2014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 2014

伊藤智幸・高橋紀夫

Tomoyuki ITOH and Norio TAKAHASHI

（独）水産総合研究センター 国際水産資源研究所

National Research Institute of Far Seas Fisheries, Fisheries Research Agency

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2013年までに更新した。2013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 2013. The index values in 2013, 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 come to new era with the agreement and implementation of Management Procedure in 2011. The Management Procedure adapted output TAC by using longline CPUE and aerial survey index, so that those indices should be evaluated with high transparency. However, because shot-by-shot data 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 (1986-2013), from Australia (RTMP data; 1989-2005) and from New Zealand (Joint venture; 1990-2013). Data from Japan are based on logbook data, but 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 logbook data will be available after one or two years later so that data of operations especially for non-SBT targeting will be added later years.

Dataset was limited within CCSBT statistical areas between Area 4 and Area 9 and months between 4 and 9. CPUE was defined as the number of SBT caught whose age was more than equal age 4 per 1000 hooks used. Proportion of age 4+ by 5x5 degree square and month was calculated from the CCSBT catch-at-age database, adding catch-at-age data made by Japan for 2012 and 2013.

Core vessels which caught many SBT were selected with x (top rank of SBT catch in a year) = 56 and y (number of years in the top ranks) = 3. A sub-dataset from vessels with a total records of 167,657 was made (Table 1). The number of vessels chosen ranged from 35 to 101 in each year.

As a reference, the number of area operated in terms of five degrees / month, one degree / month and the number of one degree square in five degrees square are shown in Fig. 1 for all operations and operations with SBT age 4+ positive.

Following corrections were further carried out before CPUE standardization. Delete records operated south of 50 degree South, combined Area 5 and Area 6 into Area 56, and delete operations with extremely high CPUE (>120). The shot-by-shot data were aggregated into 5x5 degree 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 age 4+ before log transform (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 are 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 in Base series, but the data used are shot-by-shot daily level rather than the aggregated 5x5 month level.

Estimated parameter values for Base case is shown in Table 2.   Standardized CPUE 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 appropriate model 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,

$(\text{AI}_{VS})_{ymal}$ 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 (2013), which was mainly from RTMP and targeting on SBT, was corrected with the constant of 0.977, the average in three years (1.000 in 2010, 0.922 in 2011 and 1.009 in 2012[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 2013 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 2013 with the base GLM model (0.855) is high as 128% of the previous 10 years mean (0.668). That of W0.5 in 2013 (0.618) is high as 117% of the previous 10 years mean (0.529).

The trends of the indices among GLM models (Base vs Reduced Base) were similar but different for recent four years. Differences in 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 Areas. These different trends were taken account in the Base model, but not in Reduced model, and may be resulted in the differences in the indices. However, the numbers of factors

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[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.

that significantly different were not so large in *Year*Lat5 and Year*Area* (Table 2).

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	6,919	95
1997	16,322		379	16,701	7,778	91
1998	16,310		310	16,620	8,133	101
1999	14,414		306	14,720	7,751	95
2000	11,746		265	12,011	7,051	93
2001	14,075		198	14,273	7,751	97
2002	10,721		228	10,949	6,119	88
2003	11,563		294	11,857	6,226	86
2004	13,101		349	13,450	8,068	89
2005	13,848		198	14,046	8,321	90
2006	9,124		183	9,307	6,147	79
2007	5,540		387	5,927	4,309	77
2008	6,815		167	6,982	5,000	83
2009	5,016		231	5,247	4,037	67
2010	4,102		144	4,246	3,398	61
2011	4,757		151	4,908	3,661	58
2012	4,455		163	4,618	3,199	61
2013	4,183		148	4,331	2,807	57
Total	379,102	8,776	6,662	394,540	167,657	

