2015 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 2015

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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 2014 年までに更新した。2014 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 年間の平均より高かった。

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 2014. The index values in 2014, W0.8 and W0.5 by the base GLM model, are higher than the average in the last 10 years.

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 (1986-2014), from Australia (RTMP data; 1989-2005) and from New Zealand (Joint venture; 1990-2014). 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 2013 and 2014.

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 175,060 was extracted from entire vessels (Table 1). The number of core vessels chosen ranged from 35 to 104 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 9.3). 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. 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 3).

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 (2014), which was mainly from RTMP and targeting on SBT, was corrected with the constant of 0.907, the average in three years (0.922 in 2011, 1.009 in 2012[1], and 0.790 in 2013[1] of ratio Logbook based CPUE in W0.8 / RTMP based CPUE in W0.8 in the core vessel dataset).

The area weighted CPUE series between 1986 and 2014 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 4 and Fig. 4. The relative index values of W0.8 in 2014 with the base GLM model (1.059) is high as 152% of the previous 10 years mean (0.699). That of W0.5 in 2014 (0.769) is high as 142% of the previous 10 years mean (0.541).

The trends of the indices among GLM models (Base vs Reduced Base) were similar to each other but different in recent five years. 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 degree are shown in Fig. 5. Year trends were different by latitude, such as nominal CPUE since 2010 were much higher than in the 1990s in 40S and 45S, but similar in 35S. 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

[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.

Areas. These different trends were taken account 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	6,342	96
1996	14,854			14,854	6,990	96
1997	16,322		379	16,701	7,805	92
1998	16,310		310	16,620	8,198	104
1999	14,414		306	14,720	7,833	96
2000	11,746		265	12,011	7,242	97
2001	14,075		198	14,273	7,938	100
2002	10,721		228	10,949	6,166	90
2003	11,563		294	11,857	6,434	89
2004	13,101		349	13,450	8,428	93
2005	13,848		198	14,046	8,708	94
2006	9,124		183	9,307	6,464	84
2007	5,540		387	5,927	4,515	80
2008	6,815		167	6,982	5,247	88
2009	5,016		231	5,247	4,330	73
2010	4,102		144	4,246	3,546	65
2011	4,757		151	4,908	3,975	64
2012	4,455		163	4,618	3,687	70
2013	4,157		148	4,305	3,258	67
2014	4,642		186	4,828	3,314	62
Total	383,718	8,776	6,848	399,342	175,060	

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

Table 2. Estimated parameter values in GLM Base model

Significances are * for <0.05, ** for <0.01 and *** for < 0.001.

