregated data with little effort (< 10,000 hooks) were deleted.

CPUE standardization

CPUE were standardized with GLM using SAS (version 9.4). Small constant of 0.2,

10% of nominal CPUE, was added into CPUE for age 4+ before log transformation (Nishida and Tsuji 1998).

Base series:

$$log(CPUE+0.2) = Intercept + Year + Month + Area + Lat5 + BET\_CPUE + YFT\_CPUE + (Month*Area) + (Year*Lat5) + (Year*Area) + Error,$$

Two additional CPUE series were made for monitoring purpose of the status of the stock and MP implementation.

Monitoring series 1 (Reduced base model):

$$log(CPUE+0.2) = Intercept + Year + Month + Area + Lat5 + BET\_CPUE + YFT\_CPUE + (Month*Area) + Error,$$

Monitoring series 2: Same procedure as applied in Base series, but the data used were prepared at the shot-by-shot daily level rather than the aggregated 5x5-degree/month level.

Estimated parameter values for Base case are shown in Table 2. ANOVA statistics for the three cases are shown in Table 3. Standardized CPUE (ls-mean) and QQ plots of residuals are shown in Fig.2 and Fig. 3.

AIC and BIC were calculated for the base model and the reduced base model which are nested models each other. The base model is selected in terms of AIC, but not in BIC (Table 4).

Area weighted standardized CPUE

With the estimated parameters obtained from CPUE standardization by GLM, the Constant Square (CS) and Variable Square (VS) abundance indices were computed by the following equations:

$$CS_{4+,y} = \sum_m \sum_a \sum_l (AI_{CS})_{(1969\text{-}present)} [\exp(Intercept + Year + Month + Area + Lat5 + BET\_CPUE + YFT\_CPUE + (Month*Area) + (Year*Lat5) + (Year*Area) + \sigma^2/2) - 0.2]$$

$$VS_{4+,y} = \sum_m \sum_a \sum_l (AI_{VS})_{ymal} [\exp(Intercept + Year + Month + Area + Lat5 + BET\_CPUE + YFT\_CPUE + (Month*Area) + (Year*Lat5) + (Year*Area) + \sigma^2/2) - 0.2]$$

where

$CS_{4+,y}$ is the CS abundance index for age 4+ and y-th year,

$VS_{4+,y}$	is the VS abundance index for age 4+ and y-th year,
$(AI_{CS})_{(1969\text{-present})}$	is the area index of the CS model for the period 1969-present,
$(AI_{VS})_{ymal}$	is the area index of the VS model for y-th year, m-th month, a-th SBT statistical area, and l-th latitude,
σ	is the mean square error in the GLM analyses,

Then, w0.5 and w0.8 (B-ratio and geostat proxies) were calculated using the equation below.

$$I_{y,a} = wCS_{y,a} + (1-w)VS_{y,a}$$

The area weighted CPUE value in the most recent year (2015), which was mainly from RTMP and targeting on SBT, was corrected from the average ratio of CPUEs between RTMP and Logbook data of recent three years according to the agreement in the CPUE web-meeting held in March 2010. The constant was 0.939, the average in three years (1.009 in 2012, 0.790 in 2013 and 1.0180 in 2014 of ratio Logbook based CPUE in W0.8 / RTMP based CPUE in W0.8 in the core vessel dataset[1]).

The area weighted CPUE series between 1986 and 2015 were calibrated to the historical time series since 1969 based on the agreed method (SAG9 Report in 2008, attachment 5) derived from GLM model using data from all vessels described in Nishida and Tsuji (1998). At the 3rd OMMP Technical meeting held in Seattle in 2010, it was agreed that the pre-1986 series used in MP implementation will be fixed at the values estimated based on data to 2008 only. Calibration would thus in future always be based upon the 1986-2008 points of this series.

Calculated area weighted standardized CPUE are shown in Table 5 and Fig. 4. The relative index values of W0.8 in 2015 with the base GLM model (1.358) is high as 182% of the previous 10 years mean (0.745). That of W0.5 in 2015 (1.011) is high as 180% of the previous 10 years mean (0.562).

The trends of the indices among GLM models (Base vs Reduced Base) were similar to each other but different since 2010. Differences in the two GLM models were *Year*Lat5 and Year*Area* which were included in Base but not included in Reduced Base. Nominal CPUE by year and latitude in five degrees are shown in Fig. 5. Year trends were different by latitude, such as nominal CPUE since 2010 were much higher than in

[1] X=58 was used for core vessels selection because there were some years that year*area interaction were not estimated in GLM. In addition, the threshold to be deleted for the little effort was lowered to 7000 instead of 10,000.

the 1990s in 40S and 45S, but similar in 35S except 2015. Nominal CPUE by year and Area are shown in Fig. 6. Year trends were different by Area, such as nominal CPUE since 2010 were much higher than in the 1990s in Area 7 and Area 9, but similar or lower in other Areas. These different trends were taken accounted in the Base model, but not in Reduced Base model, and may be resulted in the differences in the indices.

Reference

Nishida, T., and S. Tsuji. 1998. Estimation of abundance indices of southern bluefin tuna (*Thunnus maccoyii*) based on the coarse scale Japanese longline fisheries data (1969-97). CCSBT/SC/9807/13.27.

Table 1. Number of records in the dataset used.

Year	All vessels Japan	All vessels Australia	All vessels New Zealand	All vessels Total	Core vessel Total	Core vessel Vessel number
1986	27,005			27,005	4,068	35
1987	26,759			26,759	4,804	41
1988	24,418			24,418	5,353	49
1989	24,315	1,156		25,471	6,897	63
1990	19,899	504	475	20,878	6,546	73
1991	18,316	1,204	460	19,980	7,062	72
1992	17,233	1,717	499	19,449	7,012	85
1993	14,797	2,001	486	17,284	6,762	82
1994	12,610	1,394	268	14,272	6,136	91
1995	12,804	800	373	13,977	6,456	97
1996	14,854			14,854	7,057	97
1997	16,322		379	16,701	7,832	93
1998	16,310		310	16,620	8,268	105
1999	14,414		306	14,720	7,909	97
2000	11,746		265	12,011	7,284	98
2001	14,075		198	14,273	7,962	101
2002	10,721		228	10,949	6,273	91
2003	11,563		294	11,857	6,538	90
2004	13,101		349	13,450	8,522	94
2005	13,848		198	14,046	8,809	95
2006	9,124		183	9,307	6,523	85
2007	5,540		387	5,927	4,515	80
2008	6,815		167	6,982	5,295	89
2009	5,016		231	5,247	4,423	74
2010	4,102		144	4,246	3,631	66
2011	4,757		151	4,908	4,019	65
2012	4,432		163	4,595	3,703	71
2013	4,157		148	4,305	3,338	68
2014	4,727		186	4,913	3,421	64
2015	4,428		181	4,609	3,102	63
Total	388,208	8,776	7,029	404,013	179,520	

Data are from Area 4-9 and month 4-9.