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	2.1475	1	0.7273	2.95	0.003	**
Year 1986	-1.3200	1	0.7505	-1.76	0.079	
Year 1987	-1.2377	1	0.7551	-1.64	0.101	
Year 1988	-1.7957	1	0.7404	-2.43	0.015	*
Year 1989	-1.4903	1	0.7455	-2.00	0.046	*
Year 1990	-0.9511	1	0.7352	-1.29	0.196	
Year 1991	-1.8716	1	0.7367	-2.54	0.011	*
Year 1992	-1.2551	1	0.7687	-1.63	0.103	
Year 1993	-1.3884	1	0.7777	-1.79	0.074	
Year 1994	-0.6731	1	0.7997	-0.84	0.400	
Year 1995	-0.9575	1	0.7912	-1.21	0.226	
Year 1996	-1.4422	1	1.0970	-1.31	0.189	
Year 1997	-0.8110	1	0.7541	-1.08	0.282	
Year 1998	-0.8232	1	0.7741	-1.06	0.288	
Year 1999	-0.7829	1	0.7531	-1.04	0.299	
Year 2000	-1.3793	1	0.7721	-1.79	0.074	
Year 2001	-0.9882	1	0.7559	-1.31	0.191	
Year 2002	-0.7049	1	0.8037	-0.88	0.381	
Year 2003	-1.1663	1	0.8188	-1.42	0.155	
Year 2004	-1.2381	1	0.7774	-1.59	0.111	
Year 2005	-1.2191	1	0.8114	-1.50	0.133	
Year 2006	-0.9407	1	0.8099	-1.16	0.246	
Year 2007	-1.7746	1	0.8677	-2.05	0.041	*
Year 2008	0.1409	1	0.7775	0.18	0.856	
Year 2009	-0.2904	1	0.8578	-0.34	0.735	
Year 2010	0.2120	1	0.9905	0.21	0.831	
Year 2011	-0.2909	1	0.8118	-0.36	0.720	
Year 2012	-0.2941	1	0.8362	-0.35	0.725	
Year 2013	0	1				
Month 4	-0.6089	1	0.2097	-2.90	0.004	**
Month 5	-0.4192	1	0.1962	-2.14	0.033	*
Month 6	-0.4628	1	0.1930	-2.40	0.017	*
Month 7	-0.2735	1	0.1854	-1.47	0.140	
Month 8	-0.1616	1	0.1845	-0.88	0.381	
Month 9	0	1				
Area 4	-0.2866	1	0.3805	-0.75	0.451	
Area 7	-0.8701	1	0.5507	-1.58	0.114	
Area 8	-0.9064	1	0.4436	-2.04	0.041	*
Area 9	-0.2235	1	0.3842	-0.58	0.561	
Area 56	0	1				
Lat5 30	-2.6263	1	0.7492	-3.51	0.001	***
Lat5 35	-0.8404	1	0.7840	-1.07	0.284	
Lat5 40	-0.1911	1	0.7770	-0.25	0.806	
Lat5 45	0	1				
BETcpue5	-0.1424	0	0.0104	-13.65	<.0001	***
YFTcpue5	-0.0710	0	0.0054	-13.08	<.0001	***
Month*Area 4 4	-1.2899	1	0.2563	-5.03	<.0001	***
Month*Area 4 7	1.0966	1	0.2987	3.67	0.000	***
Month*Area 4 8	-0.8567	1	0.3109	-2.76	0.006	**
Month*Area 4 9	0.2161	1	0.2253	0.96	0.338	
Month*Area 4 56	0	1				
Month*Area 5 4	-0.5407	1	0.2433	-2.22	0.026	*
Month*Area 5 7	0.9066	1	0.2859	3.17	0.002	**
Month*Area 5 8	-0.2462	1	0.2788	-0.88	0.377	
Month*Area 5 9	0.2561	1	0.2090	1.23	0.221	
Month*Area 5 56	0	1				
Month*Area 6 4	-0.1350	1	0.2397	-0.56	0.573	
Month*Area 6 7	0.8945	1	0.2875	3.11	0.002	**
Month*Area 6 8	0.4195	1	0.2720	1.54	0.123	
Month*Area 6 9	0.3884	1	0.2072	1.87	0.061	
Month*Area 6 56	0	1				
Month*Area 7 4	0.1107	1	0.2356	0.47	0.638	
Month*Area 7 7	0.6773	1	0.2961	2.29	0.022	*
Month*Area 7 8	0.3971	1	0.2179	1.82	0.069	
Month*Area 7 9	0.4789	1	0.2022	2.37	0.018	*
Month*Area 7 56	0	1				
Month*Area 8 4	-0.0648	1	0.2435	-0.27	0.790	
Month*Area 8 7	0.0899	1	0.3964	0.23	0.821	
Month*Area 8 8	0.4501	1	0.2065	2.18	0.029	*
Month*Area 8 9	0.4139	1	0.2062	2.01	0.045	*
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	1.2182	1	0.8285	1.47	0.142	
Year*Lat5 1986 35	1.0964	1	0.8348	1.31	0.189	
Year*Lat5 1986 40	0.1238	1	0.8272	0.15	0.881	
Year*Lat5 1986 45	0	1				
Year*Lat5 1987 30	1.5270	1	0.8519	1.79	0.073	
Year*Lat5 1987 35	0.7513	1	0.8297	0.91	0.365	
Year*Lat5 1987 40	0.1624	1	0.8170	0.20	0.843	
Year*Lat5 1987 45	0	1				
Year*Lat5 1988 30	1.6902	1	0.8079	2.09	0.037	*
Year*Lat5 1988 35	0.7362	1	0.8147	0.90	0.366	
Year*Lat5 1988 40	-0.0210	1	0.8044	-0.03	0.979	
Year*Lat5 1988 45	0	1				
Year*Lat5 1989 30	1.9146	1	0.8801	2.18	0.030	*
Year*Lat5 1989 35	0.9702	1	0.8349	1.16	0.245	
Year*Lat5 1989 40	0.3103	1	0.8160	0.38	0.704	
Year*Lat5 1989 45	0	1				
Year*Lat5 1990 30	1.0958	1	0.8076	1.36	0.175	
Year*Lat5 1990 35	0.4406	1	0.8146	0.54	0.589	
Year*Lat5 1990 40	0.0994	1	0.7975	0.12	0.901	
Year*Lat5 1990 45	0	1				
Year*Lat5 1991 30	1.8852	1	0.8129	2.32	0.021	*
Year*Lat5 1991 35	0.8987	1	0.8267	1.09	0.277	
Year*Lat5 1991 40	0.4381	1	0.8178	0.54	0.592	
Year*Lat5 1991 45	0	1				
Year*Lat5 1992 30	1.1559	1	0.8413	1.37	0.170	
Year*Lat5 1992 35	0.5788	1	0.8495	0.68	0.496	
Year*Lat5 1992 40	0.2268	1	0.8389	0.27	0.787	
Year*Lat5 1992 45	0	1				
Year*Lat5 1993 30	1.0993	1	0.8554	1.29	0.199	
Year*Lat5 1993 35	0.1745	1	0.8497	0.21	0.837	
Year*Lat5 1993 40	0.5858	1	0.8380	0.70	0.485	
Year*Lat5 1993 45	0	1				
Year*Lat5 1994 30	0.5252	1	0.8840	0.59	0.553	
Year*Lat5 1994 35	0.0428	1	0.8779	0.05	0.961	
Year*Lat5 1994 40	0.4558	1	0.8609	0.53	0.597	
Year*Lat5 1994 45	0	1				