Parameter		Estimate	Biased	StdErr	tValue	Probt	Signi
Intercept		2.0157	1	0.5557	3.63	0.000	**
Year	1986	−1.2321	1	0.5876	−2.10	0.036	*
Year	1987	−1.1336	1	0.5931	−1.91	0.056	
Year	1988	−1.7386	1	0.5732	−3.03	0.002	**
Year	1989	−1.3678	1	0.5817	−2.35	0.019	*
Year	1990	−0.8398	1	0.5670	−1.48	0.139	
Year	1991	−1.7733	1	0.5706	−3.11	0.002	**
Year	1992	−1.1594	1	0.6117	−1.90	0.058	
Year	1993	−1.1482	1	0.6125	−1.87	0.061	
Year	1994	−0.5842	1	0.6496	−0.90	0.369	
Year	1995	−0.8582	1	0.6385	−1.34	0.179	
Year	1996	−1.3736	1	0.9906	−1.39	0.166	
Year	1997	−0.7138	1	0.5927	−1.20	0.229	
Year	1998	−0.7191	1	0.6169	−1.17	0.244	
Year	1999	−0.6869	1	0.5908	−1.16	0.245	
Year	2000	−1.2796	1	0.6161	−2.08	0.038	*
Year	2001	−0.8973	1	0.5947	−1.51	0.132	
Year	2002	−0.6052	1	0.6549	−0.92	0.356	
Year	2003	−1.1140	1	0.6732	−1.65	0.098	
Year	2004	−1.0844	1	0.6225	−1.74	0.082	
Year	2005	−1.0330	1	0.6623	−1.56	0.119	
Year	2006	−0.8446	1	0.6637	−1.27	0.203	
Year	2007	−1.6727	1	0.7315	−2.29	0.022	*
Year	2008	0.2421	1	0.6219	0.39	0.697	
Year	2009	−0.1972	1	0.7223	−0.27	0.785	
Year	2010	0.3053	1	0.8759	0.35	0.728	
Year	2011	−0.2092	1	0.6635	−0.32	0.753	
Year	2012	−0.1706	1	0.6948	−0.25	0.806	
Year	2013	0.0990	1	0.7382	0.13	0.893	
Year	2014	0.0000	1				
Month	4	−0.5791	1	0.2103	−2.75	0.006	**
Month	5	−0.3807	1	0.1963	−1.94	0.053	
Month	6	−0.4274	1	0.1926	−2.22	0.027	*
Month	7	−0.2629	1	0.1861	−1.41	0.158	
Month	8	−0.1555	1	0.1856	−0.84	0.402	
Month	9	0.0000	1				
Area	4	−0.1877	1	0.3923	−0.48	0.632	
Area	7	−0.3626	1	0.5375	−0.67	0.500	
Area	8	−0.6286	1	0.4413	−1.42	0.154	
Area	9	0.0219	1	0.3896	0.06	0.955	
Area	56	0.0000	1				
Lat5	30	−2.8555	1	0.5564	−5.13	<.0001	***
Lat5	35	−0.8511	1	0.5420	−1.57	0.116	
Lat5	40	−0.1405	1	0.5402	−0.26	0.795	
Lat5	45	0.0000	1				
BETcpue5		−0.1395	0	0.0104	−13.42	<.0001	***
YFTcpue5		−0.0749	0	0.0054	−13.86	<.0001	***
Month*Area	4 4	−1.3472	1	0.2566	−5.25	<.0001	***
Month*Area	4 7	1.1488	1	0.2960	3.88	0.000	**
Month*Area	4 8	−0.8552	1	0.2833	−3.02	0.003	**
Month*Area	4 9	0.2238	1	0.2253	0.99	0.321	
Month*Area	4 56	0.0000	1				
Month*Area	5 4	−0.6237	1	0.2431	−2.57	0.010	*
Month*Area	5 7	0.9531	1	0.2829	3.37	0.001	**
Month*Area	5 8	−0.4978	1	0.2625	−1.90	0.058	
Month*Area	5 9	0.2445	1	0.2087	1.17	0.242	
Month*Area	5 56	0.0000	1				
Month*Area	6 4	−0.2336	1	0.2392	−0.98	0.329	
Month*Area	6 7	0.9558	1	0.2842	3.36	0.001	**
Month*Area	6 8	0.1577	1	0.2620	0.60	0.547	
Month*Area	6 9	0.3750	1	0.2065	1.82	0.069	
Month*Area	6 56	0.0000	1				
Month*Area	7 4	0.0812	1	0.2360	0.34	0.731	
Month*Area	7 7	0.7497	1	0.2939	2.55	0.011	*
Month*Area	7 8	0.4046	1	0.2176	1.86	0.063	
Month*Area	7 9	0.4703	1	0.2024	2.32	0.020	*
Month*Area	7 56	0.0000	1				
Month*Area	8 4	−0.0930	1	0.2433	−0.38	0.702	
Month*Area	8 7	0.1736	1	0.3951	0.44	0.661	
Month*Area	8 8	0.4407	1	0.2065	2.13	0.033	*
Month*Area	8 9	0.4371	1	0.2068	2.11	0.035	*
Month*Area	8 56	0.0000	1				
Month*Area	9 4	0.0000	1				
Month*Area	9 7	0.0000	1				
Month*Area	9 8	0.0000	1				
Month*Area	9 9	0.0000	1				
Month*Area	9 56	0.0000	1				
Year*Lat5	1986 30	1.4630	1	0.6608	2.21	0.027	*
Year*Lat5	1986 35	1.1381	1	0.6142	1.85	0.064	
Year*Lat5	1986 40	0.0670	1	0.6114	0.11	0.913	
Year*Lat5	1986 45	0.0000	1				
Year*Lat5	1987 30	1.7664	1	0.6909	2.56	0.011	*
Year*Lat5	1987 35	0.7667	1	0.6083	1.26	0.208	
Year*Lat5	1987 40	0.0903	1	0.5982	0.15	0.880	
Year*Lat5	1987 45	0.0000	1				
Year*Lat5	1988 30	1.9918	1	0.6333	3.15	0.002	**
Year*Lat5	1988 35	0.8339	1	0.5824	1.43	0.152	
Year*Lat5	1988 40	−0.0338	1	0.5749	−0.06	0.953	
Year*Lat5	1988 45	0.0000	1				
Year*Lat5	1989 30	2.1408	1	0.7242	2.96	0.003	**
Year*Lat5	1989 35	0.9829	1	0.6149	1.60	0.110	
Year*Lat5	1989 40	0.2201	1	0.5962	0.37	0.712	
Year*Lat5	1989 45	0.0000	1				
Year*Lat5	1990 30	1.3225	1	0.6345	2.08	0.037	*
Year*Lat5	1990 35	0.4510	1	0.5858	0.77	0.441	
Year*Lat5	1990 40	0.0210	1	0.5685	0.04	0.971	
Year*Lat5	1990 45	0.0000	1				
Year*Lat5	1991 30	2.1224	1	0.6423	3.30	0.001	**
Year*Lat5	1991 35	0.9149	1	0.6045	1.51	0.130	
Year*Lat5	1991 40	0.3987	1	0.5992	0.67	0.506	
Year*Lat5	1991 45	0.0000	1				
Year*Lat5	1992 30	1.4014	1	0.6781	2.07	0.039	*
Year*Lat5	1992 35	0.6015	1	0.6353	0.95	0.344	
Year*Lat5	1992 40	0.1757	1	0.6280	0.28	0.780	
Year*Lat5	1992 45	0.0000	1				
Year*Lat5	1993 30	1.1709	1	0.6833	1.71	0.087	
Year*Lat5	1993 35	0.0220	1	0.6223	0.04	0.972	
Year*Lat5	1993 40	0.3789	1	0.6138	0.62	0.537	
Year*Lat5	1993 45	0.0000	1				
Year*Lat5	1994 30	0.7784	1	0.7290	1.07	0.286	
Year*Lat5	1994 35	0.0819	1	0.6723	0.12	0.903	