Table 2. Estimated parameter values in GLM Base model

Parameter		Estimate	Biased	StdErr	tValue	Probt
Intercept		2.4761	1	0.5040	4.91	<.0001
Year	1986	−1.6413	1	0.5431	−3.02	0.003
Year	1987	−1.5341	1	0.5490	−2.79	0.005
Year	1988	−2.14844	1	0.527195	−4.08	<.0001
Year	1989	−1.77469	1	0.536654	−3.31	0.001
Year	1990	−1.25316	1	0.520261	−2.41	0.0161
Year	1991	−2.18313	1	0.524468	−4.16	<.0001
Year	1992	−1.56969	1	0.569357	−2.76	0.0059
Year	1993	−1.56178	1	0.570213	−2.74	0.0062
Year	1994	−0.9965	1	0.610453	−1.63	0.1027
Year	1995	−1.26862	1	0.598372	−2.12	0.0341
Year	1996	−1.82803	1	0.967594	−1.89	0.059
Year	1997	−1.12458	1	0.548709	−2.05	0.0405
Year	1998	−1.14625	1	0.574733	−1.99	0.0462
Year	1999	−1.08821	1	0.546366	−1.99	0.0465
Year	2000	−1.68538	1	0.574205	−2.94	0.0034
Year	2001	−1.30753	1	0.550875	−2.37	0.0177
Year	2002	−1.0114	1	0.615909	−1.64	0.1007
Year	2003	−1.52546	1	0.635779	−2.4	0.0165
Year	2004	−1.4767	1	0.581067	−2.54	0.0111
Year	2005	−1.44198	1	0.623146	−2.31	0.0207
Year	2006	−1.25097	1	0.62567	−2	0.0457
Year	2007	−2.08391	1	0.697578	−2.99	0.0028
Year	2008	−0.17286	1	0.579949	−0.3	0.7657
Year	2009	−0.60112	1	0.68826	−0.87	0.3825
Year	2010	−0.09867	1	0.84964	−0.12	0.9076
Year	2011	−0.62046	1	0.624907	−0.99	0.3208
Year	2012	−0.58693	1	0.658592	−0.89	0.3729
Year	2013	−0.24931	1	0.705034	−0.35	0.7236
Year	2014	−0.42152	1	0.708175	−0.6	0.5517
Year	2015	0	1			
Month	4	−0.62831	1	0.208421	−3.01	0.0026
Month	5	−0.43714	1	0.19368	−2.26	0.0241
Month	6	−0.47227	1	0.190224	−2.48	0.0131
Month	7	−0.30348	1	0.182962	−1.66	0.0973
Month	8	−0.15978	1	0.182313	−0.88	0.3809
Month	9	0	1			
Area	4	0.419591	1	0.432658	0.97	0.3322
Area	7	−1.17132	1	0.568162	−2.06	0.0393
Area	8	−0.70421	1	0.460789	−1.53	0.1266
Area	9	−0.49539	1	0.401359	−1.23	0.2172
Area	56	0	1			
Lat5	30	−2.95091	1	0.517912	−5.7	<.0001
Lat5	35	−0.82994	1	0.448	−1.85	0.064
Lat5	40	0.157384	1	0.438363	0.36	0.7196
Lat5	45	0	1			
BETcpue5		−0.14175	0	0.010413	−13.61	<.0001
YFTcpue5		−0.07788	0	0.005412	−14.39	<.0001
Month*Area	4 4	−1.32359	1	0.255761	−5.18	<.0001
Month*Area	4 7	1.171841	1	0.294941	3.97	<.0001
Month*Area	4 8	−0.83321	1	0.277426	−3	0.0027
Month*Area	4 9	0.207987	1	0.222749	0.93	0.3505
Month*Area	4 56	0	1			
Month*Area	5 4	−0.5743	1	0.241425	−2.38	0.0174
Month*Area	5 7	1.000676	1	0.281732	3.55	0.0004
Month*Area	5 8	−0.48337	1	0.257299	−1.88	0.0604
Month*Area	5 9	0.234837	1	0.205386	1.14	0.253
Month*Area	5 56	0	1			
Month*Area	6 4	−0.24299	1	0.237911	−1.02	0.3072
Month*Area	6 7	0.991517	1	0.283342	3.5	0.0005
Month*Area	6 8	0.100654	1	0.25845	0.39	0.697
Month*Area	6 9	0.369824	1	0.203394	1.82	0.0691
Month*Area	6 56	0	1			
Month*Area	7 4	0.106356	1	0.233996	0.45	0.6495
Month*Area	7 7	0.781872	1	0.292843	2.67	0.0076
Month*Area	7 8	0.452886	1	0.2139	2.12	0.0343
Month*Area	7 9	0.451102	1	0.198735	2.27	0.0233
Month*Area	7 56	0	1			
Month*Area	8 4	−0.1058	1	0.241479	−0.44	0.6613
Month*Area	8 7	0.167956	1	0.395138	0.43	0.6708
Month*Area	8 8	0.451961	1	0.203585	2.22	0.0265
Month*Area	8 9	0.397691	1	0.203076	1.96	0.0503
Month*Area	8 56	0	1			
Month*Area	9 4	0	1			
Month*Area	9 7	0	1			
Month*Area	9 8	0	1			
Month*Area	9 9	0	1			
Month*Area	9 56	0	1			
Year*Lat5	1986 30	1.548944	1	0.628074	2.47	0.0137
Year*Lat5	1986 35	1.112017	1	0.534268	2.08	0.0375
Year*Lat5	1986 40	−0.22698	1	0.524908	−0.43	0.6655
Year*Lat5	1986 45	0	1			
Year*Lat5	1987 30	1.827578	1	0.658846	2.77	0.0056
Year*Lat5	1987 35	0.713073	1	0.527747	1.35	0.1767
Year*Lat5	1987 40	−0.2235	1	0.509446	−0.44	0.6609
Year*Lat5	1987 45	0	1			
Year*Lat5	1988 30	2.073463	1	0.59934	3.46	0.0005
Year*Lat5	1988 35	0.800395	1	0.496846	1.61	0.1073
Year*Lat5	1988 40	−0.33354	1	0.480973	−0.69	0.4881
Year*Lat5	1988 45	0	1			
Year*Lat5	1989 30	2.221146	1	0.697083	3.19	0.0015
Year*Lat5	1989 35	0.94868	1	0.53521	1.77	0.0764
Year*Lat5	1989 40	−0.08279	1	0.506924	−0.16	0.8703
Year*Lat5	1989 45	0	1			
Year*Lat5	1990 30	1.415342	1	0.600053	2.36	0.0184
Year*Lat5	1990 35	0.42268	1	0.500865	0.84	0.3988
Year*Lat5	1990 40	−0.28112	1	0.473224	−0.59	0.5525
Year*Lat5	1990 45	0	1			
Year*Lat5	1991 30	2.202883	1	0.608405	3.62	0.0003
Year*Lat5	1991 35	0.881488	1	0.523406	1.68	0.0923
Year*Lat5	1991 40	0.094856	1	0.51061	0.19	0.8526
Year*Lat5	1991 45	0	1			
Year*Lat5	1992 30	1.497523	1	0.647907	2.31	0.0209
Year*Lat5	1992 35	0.574472	1	0.559013	1.03	0.3042
Year*Lat5	1992 40	−0.12557	1	0.544538	−0.23	0.8176
Year*Lat5	1992 45	0	1			
Year*Lat5	1993 30	1.271902	1	0.653298	1.95	0.0516
Year*Lat5	1993 35	0.003862	1	0.543954	0.01	0.9943
Year*Lat5	1993 40	0.076088	1	0.527712	0.14	0.8854
Year*Lat5	1993 45	0	1			
Year*Lat5	1994 30	0.884671	1	0.702139	1.26	0.2078
Year*Lat5	1994 35	0.069531	1	0.601295	0.12	0.9079