Year*Lat5 1995 30	1.3310	1	0.9008	1.48	0.140	
Year*Lat5 1995 35	0.2484	1	0.9051	0.27	0.784	
Year*Lat5 1995 40	0.3203	1	0.8890	0.36	0.719	
Year*Lat5 1995 45	0	1				
Year*Lat5 1996 30	1.2061	1	0.8742	1.38	0.168	
Year*Lat5 1996 35	0.0906	1	0.8638	0.10	0.917	
Year*Lat5 1996 40	0.3159	1	0.8444	0.37	0.708	
Year*Lat5 1996 45	0	1				
Year*Lat5 1997 30	1.0303	1	0.8734	1.18	0.238	
Year*Lat5 1997 35	0.7074	1	0.8491	0.83	0.405	
Year*Lat5 1997 40	0.3953	1	0.8349	0.47	0.636	
Year*Lat5 1997 45	0	1				
Year*Lat5 1998 30	0.9774	1	0.8296	1.18	0.239	
Year*Lat5 1998 35	0.4163	1	0.8371	0.50	0.619	
Year*Lat5 1998 40	-0.0172	1	0.8261	-0.02	0.983	
Year*Lat5 1998 45	0	1				
Year*Lat5 1999 30	0.6612	1	0.8411	0.79	0.432	
Year*Lat5 1999 35	0.4622	1	0.8467	0.55	0.585	
Year*Lat5 1999 40	0.2447	1	0.8355	0.29	0.770	
Year*Lat5 1999 45	0	1				
Year*Lat5 2000 30	0.9956	1	0.8520	1.17	0.243	
Year*Lat5 2000 35	0.6523	1	0.8740	0.75	0.456	
Year*Lat5 2000 40	0.5302	1	0.8612	0.62	0.538	
Year*Lat5 2000 45	0	1				
Year*Lat5 2001 30	0.9353	1	0.8210	1.14	0.255	
Year*Lat5 2001 35	0.2406	1	0.8383	0.29	0.774	
Year*Lat5 2001 40	0.1822	1	0.8230	0.22	0.825	
Year*Lat5 2001 45	0	1				
Year*Lat5 2002 30	0.7795	1	0.9275	0.84	0.401	
Year*Lat5 2002 35	0.9136	1	0.9176	1.00	0.320	
Year*Lat5 2002 40	0.1803	1	0.8701	0.21	0.836	
Year*Lat5 2002 45	0	1				
Year*Lat5 2003 30	0.9651	1	0.8844	1.09	0.275	
Year*Lat5 2003 35	0.8614	1	0.9181	0.94	0.348	
Year*Lat5 2003 40	0.1239	1	0.9058	0.14	0.891	
Year*Lat5 2003 45	0	1				
Year*Lat5 2004 30	1.3644	1	0.8499	1.61	0.109	
Year*Lat5 2004 35	1.1451	1	0.8659	1.32	0.186	
Year*Lat5 2004 40	0.1748	1	0.8535	0.20	0.838	
Year*Lat5 2004 45	0	1				
Year*Lat5 2005 30	1.4662	1	0.8601	1.70	0.088	
Year*Lat5 2005 35	0.9567	1	0.8573	1.12	0.265	
Year*Lat5 2005 40	-0.0891	1	0.8506	-0.10	0.917	
Year*Lat5 2005 45	0	1				
Year*Lat5 2006 30	0.6637	1	0.8909	0.75	0.456	
Year*Lat5 2006 35	0.5932	1	0.9214	0.64	0.520	
Year*Lat5 2006 40	0.0015	1	0.9116	0.00	0.999	
Year*Lat5 2006 45	0	1				
Year*Lat5 2007 30	1.8096	1	0.9268	1.95	0.051	
Year*Lat5 2007 35	1.3239	1	0.9649	1.37	0.170	
Year*Lat5 2007 40	0.6913	1	0.9605	0.72	0.472	
Year*Lat5 2007 45	0	1				
Year*Lat5 2008 30	0.1969	1	0.8276	0.24	0.812	
Year*Lat5 2008 35	-0.0898	1	0.8375	-0.11	0.915	
Year*Lat5 2008 40	-0.0369	1	0.8311	-0.04	0.965	
Year*Lat5 2008 45	0	1				
Year*Lat5 2009 30	-0.0545	1	0.9250	-0.06	0.953	
Year*Lat5 2009 35	0.5013	1	0.9599	0.52	0.602	
Year*Lat5 2009 40	0.3328	1	0.9518	0.35	0.727	
Year*Lat5 2009 45	0	1				
Year*Lat5 2010 30	-0.6707	1	1.0609	-0.63	0.527	
Year*Lat5 2010 35	-0.3820	1	1.0918	-0.35	0.726	
Year*Lat5 2010 40	0.0207	1	1.0826	0.02	0.985	
Year*Lat5 2010 45	0	1				
Year*Lat5 2011 30	0.2938	1	0.8583	0.34	0.732	
Year*Lat5 2011 35	0.4979	1	0.8693	0.57	0.567	
Year*Lat5 2011 40	0.4063	1	0.8628	0.47	0.638	
Year*Lat5 2011 45	0	1				
Year*Lat5 2012 30	0.1488	1	0.8793	0.17	0.866	
Year*Lat5 2012 35	-0.1069	1	0.9003	-0.12	0.906	
Year*Lat5 2012 40	-0.2689	1	0.8896	-0.30	0.763	
Year*Lat5 2012 45	0	1				
Year*Lat5 2013 30	0	1				
Year*Lat5 2013 35	0	1				
Year*Lat5 2013 40	0	1				
Year*Lat5 2013 45	0	1				
Year*Area 1986 4	0.6816	1	0.4530	1.50	0.133	
Year*Area 1986 7	0.5289	1	0.5687	0.93	0.352	
Year*Area 1986 8	0.3076	1	0.4945	0.62	0.534	
Year*Area 1986 9	0.3020	1	0.4390	0.69	0.492	
Year*Area 1986 56	0	1				
Year*Area 1987 4	0.0973	1	0.4853	0.20	0.841	
Year*Area 1987 7	0.3902	1	0.5608	0.70	0.487	
Year*Area 1987 8	0.3789	1	0.4907	0.77	0.440	
Year*Area 1987 9	0.4595	1	0.4306	1.07	0.286	
Year*Area 1987 56	0	1				
Year*Area 1988 4	0.2094	1	0.4197	0.50	0.618	
Year*Area 1988 7	0.8432	1	0.5472	1.54	0.123	
Year*Area 1988 8	0.9045	1	0.4803	1.88	0.060	
Year*Area 1988 9	1.0527	1	0.4071	2.59	0.010	**
Year*Area 1988 56	0	1				
Year*Area 1989 4	0.2915	1	0.4749	0.61	0.540	
Year*Area 1989 7	0.5657	1	0.5556	1.02	0.309	
Year*Area 1989 8	0.3091	1	0.4696	0.66	0.510	
Year*Area 1989 9	0.2064	1	0.4027	0.51	0.608	
Year*Area 1989 56	0	1				
Year*Area 1990 4	0.4627	1	0.4173	1.11	0.268	
Year*Area 1990 7	0.1363	1	0.5428	0.25	0.802	
Year*Area 1990 8	0.5028	1	0.4818	1.04	0.297	
Year*Area 1990 9	-0.1302	1	0.3967	-0.33	0.743	
Year*Area 1990 56	0	1				
Year*Area 1991 4	1.0620	1	0.4012	2.65	0.008	**
Year*Area 1991 7	0.7119	1	0.5425	1.31	0.190	
Year*Area 1991 8	0.7867	1	0.4720	1.67	0.096	
Year*Area 1991 9	0.3979	1	0.3909	1.02	0.309	
Year*Area 1991 56	0	1				