Year*Lat5	1994 40	0.3995	1	0.6569	0.61	0.543	
Year*Lat5	1994 45	0.0000	1				
Year*Lat5	1995 30	1.5492	1	0.7493	2.07	0.039	*
Year*Lat5	1995 35	0.2308	1	0.7070	0.33	0.744	
Year*Lat5	1995 40	0.2763	1	0.6929	0.40	0.690	
Year*Lat5	1995 45	0.0000	1				
Year*Lat5	1996 30	1.4769	1	0.7153	2.06	0.039	*
Year*Lat5	1996 35	0.1132	1	0.6519	0.17	0.862	
Year*Lat5	1996 40	0.2521	1	0.6333	0.40	0.691	
Year*Lat5	1996 45	0.0000	1				
Year*Lat5	1997 30	1.2872	1	0.7159	1.80	0.072	
Year*Lat5	1997 35	0.7329	1	0.6342	1.16	0.248	
Year*Lat5	1997 40	0.3420	1	0.6223	0.55	0.583	
Year*Lat5	1997 45	0.0000	1				
Year*Lat5	1998 30	1.2014	1	0.6626	1.81	0.070	
Year*Lat5	1998 35	0.4235	1	0.6178	0.69	0.493	
Year*Lat5	1998 40	−0.0542	1	0.6100	−0.09	0.929	
Year*Lat5	1998 45	0.0000	1				
Year*Lat5	1999 30	0.9099	1	0.6770	1.34	0.179	
Year*Lat5	1999 35	0.5033	1	0.6306	0.80	0.425	
Year*Lat5	1999 40	0.2042	1	0.6228	0.33	0.743	
Year*Lat5	1999 45	0.0000	1				
Year*Lat5	2000 30	1.2402	1	0.6922	1.79	0.073	
Year*Lat5	2000 35	0.6885	1	0.6682	1.03	0.303	
Year*Lat5	2000 40	0.4866	1	0.6580	0.74	0.460	
Year*Lat5	2000 45	0.0000	1				
Year*Lat5	2001 30	1.1887	1	0.6525	1.82	0.069	
Year*Lat5	2001 35	0.3112	1	0.6190	0.50	0.615	
Year*Lat5	2001 40	0.1364	1	0.6060	0.23	0.822	
Year*Lat5	2001 45	0.0000	1				
Year*Lat5	2002 30	0.9781	1	0.7808	1.25	0.210	
Year*Lat5	2002 35	0.9020	1	0.7218	1.25	0.212	
Year*Lat5	2002 40	0.1344	1	0.6685	0.20	0.841	
Year*Lat5	2002 45	0.0000	1				
Year*Lat5	2003 30	1.2736	1	0.7313	1.74	0.082	
Year*Lat5	2003 35	0.9856	1	0.7246	1.36	0.174	
Year*Lat5	2003 40	0.1315	1	0.7148	0.18	0.854	
Year*Lat5	2003 45	0.0000	1				
Year*Lat5	2004 30	1.5256	1	0.6888	2.21	0.027	*
Year*Lat5	2004 35	1.0809	1	0.6566	1.65	0.100	
Year*Lat5	2004 40	0.0590	1	0.6477	0.09	0.927	
Year*Lat5	2004 45	0.0000	1				
Year*Lat5	2005 30	1.5910	1	0.6996	2.27	0.023	*
Year*Lat5	2005 35	0.8494	1	0.6434	1.32	0.187	
Year*Lat5	2005 40	−0.1954	1	0.6414	−0.30	0.761	
Year*Lat5	2005 45	0.0000	1				
Year*Lat5	2006 30	0.9793	1	0.7487	1.31	0.191	
Year*Lat5	2006 35	0.6422	1	0.7312	0.88	0.380	
Year*Lat5	2006 40	−0.0192	1	0.7250	−0.03	0.979	
Year*Lat5	2006 45	0.0000	1				
Year*Lat5	2007 30	2.0918	1	0.7847	2.67	0.008	**
Year*Lat5	2007 35	1.3991	1	0.7834	1.79	0.074	
Year*Lat5	2007 40	0.6191	1	0.7834	0.79	0.429	
Year*Lat5	2007 45	0.0000	1				
Year*Lat5	2008 30	0.4114	1	0.6622	0.62	0.535	
Year*Lat5	2008 35	−0.0779	1	0.6175	−0.13	0.900	
Year*Lat5	2008 40	−0.0998	1	0.6155	−0.16	0.871	
Year*Lat5	2008 45	0.0000	1				
Year*Lat5	2009 30	0.1669	1	0.7784	0.21	0.830	
Year*Lat5	2009 35	0.5236	1	0.7790	0.67	0.502	
Year*Lat5	2009 40	0.2833	1	0.7751	0.37	0.715	
Year*Lat5	2009 45	0.0000	1				
Year*Lat5	2010 30	−0.3603	1	0.9390	−0.38	0.701	
Year*Lat5	2010 35	−0.2486	1	0.9372	−0.27	0.791	
Year*Lat5	2010 40	−0.0902	1	0.9315	−0.10	0.923	
Year*Lat5	2010 45	0.0000	1				
Year*Lat5	2011 30	0.5331	1	0.6972	0.76	0.445	
Year*Lat5	2011 35	0.5088	1	0.6604	0.77	0.441	
Year*Lat5	2011 40	0.3489	1	0.6585	0.53	0.596	
Year*Lat5	2011 45	0.0000	1				
Year*Lat5	2012 30	0.3800	1	0.7264	0.52	0.601	
Year*Lat5	2012 35	−0.0298	1	0.7014	−0.04	0.966	
Year*Lat5	2012 40	−0.3472	1	0.6936	−0.50	0.617	
Year*Lat5	2012 45	0.0000	1				
Year*Lat5	2013 30	0.1117	1	0.7762	0.14	0.886	
Year*Lat5	2013 35	−0.0534	1	0.7612	−0.07	0.944	
Year*Lat5	2013 40	−0.1044	1	0.7541	−0.14	0.890	
Year*Lat5	2013 45	0.0000	1				
Year*Lat5	2014 30	0.0000	1				
Year*Lat5	2014 35	0.0000	1				
Year*Lat5	2014 40	0.0000	1				
Year*Lat5	2014 45	0.0000	1				
Year*Area	1986 4	0.6510	1	0.4574	1.42	0.155	
Year*Area	1986 7	−0.0141	1	0.5579	−0.03	0.980	
Year*Area	1986 8	0.0662	1	0.4930	0.13	0.893	
Year*Area	1986 9	0.0122	1	0.4435	0.03	0.978	
Year*Area	1986 56	0.0000	1				
Year*Area	1987 4	0.0618	1	0.4892	0.13	0.900	
Year*Area	1987 7	−0.1549	1	0.5493	−0.28	0.778	
Year*Area	1987 8	0.1641	1	0.4879	0.34	0.737	
Year*Area	1987 9	0.1930	1	0.4352	0.44	0.658	
Year*Area	1987 56	0.0000	1				
Year*Area	1988 4	0.1549	1	0.4240	0.37	0.715	
Year*Area	1988 7	0.3044	1	0.5349	0.57	0.569	
Year*Area	1988 8	0.6384	1	0.4774	1.34	0.181	
Year*Area	1988 9	0.7546	1	0.4095	1.84	0.065	
Year*Area	1988 56	0.0000	1				
Year*Area	1989 4	0.2424	1	0.4789	0.51	0.613	
Year*Area	1989 7	0.0073	1	0.5444	0.01	0.989	
Year*Area	1989 8	0.0737	1	0.4674	0.16	0.875	
Year*Area	1989 9	−0.0732	1	0.4071	−0.18	0.857	
Year*Area	1989 56	0.0000	1				
Year*Area	1990 4	0.4236	1	0.4218	1.00	0.315	
Year*Area	1990 7	−0.4240	1	0.5308	−0.80	0.425	
Year*Area	1990 8	0.2536	1	0.4801	0.53	0.597	
Year*Area	1990 9	−0.3770	1	0.4007	−0.94	0.347	
Year*Area	1990 56	0.0000	1				