Year*Lat5	1994 40	0.097199	1	0.578001	0.17	0.8665
Year*Lat5	1994 45	0	1			
Year*Lat5	1995 30	1.634858	1	0.720908	2.27	0.0234
Year*Lat5	1995 35	0.24628	1	0.639727	0.38	0.7003
Year*Lat5	1995 40	−0.02106	1	0.618736	−0.03	0.9728
Year*Lat5	1995 45	0	1			
Year*Lat5	1996 30	1.617126	1	0.68709	2.35	0.0187
Year*Lat5	1996 35	0.107732	1	0.576985	0.19	0.8519
Year*Lat5	1996 40	−0.04767	1	0.549977	−0.09	0.9309
Year*Lat5	1996 45	0	1			
Year*Lat5	1997 30	1.397705	1	0.688694	2.03	0.0425
Year*Lat5	1997 35	0.711543	1	0.557609	1.28	0.202
Year*Lat5	1997 40	0.044809	1	0.537809	0.08	0.9336
Year*Lat5	1997 45	0	1			
Year*Lat5	1998 30	1.307439	1	0.631131	2.07	0.0384
Year*Lat5	1998 35	0.410395	1	0.538478	0.76	0.446
Year*Lat5	1998 40	−0.3415	1	0.523138	−0.65	0.5139
Year*Lat5	1998 45	0	1			
Year*Lat5	1999 30	0.978039	1	0.644784	1.52	0.1294
Year*Lat5	1999 35	0.455375	1	0.553172	0.82	0.4105
Year*Lat5	1999 40	−0.13004	1	0.537726	−0.24	0.8089
Year*Lat5	1999 45	0	1			
Year*Lat5	2000 30	1.314707	1	0.660842	1.99	0.0467
Year*Lat5	2000 35	0.650976	1	0.596697	1.09	0.2754
Year*Lat5	2000 40	0.183833	1	0.579333	0.32	0.751
Year*Lat5	2000 45	0	1			
Year*Lat5	2001 30	1.271732	1	0.618571	2.06	0.0399
Year*Lat5	2001 35	0.28077	1	0.539955	0.52	0.6031
Year*Lat5	2001 40	−0.17117	1	0.51855	−0.33	0.7414
Year*Lat5	2001 45	0	1			
Year*Lat5	2002 30	1.068802	1	0.756883	1.41	0.158
Year*Lat5	2002 35	0.866764	1	0.656211	1.32	0.1867
Year*Lat5	2002 40	−0.16952	1	0.59076	−0.29	0.7742
Year*Lat5	2002 45	0	1			
Year*Lat5	2003 30	1.353585	1	0.702751	1.93	0.0542
Year*Lat5	2003 35	0.959025	1	0.660119	1.45	0.1464
Year*Lat5	2003 40	−0.16445	1	0.643941	−0.26	0.7984
Year*Lat5	2003 45	0	1			
Year*Lat5	2004 30	1.584891	1	0.657434	2.41	0.016
Year*Lat5	2004 35	1.024217	1	0.583499	1.76	0.0793
Year*Lat5	2004 40	−0.26625	1	0.567368	−0.47	0.6389
Year*Lat5	2004 45	0	1			
Year*Lat5	2005 30	1.673054	1	0.668652	2.5	0.0124
Year*Lat5	2005 35	0.820075	1	0.56738	1.45	0.1485
Year*Lat5	2005 40	−0.4976	1	0.559192	−0.89	0.3736
Year*Lat5	2005 45	0	1			
Year*Lat5	2006 30	1.051328	1	0.720982	1.46	0.1449
Year*Lat5	2006 35	0.604442	1	0.667633	0.91	0.3654
Year*Lat5	2006 40	−0.32329	1	0.655641	−0.49	0.622
Year*Lat5	2006 45	0	1			
Year*Lat5	2007 30	2.169473	1	0.757143	2.87	0.0042
Year*Lat5	2007 35	1.357086	1	0.724266	1.87	0.0611
Year*Lat5	2007 40	0.308628	1	0.719697	0.43	0.6681
Year*Lat5	2007 45	0	1			
Year*Lat5	2008 30	0.497594	1	0.628557	0.79	0.4286
Year*Lat5	2008 35	−0.10793	1	0.538157	−0.2	0.8411
Year*Lat5	2008 40	−0.39654	1	0.529476	−0.75	0.454
Year*Lat5	2008 45	0	1			
Year*Lat5	2009 30	0.228261	1	0.752986	0.3	0.7618
Year*Lat5	2009 35	0.451036	1	0.720679	0.63	0.5315
Year*Lat5	2009 40	0.001773	1	0.711543	0	0.998
Year*Lat5	2009 45	0	1			
Year*Lat5	2010 30	−0.28516	1	0.920429	−0.31	0.7567
Year*Lat5	2010 35	−0.28572	1	0.891128	−0.32	0.7485
Year*Lat5	2010 40	−0.39476	1	0.881025	−0.45	0.6541
Year*Lat5	2010 45	0	1			
Year*Lat5	2011 30	0.610857	1	0.66677	0.92	0.3597
Year*Lat5	2011 35	0.48261	1	0.58717	0.82	0.4112
Year*Lat5	2011 40	0.044371	1	0.57936	0.08	0.939
Year*Lat5	2011 45	0	1			
Year*Lat5	2012 30	0.470222	1	0.697955	0.67	0.5005
Year*Lat5	2012 35	−0.06135	1	0.633641	−0.1	0.9229
Year*Lat5	2012 40	−0.66695	1	0.619484	−1.08	0.2817
Year*Lat5	2012 45	0	1			
Year*Lat5	2013 30	0.131019	1	0.751121	0.17	0.8615
Year*Lat5	2013 35	−0.13917	1	0.700826	−0.2	0.8426
Year*Lat5	2013 40	−0.49355	1	0.687932	−0.72	0.4732
Year*Lat5	2013 45	0	1			
Year*Lat5	2014 30	0.100685	1	0.755652	0.13	0.894
Year*Lat5	2014 35	−0.0021	1	0.701947	0	0.9976
Year*Lat5	2014 40	−0.30384	1	0.696811	−0.44	0.6628
Year*Lat5	2014 45	0	1			
Year*Lat5	2015 30	0	1			
Year*Lat5	2015 35	0	1			
Year*Lat5	2015 40	0	1			
Year*Lat5	2015 45	0	1			
Year*Area	1986 4	0.04449	1	0.499384	0.09	0.929
Year*Area	1986 7	0.754312	1	0.591527	1.28	0.2023
Year*Area	1986 8	0.090369	1	0.515171	0.18	0.8608
Year*Area	1986 9	0.533375	1	0.460578	1.16	0.2469
Year*Area	1986 56	0	1			
Year*Area	1987 4	−0.53155	1	0.527274	−1.01	0.3135
Year*Area	1987 7	0.616505	1	0.583664	1.06	0.2909
Year*Area	1987 8	0.210344	1	0.512113	0.41	0.6813
Year*Area	1987 9	0.727494	1	0.452694	1.61	0.1082
Year*Area	1987 56	0	1			
Year*Area	1988 4	−0.45138	1	0.467545	−0.97	0.3344
Year*Area	1988 7	1.076322	1	0.569564	1.89	0.0589
Year*Area	1988 8	0.665481	1	0.499832	1.33	0.1832
Year*Area	1988 9	1.281349	1	0.427	3	0.0027
Year*Area	1988 56	0	1			
Year*Area	1989 4	−0.37007	1	0.519586	−0.71	0.4764
Year*Area	1989 7	0.780611	1	0.578229	1.35	0.1771
Year*Area	1989 8	0.102544	1	0.491148	0.21	0.8346
Year*Area	1989 9	0.452176	1	0.424995	1.06	0.2874
Year*Area	1989 56	0	1			
Year*Area	1990 4	−0.18899	1	0.466648	−0.4	0.6855
Year*Area	1990 7	0.3538	1	0.565993	0.63	0.532