Table 2 (cont.)

Parameter	Estimate	Biased	StdErr	tValue	Probt	Signi
Year*Area 1992 4	0.9012	1	0.4100	2.20	0.028	*
Year*Area 1992 7	0.3978	1	0.5460	0.73	0.466	
Year*Area 1992 8	0.5222	1	0.4693	1.11	0.266	
Year*Area 1992 9	0.2154	1	0.3955	0.54	0.586	
Year*Area 1992 56	0	1				
Year*Area 1993 4	1.6827	1	0.4331	3.88	0.000	***
Year*Area 1993 7	0.6223	1	0.5612	1.11	0.268	
Year*Area 1993 8	1.0889	1	0.4818	2.26	0.024	*
Year*Area 1993 9	0.3699	1	0.4023	0.92	0.358	
Year*Area 1993 56	0	1				
Year*Area 1994 4	0.8690	1	0.5049	1.72	0.085	
Year*Area 1994 7	0.0929	1	0.6185	0.15	0.881	
Year*Area 1994 8	0.8144	1	0.5497	1.48	0.139	
Year*Area 1994 9	−0.3755	1	0.4749	−0.79	0.429	
Year*Area 1994 56	0	1				
Year*Area 1995 4	0.6158	1	0.5067	1.22	0.224	
Year*Area 1995 7	0.8055	1	0.5996	1.34	0.179	
Year*Area 1995 8	0.8993	1	0.5477	1.64	0.101	
Year*Area 1995 9	0.0685	1	0.4842	0.14	0.888	
Year*Area 1995 56	0	1				
Year*Area 1996 4	1.2324	1	0.7946	1.55	0.121	
Year*Area 1996 7	0.7096	1	0.9296	0.76	0.445	
Year*Area 1996 8	1.3958	1	0.9007	1.55	0.121	
Year*Area 1996 9	0.3244	1	0.8357	0.39	0.698	
Year*Area 1996 56	0	1				
Year*Area 1997 4	0.4005	1	0.4985	0.80	0.422	
Year*Area 1997 7	−0.0675	1	0.5719	−0.12	0.906	
Year*Area 1997 8	0.0810	1	0.5580	0.15	0.885	
Year*Area 1997 9	−0.5785	1	0.4552	−1.27	0.204	
Year*Area 1997 56	0	1				
Year*Area 1998 4	0.1590	1	0.4199	0.38	0.705	
Year*Area 1998 7	−0.0499	1	0.5743	−0.09	0.931	
Year*Area 1998 8	0.5728	1	0.4994	1.15	0.252	
Year*Area 1998 9	0.0350	1	0.4230	0.08	0.934	
Year*Area 1998 56	0	1				
Year*Area 1999 4	0.3023	1	0.4433	0.68	0.495	
Year*Area 1999 7	0.0156	1	0.5744	0.03	0.978	
Year*Area 1999 8	0.3902	1	0.5040	0.77	0.439	
Year*Area 1999 9	−0.2669	1	0.4352	−0.61	0.540	
Year*Area 1999 56	0	1				
Year*Area 2000 4	0.8471	1	0.4397	1.93	0.054	
Year*Area 2000 7	0.2709	1	0.5640	0.48	0.631	
Year*Area 2000 8	1.0026	1	0.5286	1.90	0.058	
Year*Area 2000 9	−0.0415	1	0.4295	−0.10	0.923	
Year*Area 2000 56	0	1				
Year*Area 2001 4	0.6615	1	0.4355	1.52	0.129	
Year*Area 2001 7	0.2358	1	0.5642	0.42	0.676	
Year*Area 2001 8	0.7305	1	0.5269	1.39	0.166	
Year*Area 2001 9	0.2325	1	0.4334	0.54	0.592	
Year*Area 2001 56	0	1				
Year*Area 2002 4	0.0488	1	0.5449	0.09	0.929	
Year*Area 2002 7	0.0993	1	0.6488	0.15	0.878	
Year*Area 2002 8	−0.2533	1	0.5753	−0.44	0.660	
Year*Area 2002 9	0.3008	1	0.4785	0.63	0.530	
Year*Area 2002 56	0	1				
Year*Area 2003 4	0.7979	1	0.4595	1.74	0.083	
Year*Area 2003 7	0.2118	1	0.6608	0.32	0.749	
Year*Area 2003 8	0.6581	1	0.5920	1.11	0.266	
Year*Area 2003 9	0.4324	1	0.4786	0.90	0.366	
Year*Area 2003 56	0	1				
Year*Area 2004 4	0.4387	1	0.4300	1.02	0.308	
Year*Area 2004 7	0.0460	1	0.6701	0.07	0.945	
Year*Area 2004 8	0.8773	1	0.4868	1.80	0.072	
Year*Area 2004 9	0.1282	1	0.4206	0.30	0.761	
Year*Area 2004 56	0	1				
Year*Area 2005 4	−0.1490	1	0.4477	−0.33	0.739	
Year*Area 2005 7	−0.0860	1	0.6687	−0.13	0.898	
Year*Area 2005 8	0.8391	1	0.5311	1.58	0.114	
Year*Area 2005 9	0.2249	1	0.4549	0.49	0.621	
Year*Area 2005 56	0	1				
Year*Area 2006 4	0.2801	1	0.4487	0.62	0.533	
Year*Area 2006 7	−0.4867	1	0.6193	−0.79	0.432	
Year*Area 2006 8	0.6120	1	0.5220	1.17	0.241	
Year*Area 2006 9	−0.5637	1	0.4320	−1.30	0.192	
Year*Area 2006 56	0	1				
Year*Area 2007 4	0.0990	1	0.4185	0.24	0.813	
Year*Area 2007 7	−0.2918	1	0.6159	−0.47	0.636	
Year*Area 2007 8	0.2482	1	0.5013	0.50	0.621	
Year*Area 2007 9	−0.4165	1	0.4285	−0.97	0.331	
Year*Area 2007 56	0	1				
Year*Area 2008 4	0.3570	1	0.4290	0.83	0.405	
Year*Area 2008 7	−0.3988	1	0.6564	−0.61	0.544	
Year*Area 2008 8	−0.1685	1	0.5168	−0.33	0.744	
Year*Area 2008 9	−1.1034	1	0.4374	−2.52	0.012	*
Year*Area 2008 56	0	1				
Year*Area 2009 4	1.0501	1	0.4246	2.47	0.013	*
Year*Area 2009 7	0.0869	1	0.6757	0.13	0.898	
Year*Area 2009 8	−0.3818	1	0.5121	−0.75	0.456	
Year*Area 2009 9	−0.7267	1	0.4268	−1.70	0.089	
Year*Area 2009 56	0	1				
Year*Area 2010 4	0.6047	1	0.4483	1.35	0.178	
Year*Area 2010 7	0.3017	1	0.6605	0.46	0.648	
Year*Area 2010 8	0.1963	1	0.5375	0.37	0.715	
Year*Area 2010 9	−0.4131	1	0.4534	−0.91	0.362	
Year*Area 2010 56	0	1				
Year*Area 2011 4	0.1020	1	0.4224	0.24	0.809	
Year*Area 2011 7	0.2830	1	0.6518	0.43	0.664	
Year*Area 2011 8	−0.2651	1	0.5272	−0.50	0.615	
Year*Area 2011 9	−0.4169	1	0.4353	−0.96	0.338	
Year*Area 2011 56	0	1				
Year*Area 2012 4	−0.1907	1	0.4177	−0.46	0.648	
Year*Area 2012 7	1.0942	1	0.6350	1.72	0.085	
Year*Area 2012 8	−0.0611	1	0.5298	−0.12	0.908	
Year*Area 2012 9	0.6438	1	0.4414	1.46	0.145	
Year*Area 2012 56	0	1				
Year*Area 2013 4	0	1				
Year*Area 2013 7	0	1				
Year*Area 2013 8	0	1				
Year*Area 2013 9	0	1				
Year*Area 2013 56	0	1				