Table 2 (cont.)

Parameter		Estimate	Biased	StdErr	tValue	Probt	Signi
Year*Area	1991 4	1.0292	1	0.4061	2.53	0.011	*
Year*Area	1991 7	0.1459	1	0.5296	0.28	0.783	
Year*Area	1991 8	0.5338	1	0.4697	1.14	0.256	
Year*Area	1991 9	0.1583	1	0.3952	0.40	0.689	
Year*Area	1991 56	0.0000	1				
Year*Area	1992 4	0.8678	1	0.4149	2.09	0.037	*
Year*Area	1992 7	−0.1620	1	0.5338	−0.30	0.762	
Year*Area	1992 8	0.2710	1	0.4667	0.58	0.562	
Year*Area	1992 9	−0.0270	1	0.4001	−0.07	0.946	
Year*Area	1992 56	0.0000	1				
Year*Area	1993 4	1.6733	1	0.4382	3.82	0.000	**
Year*Area	1993 7	0.0390	1	0.5498	0.07	0.944	
Year*Area	1993 8	0.8966	1	0.4792	1.87	0.061	
Year*Area	1993 9	0.1793	1	0.4064	0.44	0.659	
Year*Area	1993 56	0.0000	1				
Year*Area	1994 4	0.8322	1	0.5086	1.64	0.102	
Year*Area	1994 7	−0.4607	1	0.6066	−0.76	0.448	
Year*Area	1994 8	0.5705	1	0.5482	1.04	0.298	
Year*Area	1994 9	−0.6313	1	0.4786	−1.32	0.187	
Year*Area	1994 56	0.0000	1				
Year*Area	1995 4	0.6220	1	0.5104	1.22	0.223	
Year*Area	1995 7	0.2394	1	0.5900	0.41	0.685	
Year*Area	1995 8	0.6776	1	0.5459	1.24	0.215	
Year*Area	1995 9	−0.1392	1	0.4878	−0.29	0.775	
Year*Area	1995 56	0.0000	1				
Year*Area	1996 4	1.2129	1	0.7978	1.52	0.129	
Year*Area	1996 7	0.1957	1	0.9226	0.21	0.832	
Year*Area	1996 8	1.1726	1	0.8993	1.30	0.192	
Year*Area	1996 9	0.1137	1	0.8389	0.14	0.892	
Year*Area	1996 56	0.0000	1				
Year*Area	1997 4	0.3633	1	0.5025	0.72	0.470	
Year*Area	1997 7	−0.6270	1	0.5609	−1.12	0.264	
Year*Area	1997 8	−0.2369	1	0.5498	−0.43	0.667	
Year*Area	1997 9	−0.8082	1	0.4594	−1.76	0.079	
Year*Area	1997 56	0.0000	1				
Year*Area	1998 4	0.1232	1	0.4251	0.29	0.772	
Year*Area	1998 7	−0.6270	1	0.5636	−1.11	0.266	
Year*Area	1998 8	0.3034	1	0.4977	0.61	0.542	
Year*Area	1998 9	−0.1938	1	0.4278	−0.45	0.651	
Year*Area	1998 56	0.0000	1				
Year*Area	1999 4	0.2368	1	0.4475	0.53	0.597	
Year*Area	1999 7	−0.5385	1	0.5637	−0.96	0.340	
Year*Area	1999 8	0.1120	1	0.5012	0.22	0.823	
Year*Area	1999 9	−0.4946	1	0.4393	−1.13	0.260	
Year*Area	1999 56	0.0000	1				
Year*Area	2000 4	0.7864	1	0.4447	1.77	0.077	
Year*Area	2000 7	−0.2950	1	0.5529	−0.53	0.594	
Year*Area	2000 8	0.7234	1	0.5266	1.37	0.170	
Year*Area	2000 9	−0.2955	1	0.4331	−0.68	0.495	
Year*Area	2000 56	0.0000	1				
Year*Area	2001 4	0.5801	1	0.4400	1.32	0.188	
Year*Area	2001 7	−0.3167	1	0.5535	−0.57	0.567	
Year*Area	2001 8	0.4190	1	0.5248	0.80	0.425	
Year*Area	2001 9	−0.0066	1	0.4372	−0.02	0.988	
Year*Area	2001 56	0.0000	1				
Year*Area	2002 4	0.0338	1	0.5463	0.06	0.951	
Year*Area	2002 7	−0.4687	1	0.6392	−0.73	0.463	
Year*Area	2002 8	−0.5280	1	0.5720	−0.92	0.356	
Year*Area	2002 9	0.0583	1	0.4820	0.12	0.904	
Year*Area	2002 56	0.0000	1				
Year*Area	2003 4	0.7073	1	0.4647	1.52	0.128	
Year*Area	2003 7	−0.5928	1	0.6420	−0.92	0.356	
Year*Area	2003 8	0.3140	1	0.5901	0.53	0.595	
Year*Area	2003 9	0.1465	1	0.4824	0.30	0.761	
Year*Area	2003 56	0.0000	1				
Year*Area	2004 4	0.4179	1	0.4347	0.96	0.336	
Year*Area	2004 7	−0.5022	1	0.6619	−0.76	0.448	
Year*Area	2004 8	0.7110	1	0.4830	1.47	0.141	
Year*Area	2004 9	−0.1303	1	0.4243	−0.31	0.759	
Year*Area	2004 56	0.0000	1				
Year*Area	2005 4	−0.1581	1	0.4518	−0.35	0.727	
Year*Area	2005 7	−0.6757	1	0.6603	−1.02	0.306	
Year*Area	2005 8	0.6864	1	0.5279	1.30	0.194	
Year*Area	2005 9	−0.0878	1	0.4587	−0.19	0.848	
Year*Area	2005 56	0.0000	1				
Year*Area	2006 4	0.1996	1	0.4565	0.44	0.662	
Year*Area	2006 7	−1.0618	1	0.6094	−1.74	0.082	
Year*Area	2006 8	0.2959	1	0.5212	0.57	0.570	
Year*Area	2006 9	−0.8257	1	0.4372	−1.89	0.059	
Year*Area	2006 56	0.0000	1				
Year*Area	2007 4	0.0055	1	0.4260	0.01	0.990	
Year*Area	2007 7	−0.8350	1	0.6061	−1.38	0.168	
Year*Area	2007 8	−0.0241	1	0.5001	−0.05	0.962	
Year*Area	2007 9	−0.7329	1	0.4331	−1.69	0.091	
Year*Area	2007 56	0.0000	1				
Year*Area	2008 4	0.3249	1	0.4366	0.74	0.457	
Year*Area	2008 7	−0.9471	1	0.6482	−1.46	0.144	
Year*Area	2008 8	−0.5589	1	0.5093	−1.10	0.273	
Year*Area	2008 9	−1.3347	1	0.4426	−3.02	0.003	**
Year*Area	2008 56	0.0000	1				
Year*Area	2009 4	0.9888	1	0.4265	2.32	0.021	*
Year*Area	2009 7	−0.4840	1	0.6675	−0.73	0.468	
Year*Area	2009 8	−0.6245	1	0.5097	−1.23	0.221	
Year*Area	2009 9	−0.9455	1	0.4302	−2.20	0.028	*
Year*Area	2009 56	0.0000	1				
Year*Area	2010 4	0.4588	1	0.4530	1.01	0.311	
Year*Area	2010 7	−0.1891	1	0.6524	−0.29	0.772	
Year*Area	2010 8	0.1124	1	0.5316	0.21	0.833	
Year*Area	2010 9	−0.7506	1	0.4567	−1.64	0.100	
Year*Area	2010 56	0.0000	1				
Year*Area	2011 4	0.1042	1	0.4227	0.25	0.805	
Year*Area	2011 7	−0.2550	1	0.6427	−0.40	0.692	
Year*Area	2011 8	−0.3391	1	0.5075	−0.67	0.504	
Year*Area	2011 9	−0.6337	1	0.4379	−1.45	0.148	
Year*Area	2011 56	0.0000	1				
Year*Area	2012 4	−0.2577	1	0.4249	−0.61	0.544	
Year*Area	2012 7	0.5257	1	0.6263	0.84	0.401	
Year*Area	2012 8	0.1594	1	0.5163	0.31	0.758	
Year*Area	2012 9	0.3435	1	0.4462	0.77	0.442	
Year*Area	2012 56	0.0000	1				
Year*Area	2013 4	0.0835	1	0.4463	0.19	0.852	
Year*Area	2013 7	−0.4941	1	0.6606	−0.75	0.455	
Year*Area	2013 8	0.1845	1	0.5351	0.34	0.730	
Year*Area	2013 9	−0.2088	1	0.4639	−0.45	0.653	
Year*Area	2013 56	0.0000	1				
Year*Area	2014 4	0.0000	1				
Year*Area	2014 7	0.0000	1				
Year*Area	2014 8	0.0000	1				
Year*Area	2014 9	0.0000	1				
Year*Area	2014 56	0.0000	1				

Table 3. AIC and BIC of Base case model and reduced base case

Model	AIC	BIC
Base	6,907	8,473
Reduced Base	7,163	7,544

Table 4. 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	0.6341	0.6660	0.6386	0.6753	0.6647	0.6925
1987	0.6364	0.6623	0.6587	0.6797	0.6442	0.6657
1988	0.5364	0.5480	0.5179	0.5213	0.5865	0.5908
1989	0.5344	0.5559	0.5184	0.5413	0.5482	0.5638
1990	0.5383	0.5316	0.5846	0.5703	0.4864	0.4827
1991	0.4648	0.4688	0.5135	0.5091	0.4487	0.4599
1992	0.5488	0.5381	0.6014	0.5773	0.5514	0.5430
1993	0.7236	0.6642	0.6998	0.6343	0.6912	0.6527
1994	0.6979	0.5835	0.5801	0.4880	0.7122	0.6010
1995	0.7564	0.6677	0.7206	0.6418	0.8206	0.7073
1996	0.5656	0.5183	0.5520	0.5111	0.5834	0.5423
1997	0.5208	0.4706	0.5514	0.4992	0.4968	0.4560
1998	0.5669	0.5502	0.5816	0.5586	0.5400	0.5181
1999	0.5807	0.5553	0.5958	0.5700	0.5430	0.5200
2000	0.5412	0.4816	0.5315	0.4737	0.5234	0.4738
2001	0.6071	0.5664	0.6178	0.5704	0.5912	0.5478
2002	0.8991	0.7413	0.8095	0.6719	0.8400	0.6964
2003	0.6621	0.5532	0.6894	0.5701	0.6481	0.5464
2004	0.6247	0.5665	0.6705	0.5970	0.5993	0.5388
2005	0.5014	0.4620	0.5196	0.4704	0.5885	0.5301
2006	0.3672	0.3244	0.3641	0.3292	0.3925	0.3404

Table 4. (cont.)