Table 2 (cont.)

Parameter		Estimate	Biased	StdErr	tValue	Probt
Year*Area	1990 8	0.280435	1	0.500948	0.56	0.5757
Year*Area	1990 9	0.158693	1	0.418798	0.38	0.7048
Year*Area	1990 56	0	1			
Year*Area	1991 4	0.416383	1	0.45199	0.92	0.357
Year*Area	1991 7	0.917494	1	0.565393	1.62	0.1047
Year*Area	1991 8	0.565016	1	0.493829	1.14	0.2527
Year*Area	1991 9	0.692095	1	0.413794	1.67	0.0945
Year*Area	1991 56	0	1			
Year*Area	1992 4	0.247002	1	0.460517	0.54	0.5918
Year*Area	1992 7	0.609394	1	0.568881	1.07	0.2842
Year*Area	1992 8	0.301403	1	0.492026	0.61	0.5402
Year*Area	1992 9	0.504151	1	0.418328	1.21	0.2282
Year*Area	1992 56	0	1			
Year*Area	1993 4	1.042584	1	0.481729	2.16	0.0305
Year*Area	1993 7	0.813495	1	0.584237	1.39	0.1639
Year*Area	1993 8	0.944787	1	0.505241	1.87	0.0616
Year*Area	1993 9	0.714797	1	0.424941	1.68	0.0927
Year*Area	1993 56	0	1			
Year*Area	1994 4	0.201827	1	0.548023	0.37	0.7127
Year*Area	1994 7	0.311227	1	0.640235	0.49	0.6269
Year*Area	1994 8	0.594096	1	0.570768	1.04	0.298
Year*Area	1994 9	−0.09697	1	0.495842	−0.2	0.845
Year*Area	1994 56	0	1			
Year*Area	1995 4	0.024554	1	0.546743	0.04	0.9642
Year*Area	1995 7	1.007373	1	0.62218	1.62	0.1055
Year*Area	1995 8	0.749761	1	0.566931	1.32	0.1861
Year*Area	1995 9	0.376215	1	0.504263	0.75	0.4557
Year*Area	1995 56	0	1			
Year*Area	1996 4	0.604285	1	0.824951	0.73	0.4639
Year*Area	1996 7	1.008046	1	0.946531	1.06	0.287
Year*Area	1996 8	1.302347	1	0.916099	1.42	0.1552
Year*Area	1996 9	0.680604	1	0.851166	0.8	0.424
Year*Area	1996 56	0	1			
Year*Area	1997 4	−0.26062	1	0.541647	−0.48	0.6304
Year*Area	1997 7	0.144275	1	0.594451	0.24	0.8083
Year*Area	1997 8	−0.22514	1	0.571617	−0.39	0.6937
Year*Area	1997 9	−0.27957	1	0.476226	−0.59	0.5572
Year*Area	1997 56	0	1			
Year*Area	1998 4	−0.49757	1	0.470635	−1.06	0.2905
Year*Area	1998 7	0.146371	1	0.597012	0.25	0.8063
Year*Area	1998 8	0.332626	1	0.520698	0.64	0.523
Year*Area	1998 9	0.339491	1	0.445526	0.76	0.4461
Year*Area	1998 56	0	1			
Year*Area	1999 4	−0.39099	1	0.490679	−0.8	0.4256
Year*Area	1999 7	0.186992	1	0.594312	0.31	0.7531
Year*Area	1999 8	0.15599	1	0.523151	0.3	0.7656
Year*Area	1999 9	0.057786	1	0.456091	0.13	0.8992
Year*Area	1999 56	0	1			
Year*Area	2000 4	0.169564	1	0.488079	0.35	0.7283
Year*Area	2000 7	0.478228	1	0.586672	0.82	0.415
Year*Area	2000 8	0.755249	1	0.549205	1.38	0.1692
Year*Area	2000 9	0.233993	1	0.4507	0.52	0.6037
Year*Area	2000 56	0	1			
Year*Area	2001 4	−0.03603	1	0.483824	−0.07	0.9406
Year*Area	2001 7	0.464657	1	0.586945	0.79	0.4286
Year*Area	2001 8	0.446326	1	0.547474	0.82	0.415
Year*Area	2001 9	0.528862	1	0.454583	1.16	0.2448
Year*Area	2001 56	0	1			
Year*Area	2002 4	−0.60345	1	0.584284	−1.03	0.3018
Year*Area	2002 7	0.303448	1	0.669766	0.45	0.6505
Year*Area	2002 8	−0.50169	1	0.593448	−0.85	0.398
Year*Area	2002 9	0.586216	1	0.498198	1.18	0.2394
Year*Area	2002 56	0	1			
Year*Area	2003 4	0.088735	1	0.505888	0.18	0.8608
Year*Area	2003 7	0.174762	1	0.672129	0.26	0.7949
Year*Area	2003 8	0.329919	1	0.61112	0.54	0.5893
Year*Area	2003 9	0.672687	1	0.498537	1.35	0.1773
Year*Area	2003 56	0	1			
Year*Area	2004 4	−0.19223	1	0.478174	−0.4	0.6877
Year*Area	2004 7	0.280427	1	0.690271	0.41	0.6846
Year*Area	2004 8	0.769416	1	0.509655	1.51	0.1312
Year*Area	2004 9	0.406988	1	0.441489	0.92	0.3567
Year*Area	2004 56	0	1			
Year*Area	2005 4	−0.77898	1	0.493775	−1.58	0.1148
Year*Area	2005 7	0.103486	1	0.688687	0.15	0.8806
Year*Area	2005 8	0.740136	1	0.553893	1.34	0.1816
Year*Area	2005 9	0.44366	1	0.475025	0.93	0.3504
Year*Area	2005 56	0	1			
Year*Area	2006 4	−0.41738	1	0.498259	−0.84	0.4023
Year*Area	2006 7	−0.28982	1	0.641281	−0.45	0.6514
Year*Area	2006 8	0.324419	1	0.543251	0.6	0.5504
Year*Area	2006 9	−0.30153	1	0.454215	−0.66	0.5068
Year*Area	2006 56	0	1			
Year*Area	2007 4	−0.60139	1	0.468418	−1.28	0.1993
Year*Area	2007 7	−0.04756	1	0.637257	−0.07	0.9405
Year*Area	2007 8	0.013842	1	0.521997	0.03	0.9788
Year*Area	2007 9	−0.19359	1	0.449806	−0.43	0.667
Year*Area	2007 56	0	1			
Year*Area	2008 4	−0.28626	1	0.478286	−0.6	0.5495
Year*Area	2008 7	−0.16734	1	0.676568	−0.25	0.8047
Year*Area	2008 8	−0.51902	1	0.532054	−0.98	0.3294
Year*Area	2008 9	−0.8028	1	0.4586	−1.75	0.0801
Year*Area	2008 56	0	1			
Year*Area	2009 4	0.400229	1	0.4707	0.85	0.3952
Year*Area	2009 7	0.272234	1	0.695814	0.39	0.6956
Year*Area	2009 8	−0.5747	1	0.531572	−1.08	0.2797
Year*Area	2009 9	−0.45266	1	0.447562	−1.01	0.3119
Year*Area	2009 56	0	1			
Year*Area	2010 4	−0.1561	1	0.496056	−0.31	0.753
Year*Area	2010 7	0.587541	1	0.681569	0.86	0.3887
Year*Area	2010 8	0.182196	1	0.558799	0.33	0.7444
Year*Area	2010 9	−0.22366	1	0.473906	−0.47	0.637
Year*Area	2010 56	0	1			
Year*Area	2011 4	−0.51134	1	0.46618	−1.1	0.2728
Year*Area	2011 7	0.52884	1	0.671732	0.79	0.4312
Year*Area	2011 8	−0.28163	1	0.534219	−0.53	0.5981
Year*Area	2011 9	−0.10238	1	0.454754	−0.23	0.8219
Year*Area	2011 56	0	1			
Year*Area	2012 4	−0.86968	1	0.469451	−1.85	0.064
Year*Area	2012 7	1.336751	1	0.655949	2.04	0.0417
Year*Area	2012 8	0.182327	1	0.541262	0.34	0.7363
Year*Area	2012 9	0.763276	1	0.463117	1.65	0.0994
Year*Area	2012 56	0	1			
Year*Area	2013 4	−0.53332	1	0.489891	−1.09	0.2764
Year*Area	2013 7	0.310539	1	0.689631	0.45	0.6525
Year*Area	2013 8	0.209091	1	0.561404	0.37	0.7096
Year*Area	2013 9	0.237357	1	0.481107	0.49	0.6218
Year*Area	2013 56	0	1			
Year*Area	2014 4	−0.62702	1	0.503749	−1.24	0.2133
Year*Area	2014 7	0.791654	1	0.688976	1.15	0.2506
Year*Area	2014 8	0.05497	1	0.578125	0.1	0.9243
Year*Area	2014 9	0.545994	1	0.498872	1.09	0.2738
Year*Area	2014 56	0	1			
Year*Area	2015 4	0	1			
Year*Area	2015 7	0	1			
Year*Area	2015 8	0	1			
Year*Area	2015 9	0	1			
Year*Area	2015 56	0	1			

Table 3. ANOVA statistics

Base

HypothesisType	Source	DF	SS	MS	FValue	ProbF
2	Year	29	170.883	5.893	11.87	<.0001
2	Month	5	181.942	36.388	73.31	<.0001
2	Area	4	52.893	13.223	26.64	<.0001
2	Lat5	3	277.383	92.461	186.27	<.0001
2	BETcpue5	1	91.973	91.973	185.29	<.0001
2	YFTcpue5	1	102.801	102.801	207.1	<.0001
2	Month*Area	20	111.832	5.592	11.26	<.0001
2	Year*Lat5	87	134.700	1.548	3.12	<.0001
2	Year*Area	116	154.415	1.331	2.68	<.0001
HypothesisType	Source	DF	SS	MS	FValue	ProbF
3	Year	29	55.121	1.901	3.83	<.0001
3	Month	5	95.103	19.021	38.32	<.0001
3	Area	4	42.903	10.726	21.61	<.0001
3	Lat5	3	280.874	93.625	188.62	<.0001
3	BETcpue5	1	91.973	91.973	185.29	<.0001
3	YFTcpue5	1	102.801	102.801	207.1	<.0001
3	Month*Area	20	111.832	5.592	11.26	<.0001
3	Year*Lat5	87	134.700	1.548	3.12	<.0001
3	Year*Area	116	154.415	1.331	2.68	<.0001

RedB

HypothesisType	Source	DF	SS	MS	FValue	ProbF
2	Year	29	170.883	5.893	10.36	<.0001
2	Month	5	201.914	40.383	71.02	<.0001
2	Area	4	67.045	16.761	29.48	<.0001
2	Lat5	3	299.161	99.720	175.37	<.0001
2	BETcpue5	1	161.665	161.665	284.3	<.0001
2	YFTcpue5	1	118.291	118.291	208.02	<.0001
2	Month*Area	20	126.417	6.321	11.12	<.0001
HypothesisType	Source	DF	SS	MS	FValue	ProbF
3	Year	29	170.883	5.893	10.36	<.0001
3	Month	5	115.595	23.119	40.66	<.0001
3	Area	4	71.445	17.861	31.41	<.0001
3	Lat5	3	299.161	99.720	175.37	<.0001
3	BETcpue5	1	161.665	161.665	284.3	<.0001
3	YFTcpue5	1	118.291	118.291	208.02	<.0001
3	Month*Area	20	126.417	6.321	11.12	<.0001