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

Model	AIC	BIC
Base	6,546	8,051
Reduced Base	6,783	7,155

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	0.6410	0.6746	0.6511	0.6877	0.6638	0.6930
1987	0.6379	0.6646	0.6574	0.6781	0.6417	0.6645
1988	0.5462	0.5589	0.5180	0.5214	0.5857	0.5905
1989	0.5382	0.5613	0.5247	0.5478	0.5457	0.5618
1990	0.5384	0.5311	0.5875	0.5720	0.4875	0.4828
1991	0.4584	0.4622	0.5070	0.5030	0.4500	0.4604
1992	0.5452	0.5344	0.5969	0.5735	0.5522	0.5430
1993	0.6961	0.6400	0.6796	0.6162	0.6882	0.6493
1994	0.7052	0.5887	0.5783	0.4864	0.7270	0.6085
1995	0.7393	0.6513	0.7077	0.6300	0.8402	0.7195
1996	0.5692	0.5208	0.5464	0.5068	0.5887	0.5454
1997	0.5216	0.4700	0.5482	0.4965	0.4980	0.4565
1998	0.5580	0.5401	0.5730	0.5503	0.5481	0.5232
1999	0.5727	0.5466	0.5874	0.5627	0.5416	0.5179
2000	0.5423	0.4816	0.5284	0.4713	0.5319	0.4793
2001	0.6038	0.5614	0.6083	0.5616	0.5980	0.5529
2002	0.8984	0.7399	0.8062	0.6694	0.8363	0.6941
2003	0.6886	0.5746	0.7122	0.5897	0.6700	0.5647
2004	0.6169	0.5630	0.6800	0.6055	0.5649	0.5174
2005	0.5045	0.4721	0.5359	0.4858	0.5257	0.4882
2006	0.3690	0.3250	0.3632	0.3288	0.3981	0.3439
2007	0.2765	0.2350	0.3394	0.2778	0.3108	0.2641
2008	0.5849	0.4454	0.5156	0.4201	0.5582	0.4214
2009	0.7116	0.5477	0.6447	0.5055	0.6850	0.5114
2010	1.0069	0.7160	0.6352	0.4717	0.9545	0.6662
2011	0.8337	0.6166	0.6840	0.5127	0.8384	0.5984
2012	1.0822	0.7923	0.7097	0.5242	1.0688	0.7780
2013	0.8551	0.6175	0.7318	0.5268	1.0040	0.7147
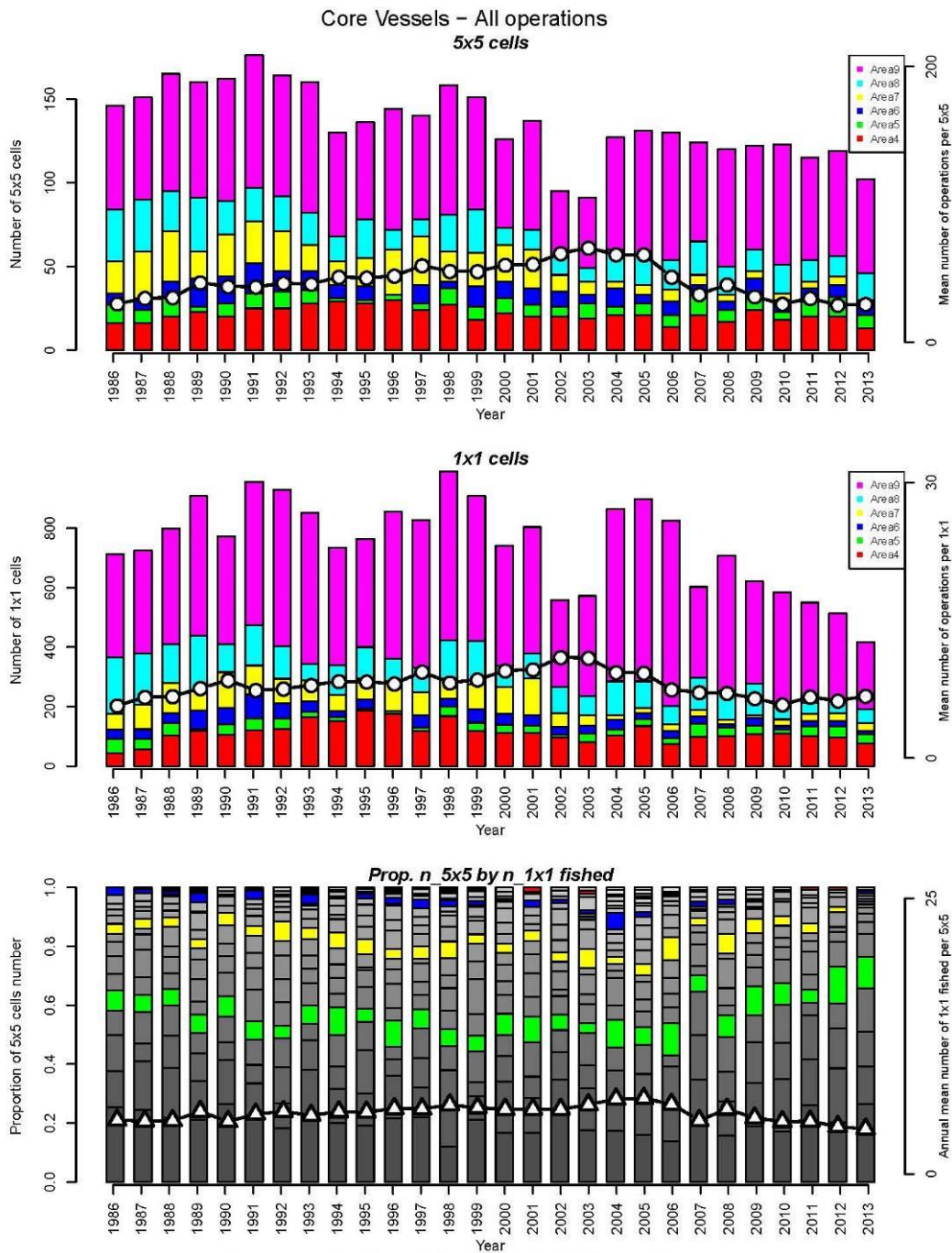
Figure 1a.   Number of cells in the core vessel for all operations.

(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.