Year	Base w08	Base w05	Reduced Base w08	Reduced Base w05	Base with SxS w08	Base with SxS w05
2007	0.2708	0.2301	0.3301	0.2704	0.3067	0.2613
2008	0.5735	0.4366	0.5054	0.4120	0.5453	0.4118
2009	0.7172	0.5524	0.6447	0.5054	0.6778	0.5070
2010	1.0065	0.7091	0.6398	0.4749	1.0266	0.7113
2011	0.8601	0.6346	0.6913	0.5180	0.8401	0.5999
2012	1.1293	0.8235	0.7720	0.5704	1.1008	0.7973
2013	0.9365	0.6731	0.7742	0.5584	1.0625	0.7539
2014	1.0587	0.7689	0.7215	0.5270	0.9112	0.6532

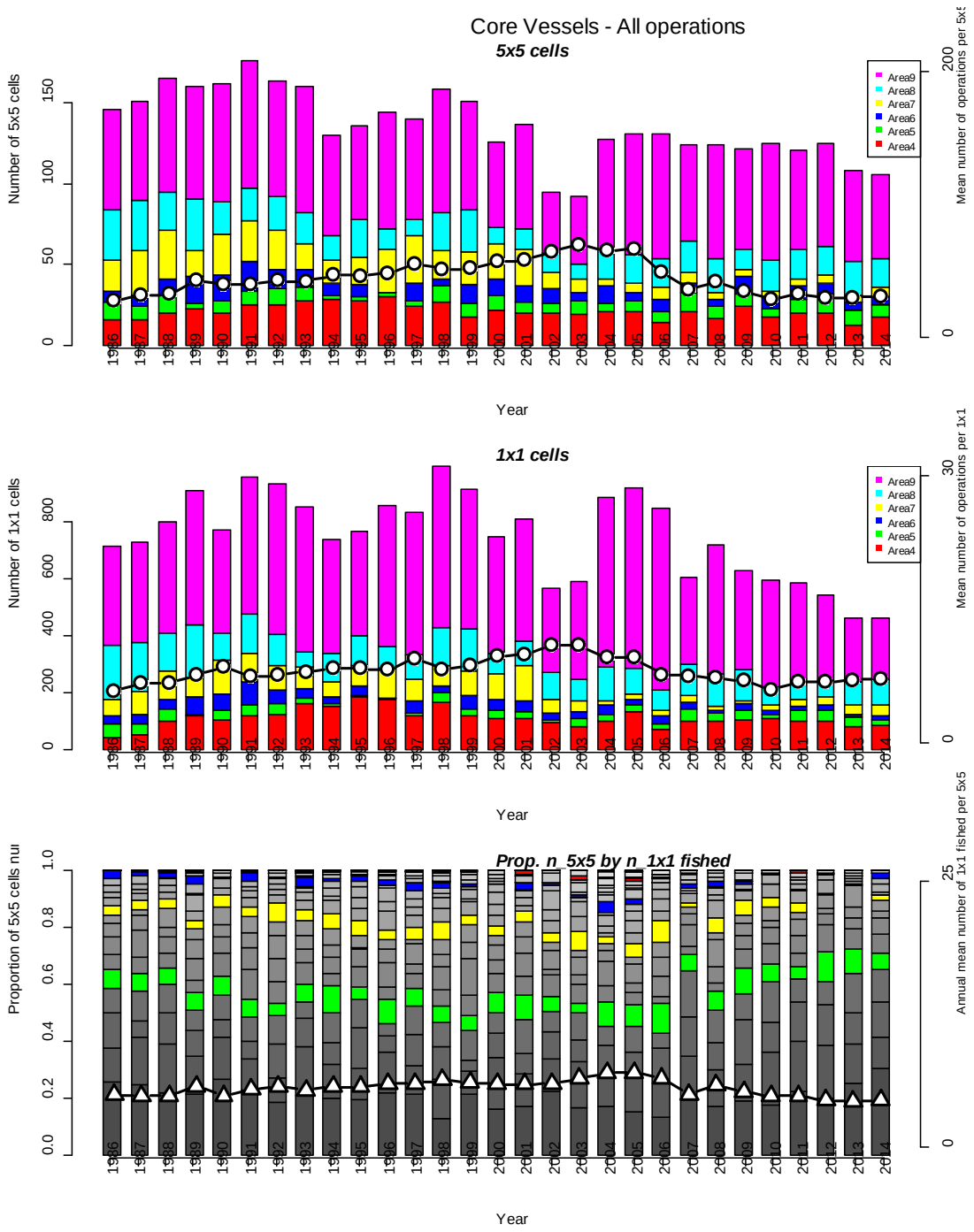

Figure 1a. Number of cells in the core vessel for all operations.

(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.