BaseSxS

HypothesisType	Source	DF	SS	MS	FValue	ProbF
2	Year	29	6828.305	235.459	311.54	<.0001
2	Month	5	3748.258	749.652	991.89	<.0001
2	Area	4	644.930	161.232	213.33	<.0001
2	Lat5	3	8861.716	2953.905	3908.41	<.0001
2	BETcpue	1	4254.504	4254.504	5629.28	<.0001
2	YFTcpue	1	4114.009	4114.009	5443.38	<.0001
2	Month*Area	20	4405.292	220.265	291.44	<.0001
2	Year*Lat5	87	9603.426	110.384	146.05	<.0001
2	Year*Area	116	8448.026	72.828	96.36	<.0001
HypothesisType	Source	DF	SS	MS	FValue	ProbF
3	Year	29	1152.740	39.750	52.59	<.0001
3	Month	5	2310.890	462.178	611.52	<.0001
3	Area	4	1111.863	277.966	367.79	<.0001
3	Lat5	3	8976.224	2992.075	3958.91	<.0001
3	BETcpue	1	4254.504	4254.504	5629.28	<.0001
3	YFTcpue	1	4114.009	4114.009	5443.38	<.0001
3	Month*Area	20	4405.292	220.265	291.44	<.0001
3	Year*Lat5	87	9603.426	110.384	146.05	<.0001
3	Year*Area	116	8448.026	72.828	96.36	<.0001

Table 4. AIC and BIC of Base case model and reduced base case

Model	AIC	BIC
Base	7,125	8,747
Reduced Base	7,370	7,759

Table 5. Area weighted standardized CPUE

Year	Base w08	Base w05	Reduced Base w08	Reduced Base w05	Base with SxS w08	Base with SxS w05
1969	2.2841	2.4934	2.2841	2.4934	2.2841	2.4934
1970	2.2268	2.4169	2.2268	2.4169	2.2268	2.4169
1971	2.0654	2.2054	2.0654	2.2054	2.0654	2.2054
1972	2.1669	2.2273	2.1669	2.2273	2.1669	2.2273
1973	1.8263	1.9271	1.8263	1.9271	1.8263	1.9271
1974	1.8989	1.9710	1.8989	1.9710	1.8989	1.9710
1975	1.4556	1.4974	1.4556	1.4974	1.4556	1.4974
1976	1.8715	1.9279	1.8715	1.9279	1.8715	1.9279
1977	1.6556	1.6850	1.6556	1.6850	1.6556	1.6850
1978	1.4300	1.3820	1.4300	1.3820	1.4300	1.3820
1979	1.1472	1.2558	1.1472	1.2558	1.1472	1.2558
1980	1.3862	1.3852	1.3862	1.3852	1.3862	1.3852
1981	1.3103	1.2917	1.3103	1.2917	1.3103	1.2917
1982	1.0285	1.0220	1.0285	1.0220	1.0285	1.0220
1983	1.0103	1.0228	1.0103	1.0228	1.0103	1.0228
1984	1.0261	1.0603	1.0261	1.0603	1.0261	1.0603
1985	0.8578	0.8861	0.8578	0.8861	0.8578	0.8861
1986	0.6345	0.6667	0.6380	0.6751	0.6641	0.6918
1987	0.6361	0.6620	0.6585	0.6797	0.6434	0.6647
1988	0.5346	0.5464	0.5168	0.5204	0.5851	0.5893
1989	0.5333	0.5553	0.5158	0.5393	0.5479	0.5636
1990	0.5384	0.5318	0.5842	0.5701	0.4864	0.4828
1991	0.4639	0.4682	0.5127	0.5084	0.4481	0.4594
1992	0.5486	0.5380	0.6014	0.5772	0.5511	0.5426
1993	0.7249	0.6653	0.7023	0.6363	0.6920	0.6532
1994	0.6950	0.5818	0.5834	0.4907	0.7091	0.5991
1995	0.7667	0.6770	0.7370	0.6563	0.8311	0.7168
1996	0.5720	0.5229	0.5563	0.5149	0.5865	0.5449
1997	0.5200	0.4699	0.5524	0.4998	0.4954	0.4549
1998	0.5642	0.5480	0.5794	0.5563	0.5382	0.5168
1999	0.5713	0.5473	0.5881	0.5628	0.5413	0.5189
2000	0.5408	0.4815	0.5309	0.4732	0.5198	0.4714
2001	0.6059	0.5655	0.6164	0.5692	0.5895	0.5465
2002	0.8991	0.7406	0.8021	0.6661	0.8364	0.6935
2003	0.6614	0.5525	0.6873	0.5686	0.6443	0.5434
2004	0.6275	0.5676	0.6705	0.5963	0.6002	0.5382
2005	0.5051	0.4647	0.5212	0.4716	0.5996	0.5384
2006	0.3654	0.3232	0.3624	0.3279	0.3917	0.3399

Table 5. (cont.)

Year	Base w08	Base w05	Reduced Base w08	Reduced Base w05	Base with SxS w08	Base with SxS w05
2007	0.2697	0.2294	0.3295	0.2701	0.3056	0.2606
2008	0.5741	0.4371	0.5057	0.4123	0.5457	0.4120
2009	0.7157	0.5501	0.6336	0.4969	0.6788	0.5065
2010	1.0158	0.7146	0.6430	0.4767	1.0489	0.7243
2011	0.8626	0.6356	0.6932	0.5188	0.8445	0.6017
2012	1.0611	0.7670	0.7173	0.5292	1.0451	0.7502
2013	0.9011	0.6433	0.7366	0.5309	1.0630	0.7488
2014	1.1789	0.8574	0.8119	0.5937	1.0099	0.7231
2015	1.3576	1.0110	1.1761	0.8710	1.3771	1.0215