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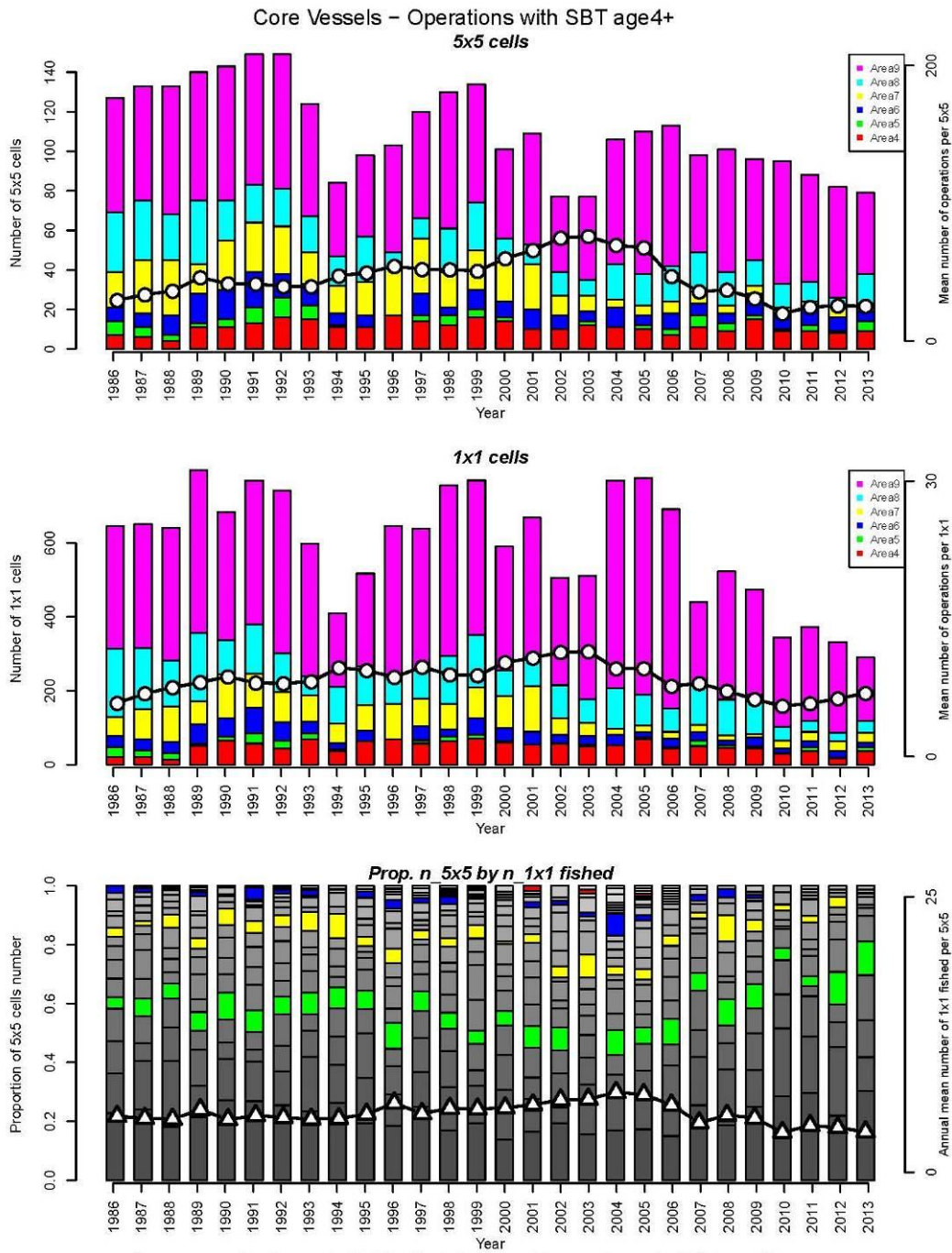
Figure 1b. Number of cells in the core vessel for SBT 4+ catch positive. See explanation in Fig. 1a.
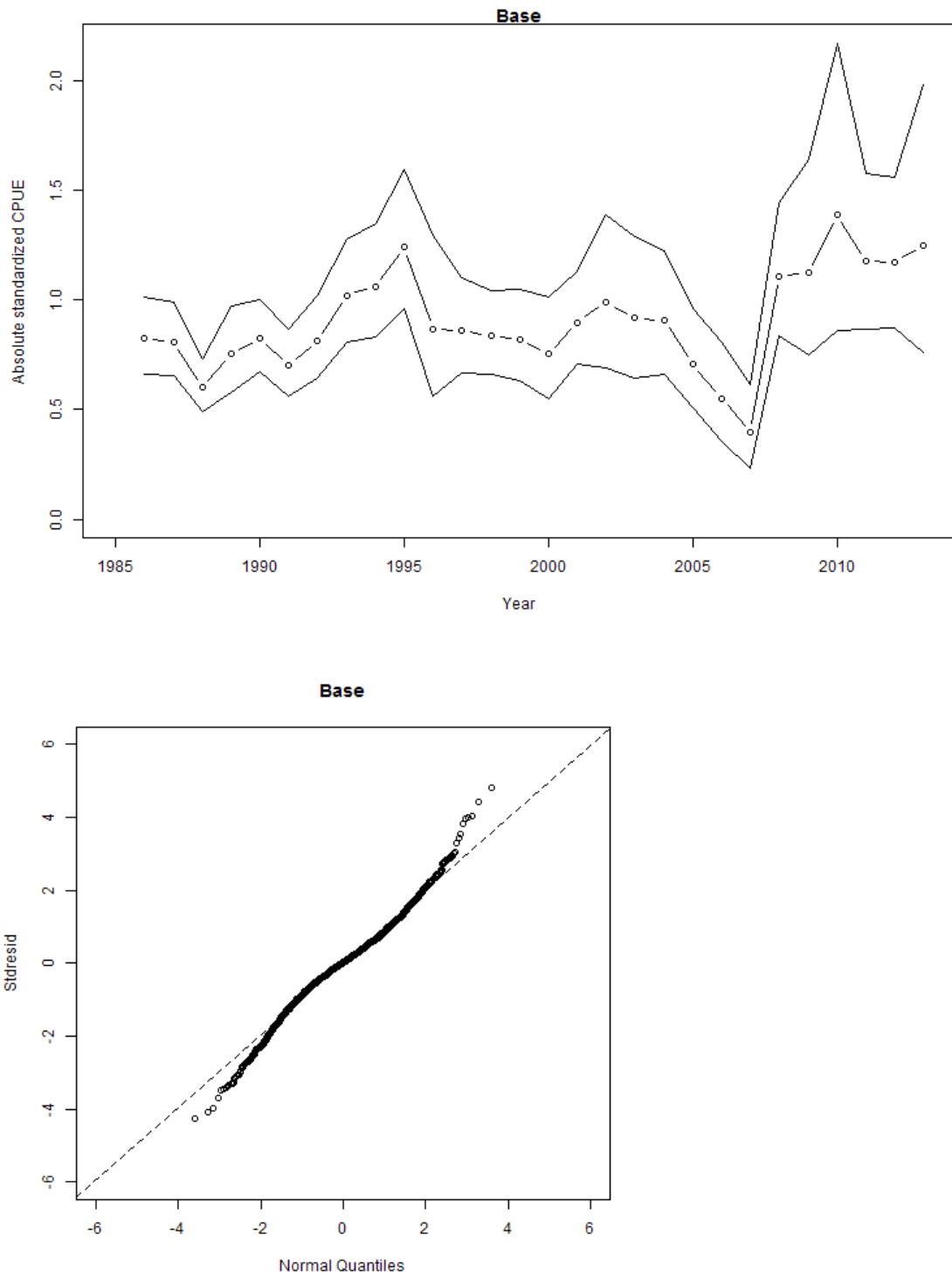
Fig 2. Standardized CPUE (mean with 95% confidence interval) of the core vessel data (upper panel) and its QQ plot of residual (lower panel) for Base case.
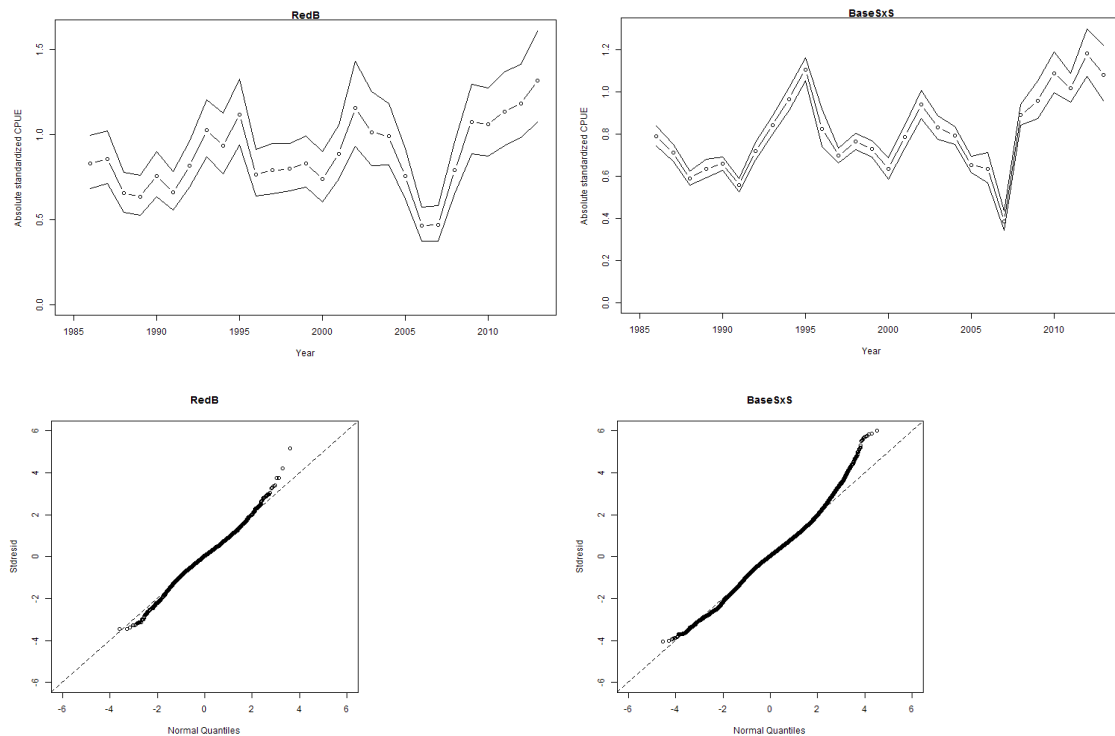
Fig 3. Standardized CPUE (mean with 95% confidence interval) of the core vessel data (upper panel) and its QQ plot of residual (lower panel) for monitoring series. Left panels for reduced base case and right panels for shot-by-shot data with base case GLM model.