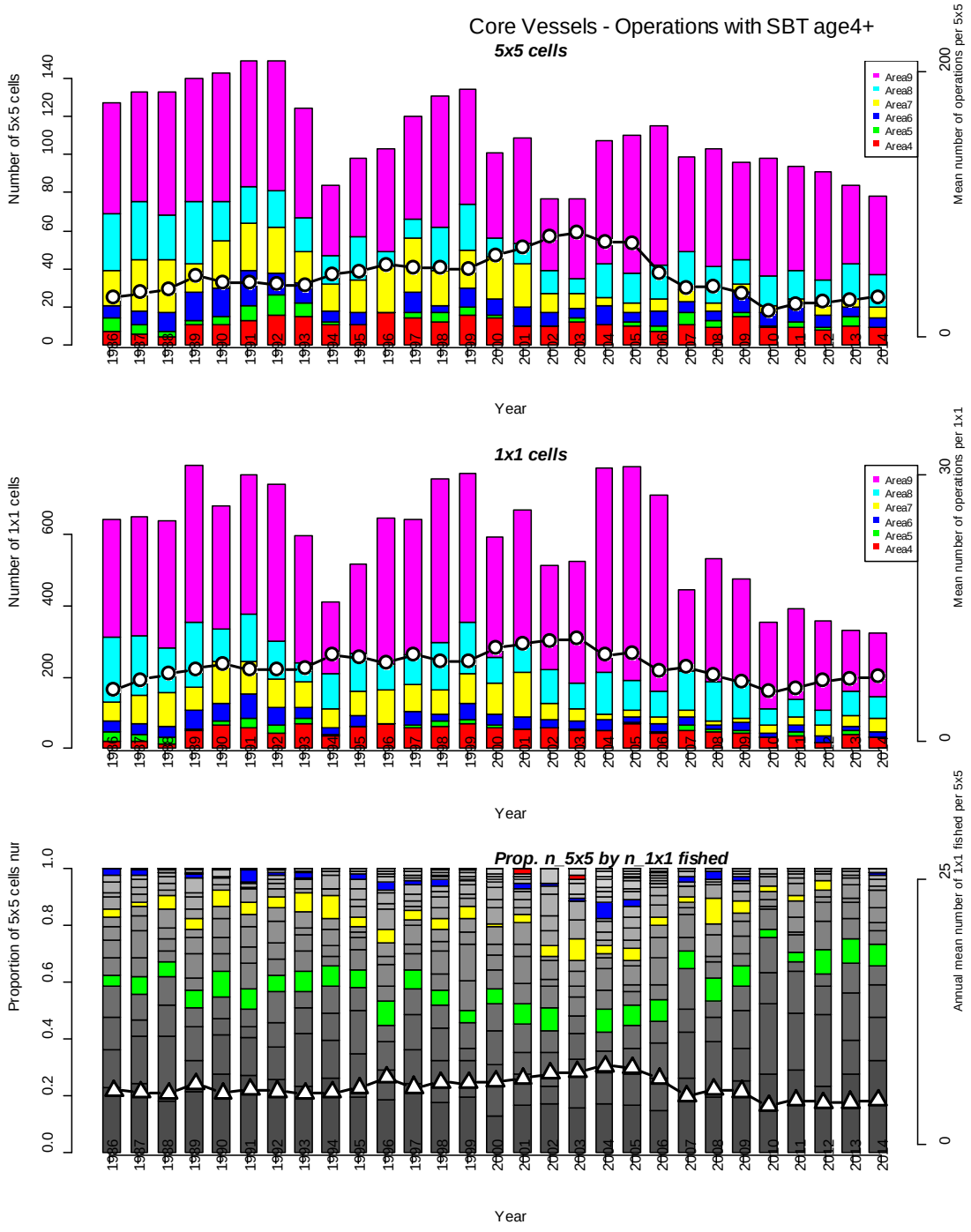

Figure 1b. Number of cells in the core vessel for SBT 4+ catch positive. See explanation in Fig. 1a.

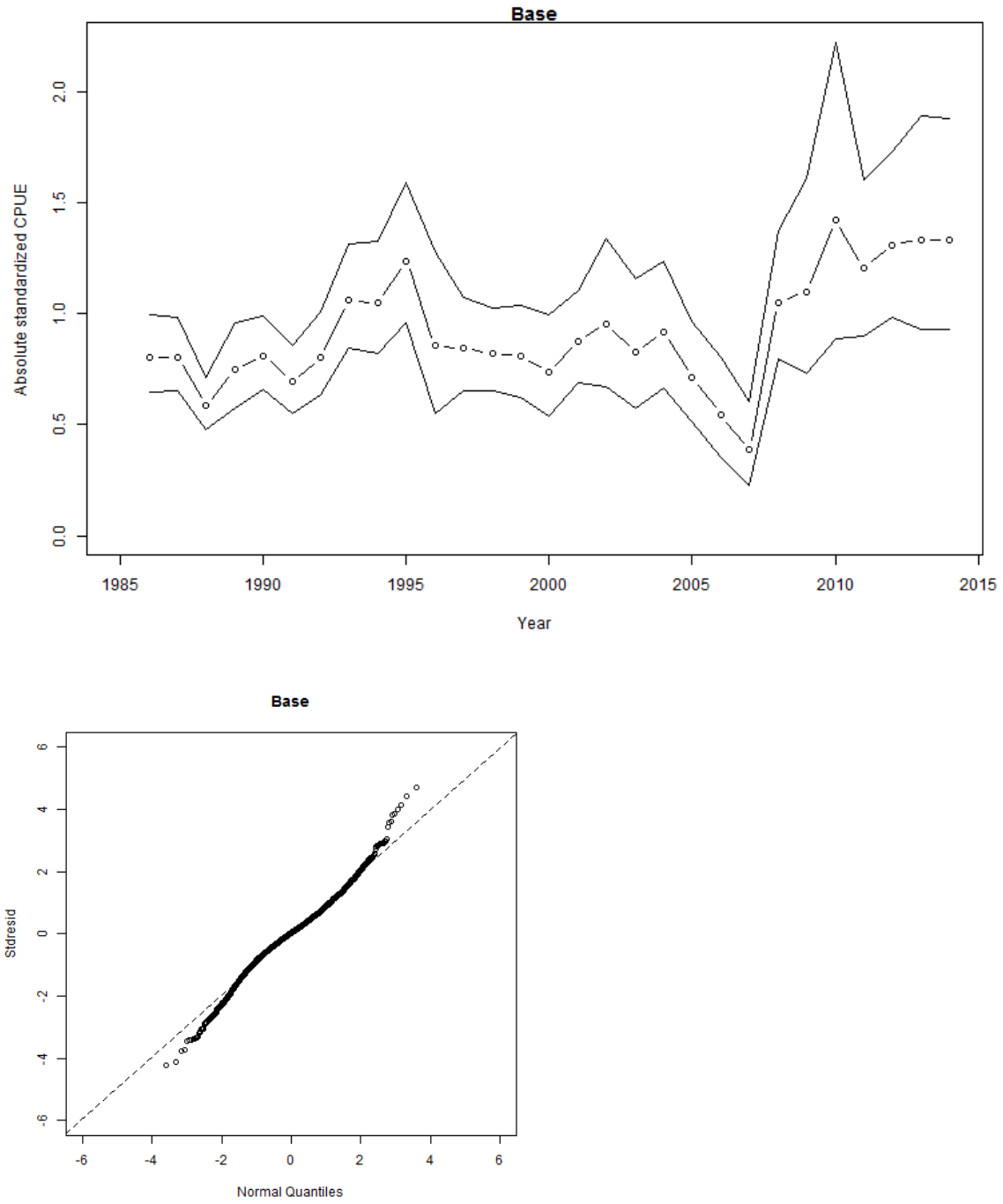

Fig 2. Standardized CPUE (ls-mean with 95% confidence interval) of the core vessel data (upper panel) and its QQ plot of residual (lower panel) for Base case.