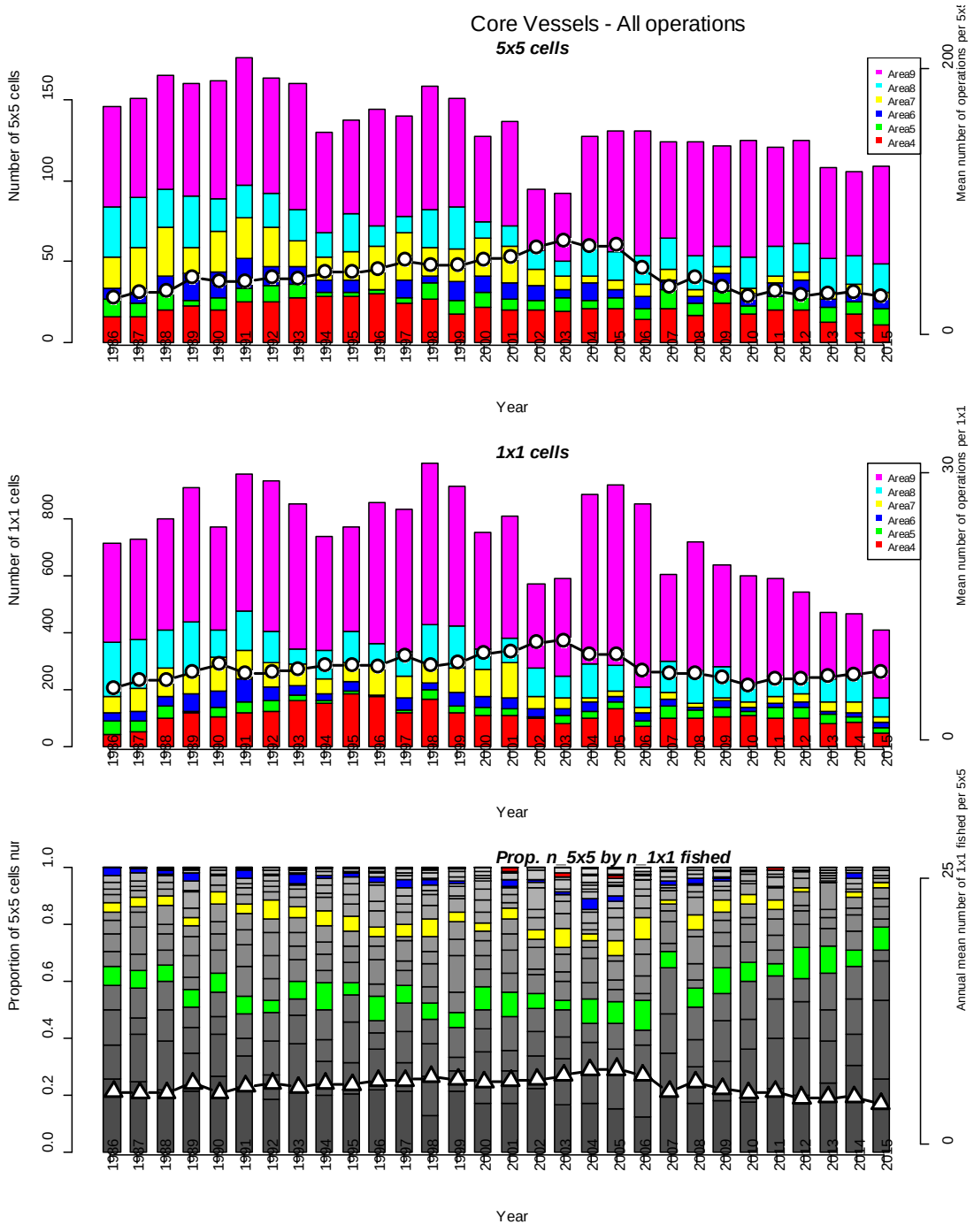

Figure 1a. Number of cells in the core vessel for all operations.

(Top panel) Bar represents the number of 5x5 degrees square and month (cell) where fishing operated by CCSBT statistical area and refer to left side y-axis. Line with circle plot represents the mean annual number of operations per cell and refer to right side y-axis. (Middle panel) Bar represents the number of 1x1 degree square and month (cell) where fishing operated by CCSBT statistical area and refer to left side y-axis. Line with circle plot represents the mean annual number of operations per cell and refer to right side y-axis. (Bottom panel) Composition of frequency for the number of 1x1 degree square and month cells operated in a 5x5 degree squares and month cell. Refer to left side y-axis. The grey band is one of 25 cells and that at top is 25 of 25 cells, and every five is colored. Line with triangle represents the mean number of 1x1 month cells operated in a 5x5 month cell and refer to right side y-axis.

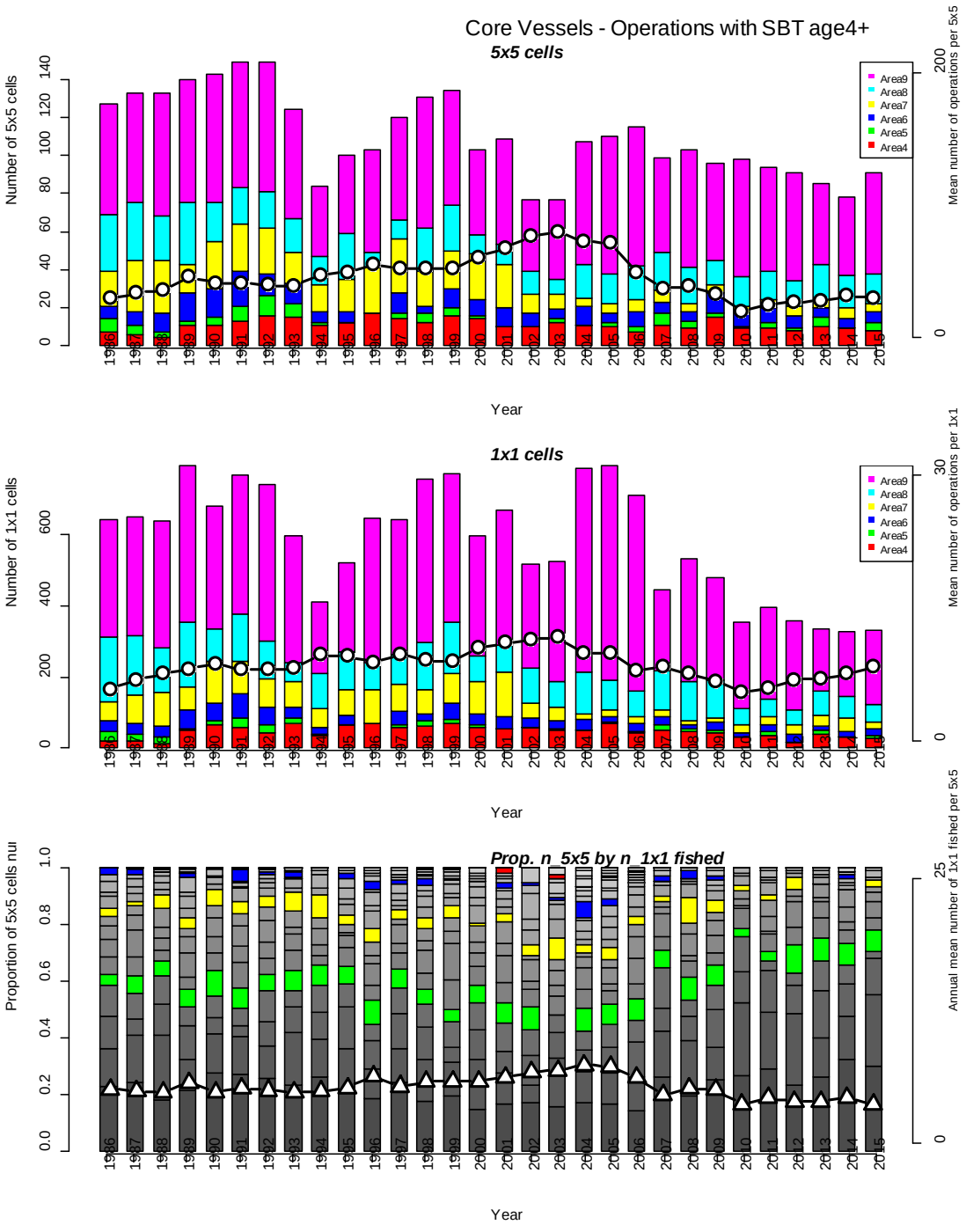

Figure 1b. Number of cells in the core vessel for SBT 4+ catch positive. See explanation in Fig. 1a.