W0.8

W0.5
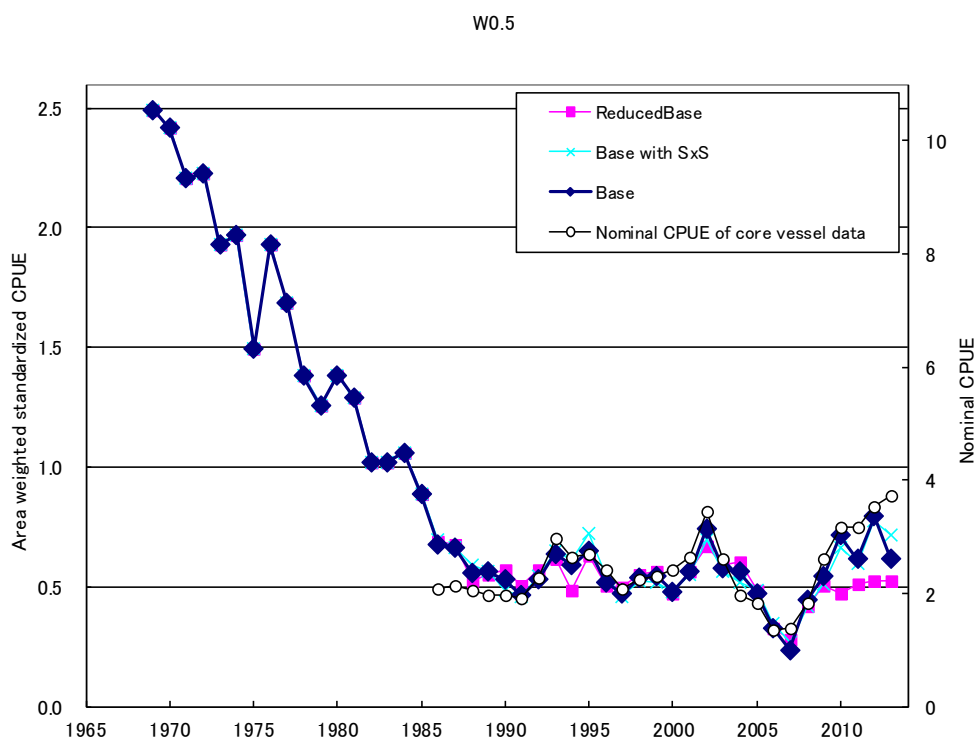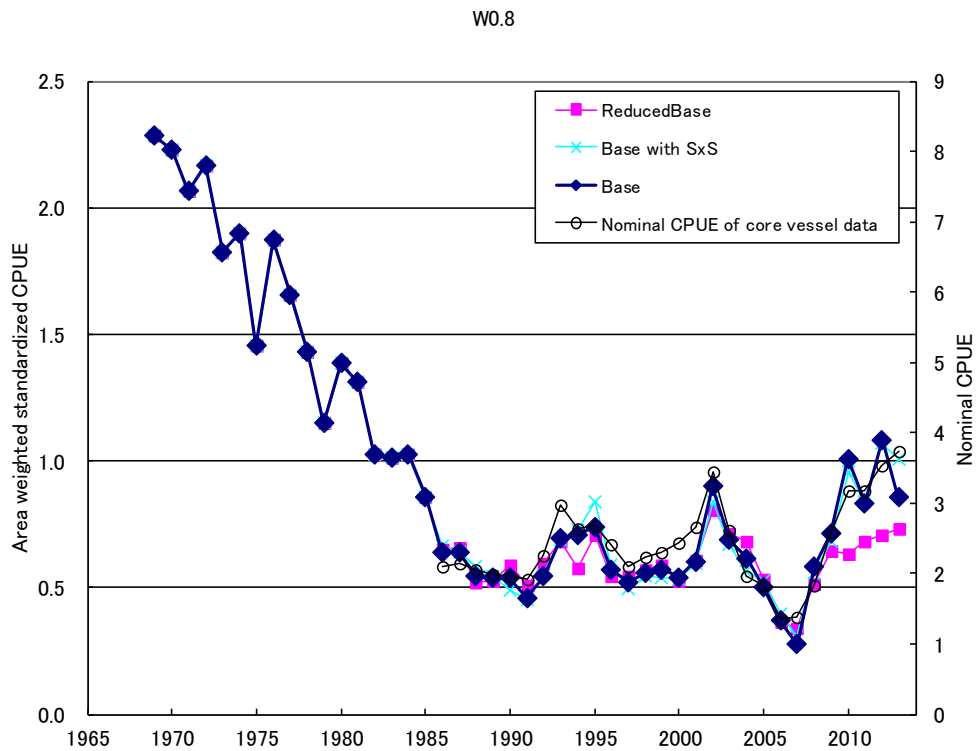
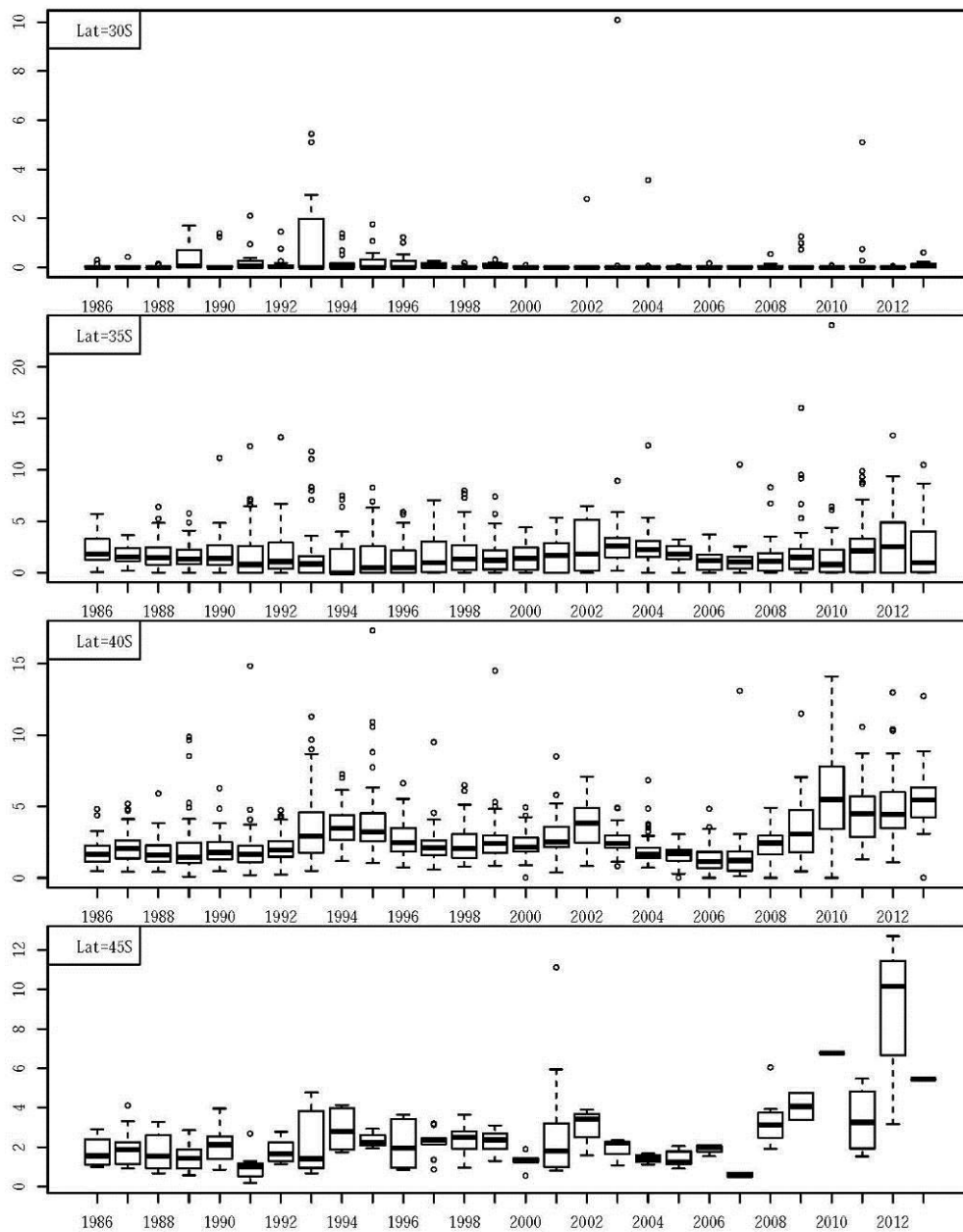Fig 4.   Area weighed standardized CPUEs.   Nominal CPUE of the core vessels is also shown.