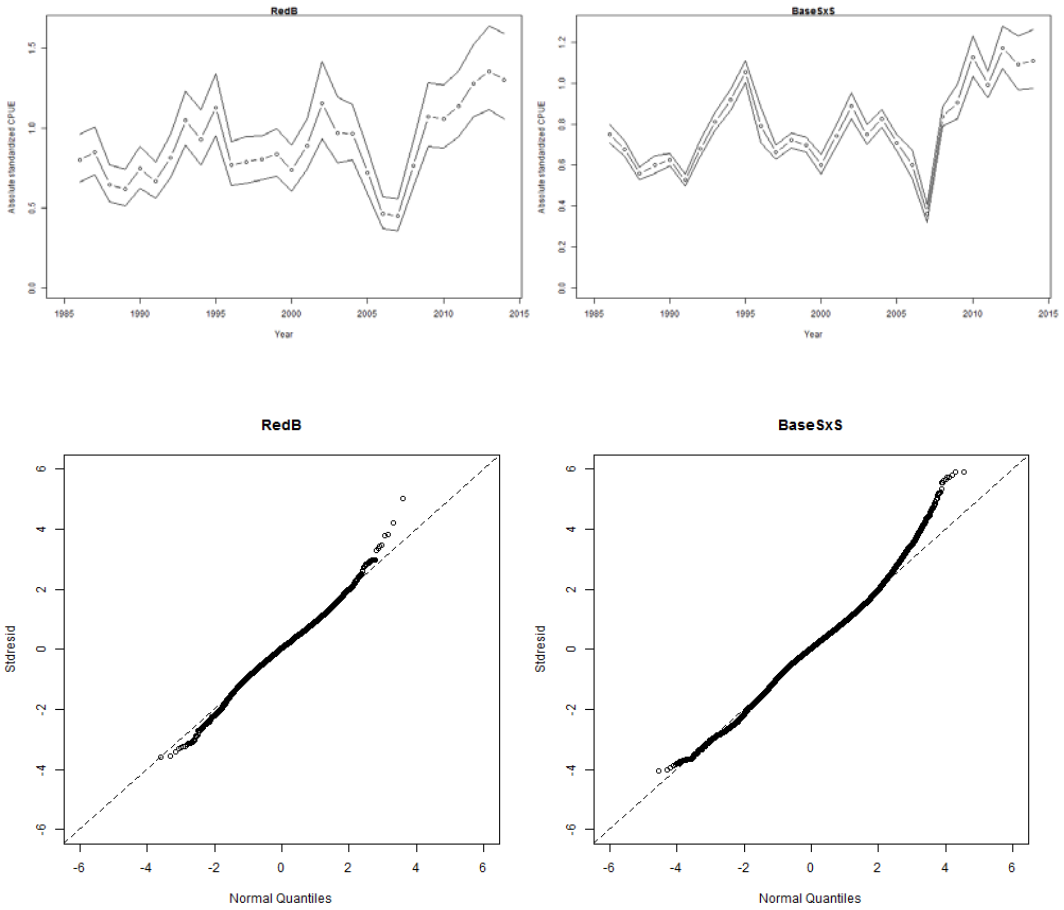

Fig 3. Standardized CPUE (ls-mean with 95% confidence interval) of the core vessel data (upper panel) and its QQ plot of residual (lower panel) for monitoring series. Left panels for reduced base case and right panels for shot-by-shot data with base case GLM model.

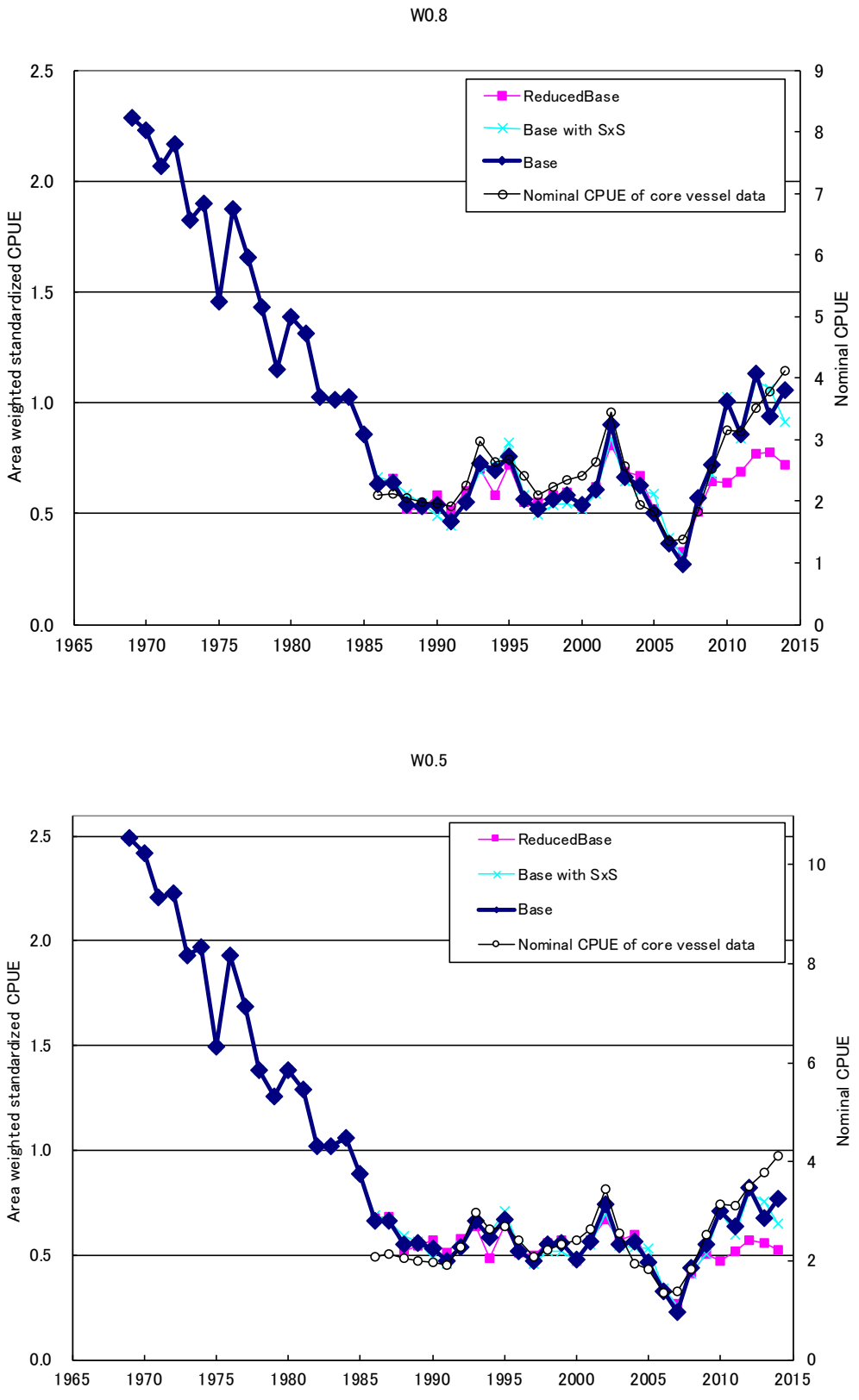

Fig 4. Area weighed standardized CPUEs. Nominal CPUE of the core vessels is also shown.