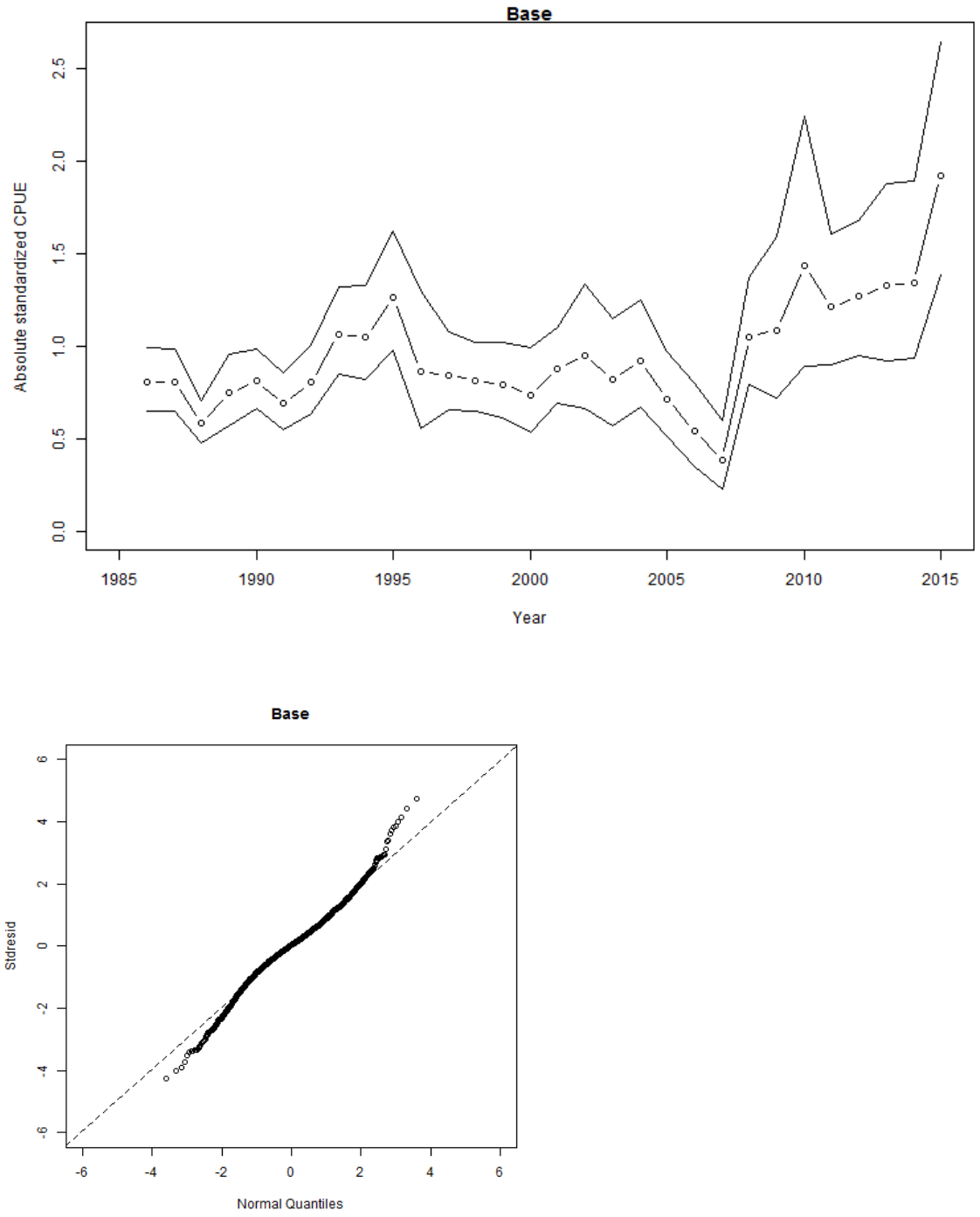

Fig 2. Standardized CPUE (ls-mean with 95% confidence interval) of the core vessel data (upper panel) and its QQ plot of residual (lower panel) for Base case.

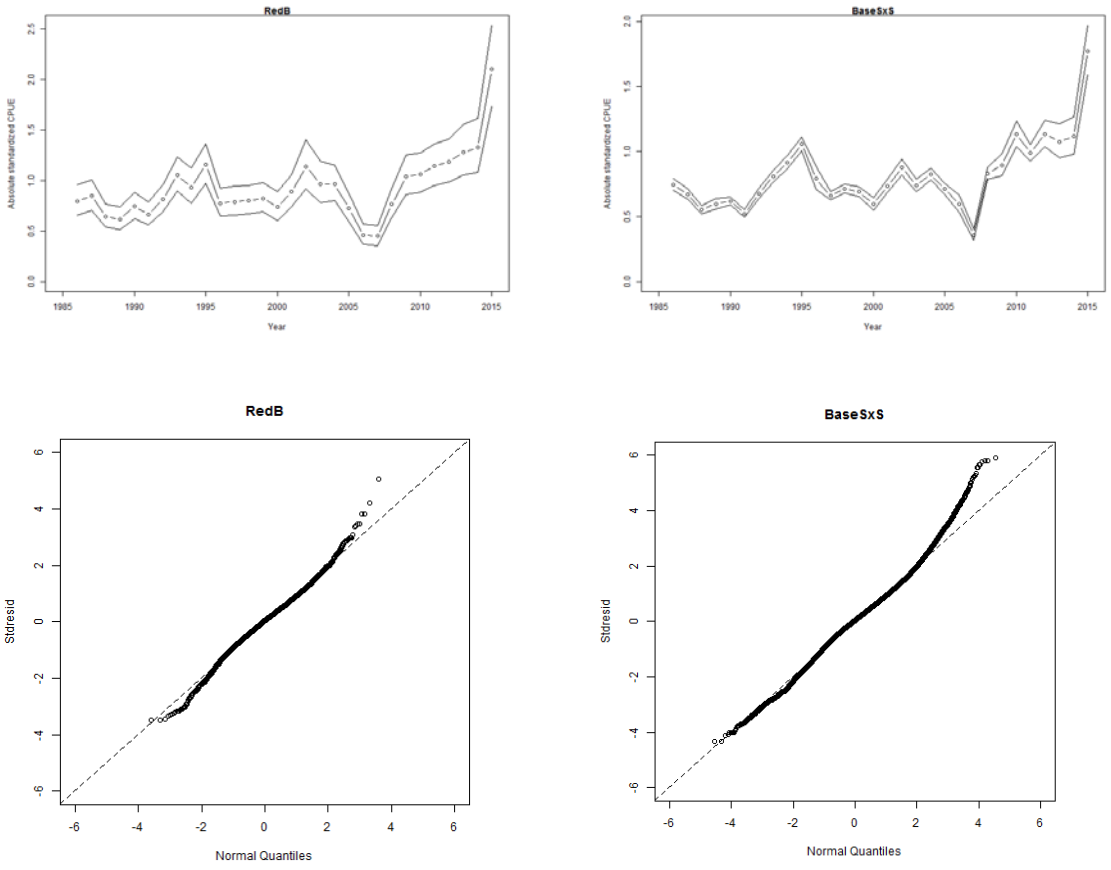

Fig 3. Standardized CPUE (ls-mean with 95% confidence interval) of the core vessel data (upper panel) and its QQ plot of residual (lower panel) for monitoring series. Left panels for reduced base case and right panels for shot-by-shot data with base case GLM model.

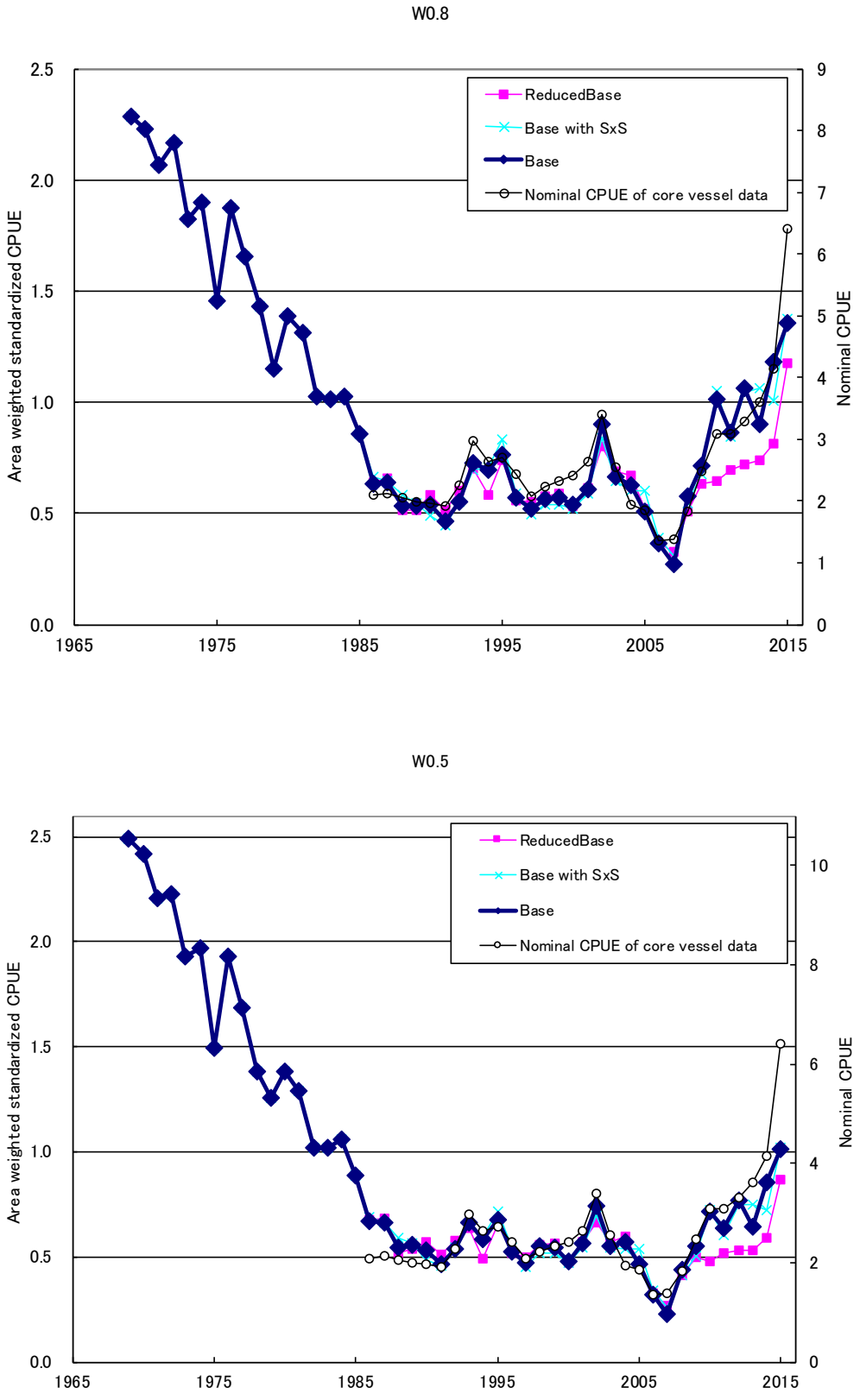

Fig 4. Area weighed standardized CPUEs. Nominal CPUE of the core vessels is also shown.