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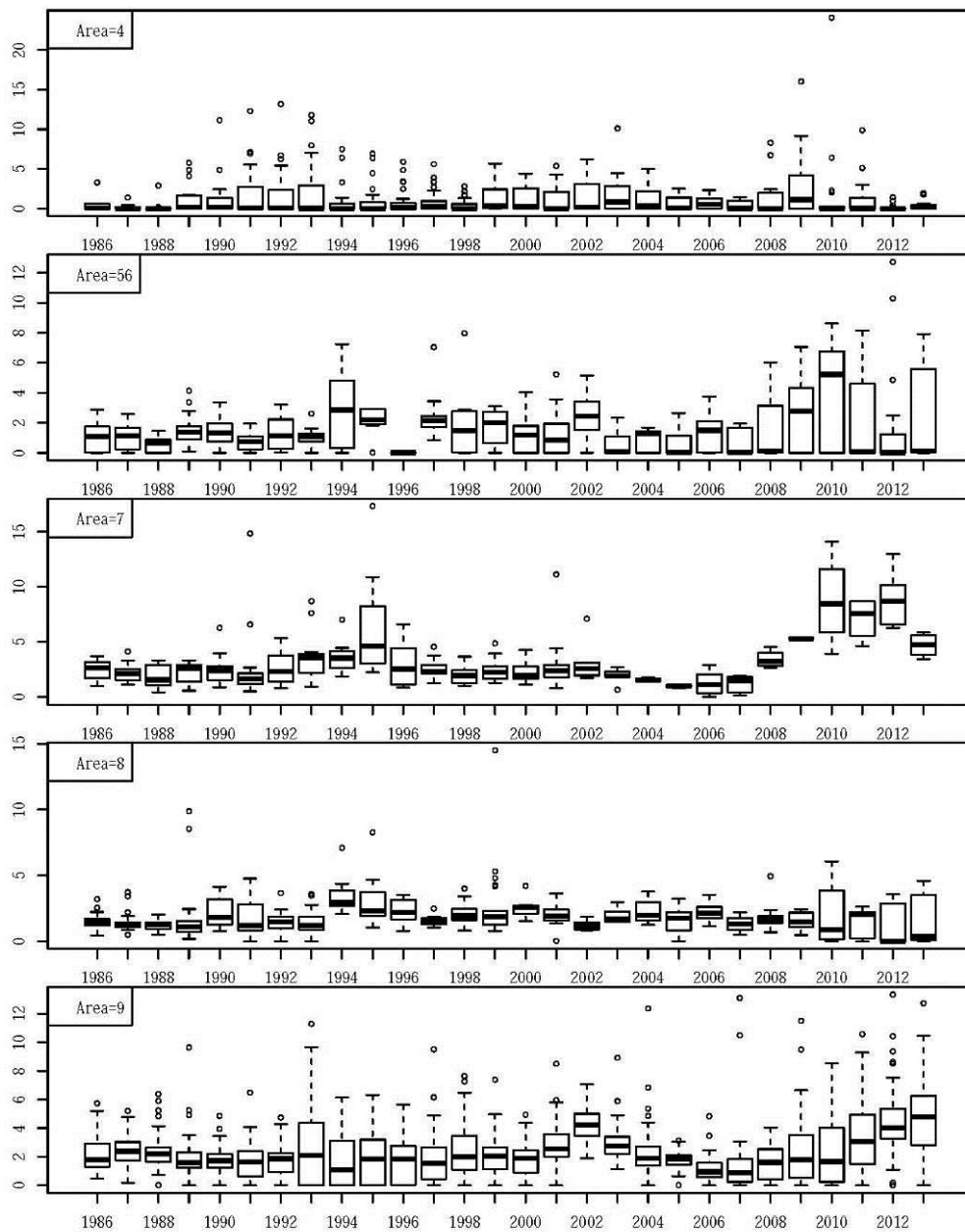should be included in the GLM model

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