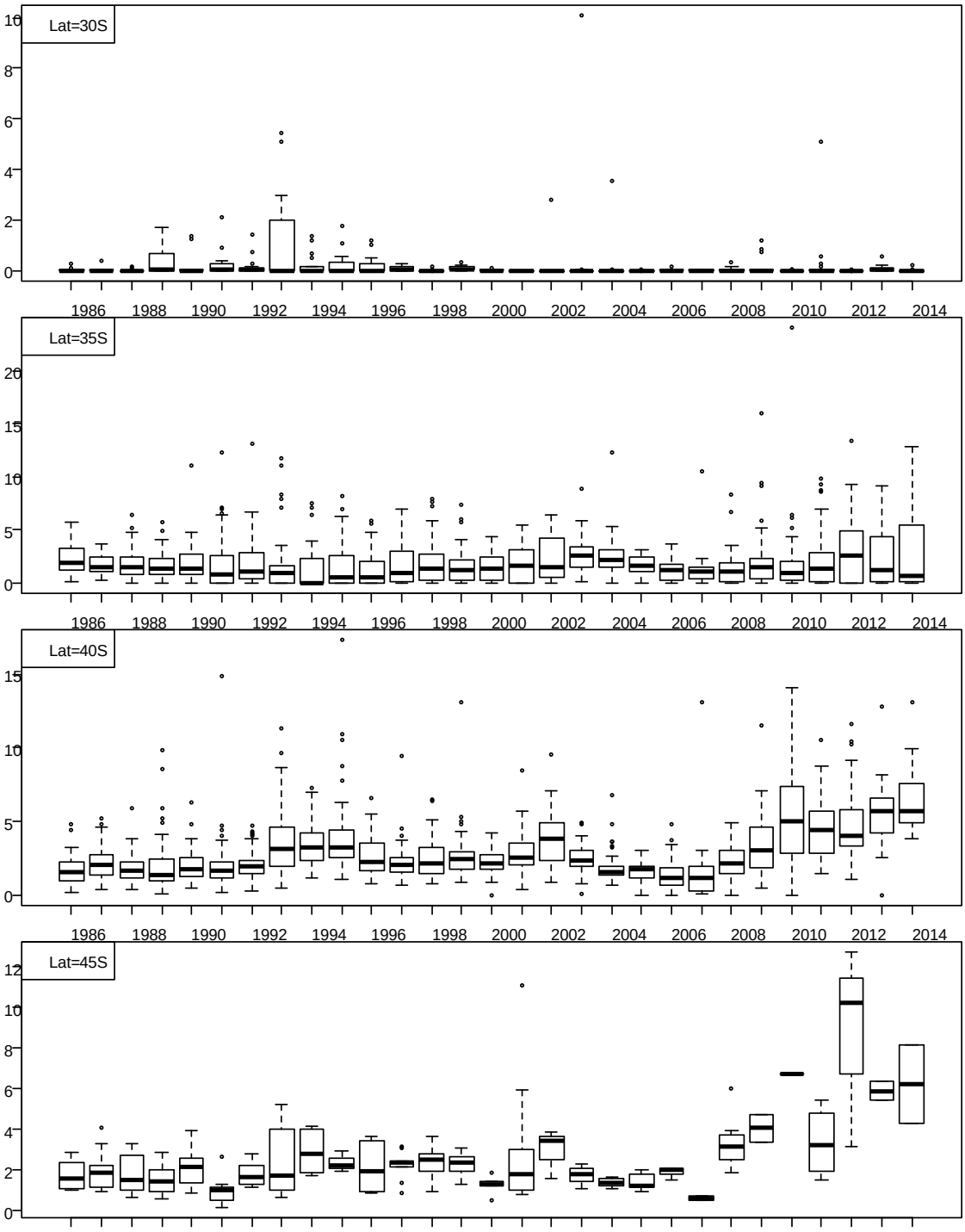

Fig 5. Nominal CPUE by year and latitude to evaluate whether year*latitude interaction should be included in the GLM model

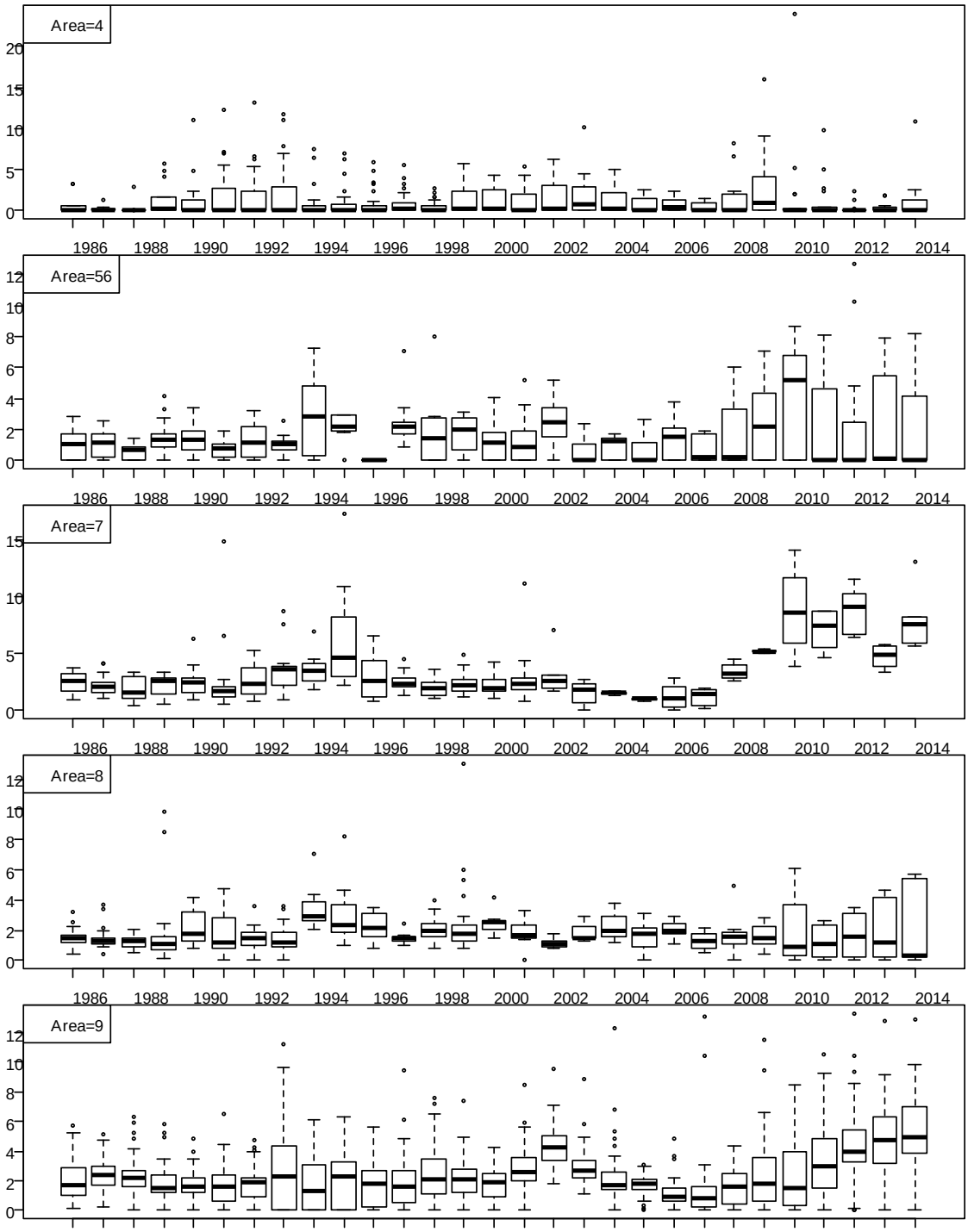

Fig 6. Nominal CPUE by year and Area to evaluate whether year*Area interaction should be included in the GLM model