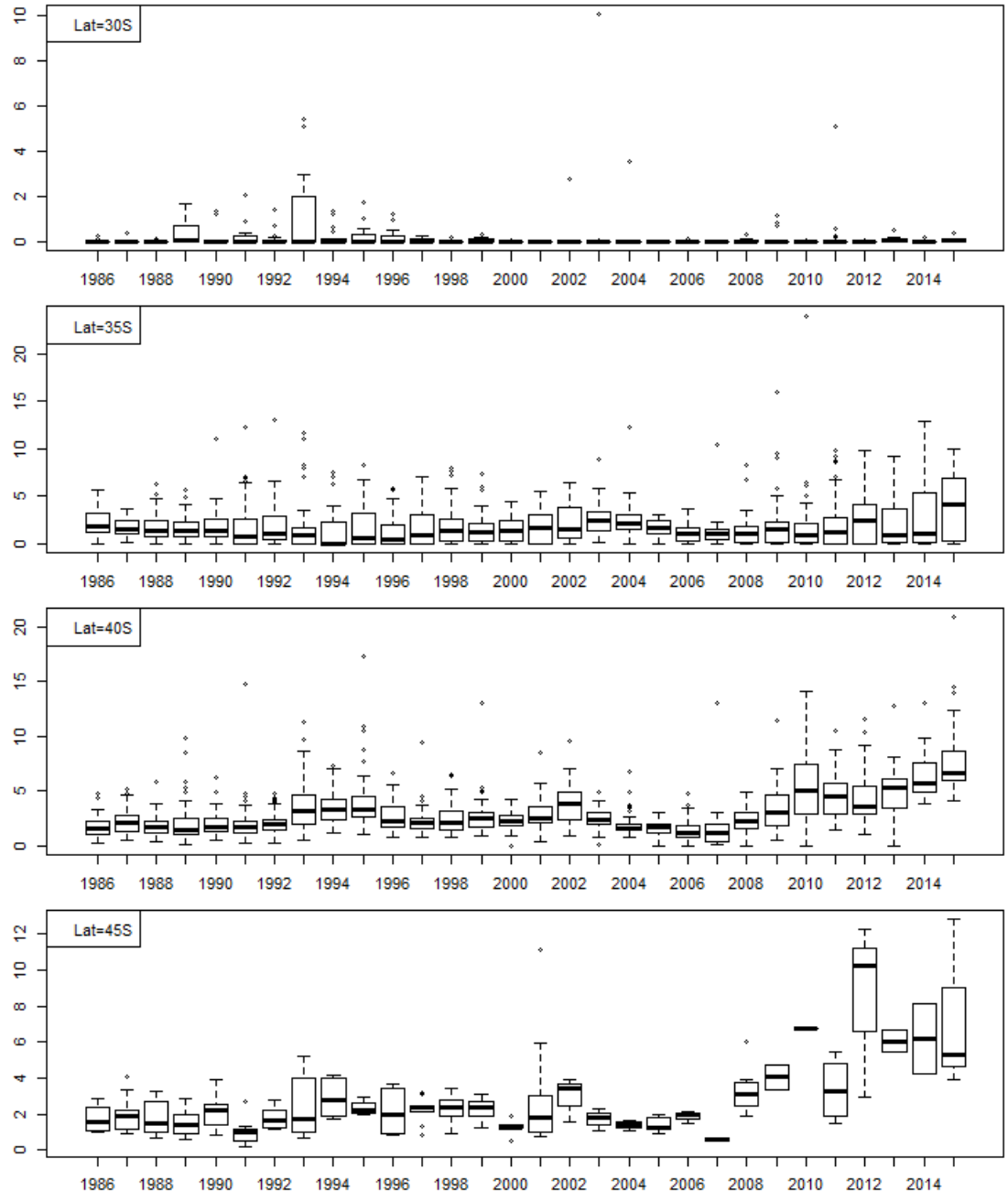

Fig 5. Nominal CPUE by year and latitude to evaluate whether year*latitude interaction should be included in the GLM model

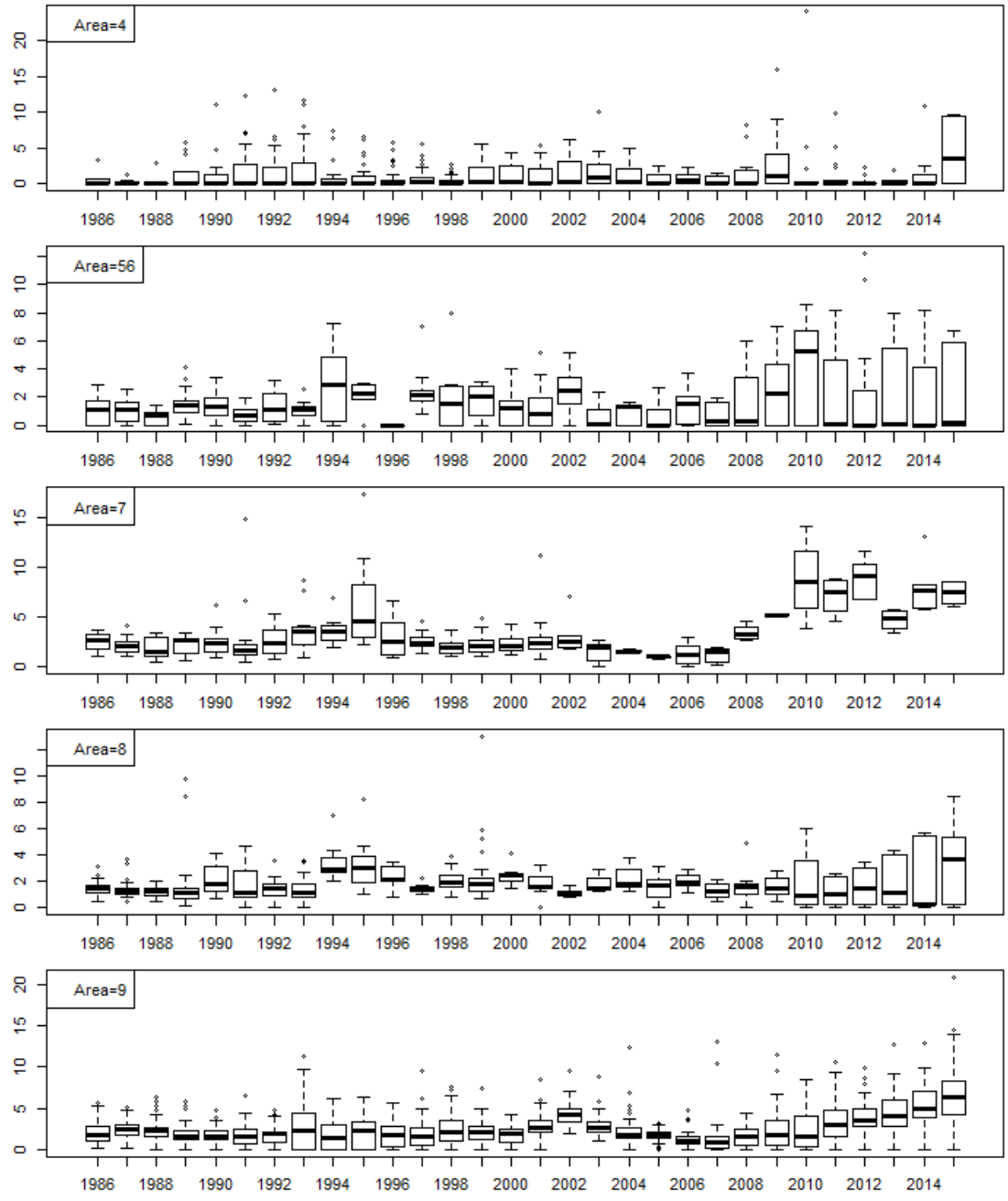

Fig 6. Nominal CPUE by year and Area to evaluate whether year*Area interaction should be included in the GLM model