CCSBT-ESC/1708/24
(ESC Agenda item 7)

環境変数を取り込んだ GTI の標準化

Standardization of Grid-type Trolling Index of age-1 southern bluefin tuna using environmental factors

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● **要約**

2014 年に開発した GTI は、漁獲情報を基に標準化されたミナミマグロの加入指数である。GTI をミナミマグロの加入状況を反映した頑健な指標にするためには、環境要因の影響を考慮しなければならない。本解析では、現行 GTI に、曳縄調査の漁獲過程に影響するだろう気象要因を標準化モデルに加えてその影響を評価した。現行 GTI の説明変数に加えて風や気温、日照などの環境要因を加えたデルタ二段階 GLM モデルで標準化を行った結果、環境要因を含んだ GTI の年トレンドは現行 GTI と同様のトレンドを示した。つまり、曳縄調査の漁獲に関して、気象条件は大きな影響を及ぼさない。本結果によって、曳縄調査による漁獲方法は頑健な調査方法であることが確認された。

● **Summary**

The Grid-type Trolling Index of age-1 southern bluefin tuna (GTI) developed in 2014 was the standardization using only fishing information of the trolling survey in the southern coast of Western Australia. Therefore, to make a robust indicator reflects a recruitment of SBT, it should consider the influence of environmental factors on GTI trends. In this analysis, GTI was evaluated and standardized using weather factors such as air temperature, rainfall, wind, sunshine affecting the fishing process to the current GTI. As a preliminary result of standardizing with the delta log normal GLM model using weather factors to the current GTI, the year trend of GTI including weather factors was very similar trend as the current GTI. In other words, the weather conditions have no major impact on catch of the trolling survey. GTI is a robust index against weather condition and consistent to year trend.

1. Introduction

Two recruitment indices of age-1 southern bluefin tuna *Thunnus maccoyii* (SBT) was developed using trolling catch data in two scientific surveys in the south coast of Western Australia, the acoustic survey from 1996 to 2006 and the trolling survey from 2006 to 2014 and from 2015 to 2017. One index is piston-line trolling index (PTI) which have been reported to CCSBT. The other index is grid-type trolling index (GTI) which was developed in 2014. GTI utilizes all of the trolling data that aggregated the trolling effort and the number of SBT schools caught by date, hour, area type and 0.1 degrees square in latitude and longitude (see CCSBT-ESC/1709/23).

In OMMP 6 in 2015, the GTI was discussed and advised that needs to review survey methods and evaluate to effects of covariate of environmental factor such as ocean environment and weather condition on year trends and sequential residual trends of GTI. However, the GTI is recognized that it is a qualitative index of SBT recruitment in CCSBT and that it has the possibility to be index of the recruitment of SBT.

As a first step to improve the current GTI, the influence of weather conditions on catch in the trolling survey was explored. This document presents the results of comparison between the current GTI and the GTI including the weather variables.

2. Materials and methods

2.1. Data preparation for weather condition during trolling survey

Weather data such as air temperature, rainfall, wind speed, solar exposure at Albany and Esperance in Western Australia were collected from Climate Data Online website in Bureau of Meteorology, Australian Government. Albany and Esperance are the east and west ends of the survey area, respectively. There are no suitable weather observation points between Albany and Esperance. Therefore, weather data used the average values of the data of Albany and Esperance. If there is no data at Albany, we used data from Esperance and vise vasa. In addition, the phase of the moon and sea surface temperature (SST) was included to determine the effect on SBT existing. SST were obtained from NOAA OI SST V2 High Resolution Dataset (resolution: 0.25degree). The SST data corresponded to 0.1 degree grid to combine with the catch data in current GTI.

The catch data in the trolling survey were the same as used in CCSBT-ESC/17/08/23. Data were limited for age-1 SBT (40-63 cmFL). The SBT school definition used was that successive catches more than 30 minutes were from difference school. The catch data in December were excluded, because the data and effort were few.

2.2. GLM model included weather variables

Delta model was applied for the GTI standardization using seven weather variables to make consistent with current GTI model (Lo et al. 1992, Li and Jiao 2013). The delta model handles zero data and positive catch data in two separated sub-models, i.e. one sub-model to estimated the probability of catching SBT age-1 (probability sub-model) with an assumption of binomial distribution and logit like function, and the other to fit the positive catch data (positive catch sub-model) with an assumption of lognormal distribution. We fitted the following two sub-model that includes all weather variables as full model,

Full probability sub-model

Log(p/(1-p)) ~ year + month + area + Minimum air temperature+ Maximum air temperature + Rainfall + Solar exposure + SST + Max wind speed + Moon + offset(log(dist)) + error,

error ~ binomial

where p is probability of positive catch

Full positive catch sub-model

Log(catch) ~ year + month + area + Minimum air temperature+ Maximum air temperature + Rainfall + Solar exposure + SST + Max wind speed + Moon + offset(log(dist)) + error,

error ~ gaussian

To evaluate the effects of the weather variables on GTI, the explanatory variables were selected through a stepwise approach based on the AIC. R software (version 3.3.2) was used for analysis (R-core team 2012).

3. Results

The average weather conditions during the surveys by year are shown in Table 1 and Fig. 1. Air temperature between 1996 and 2017 ranged between 8.5 °C and 40.1 °C. Averages of minimum and maximum air temperature was 15.1 °C and 25.1 °C, respectively. Minimum air temperature was high levels between 2007 and 2012. Maximum air temperature had a large temperature distribution difference. The temperature distributions in 1996, 1997, 2002, 2003, 2007 and 2012 were wider than other years. While heavy rain was observed in 2000, 2005, 2009 2011 and 2017, rainfall was generally very few over the survey period. Maximum wind speed was usually high over 29 km/h (15 knots), and its maximum and average the survey period was observed 78.5 km/h (42.4 knots) and 44.0 km/h (23.8 knots). The maximum wind speed slightly increased from 2001 to 2003, decreased since 2008, and it was in low level from 2012 and 2017. Average of solar

exposure which reflects sunshine and cloud cover was 22.9 MJ/m^2. Sea surface temperature (SST) ranged between 17.1 °C and 24.0 °C and it's average was 20.1 °C over the survey period. The SST maintained around average value from 1996 to 1999, and was low levels from 2000 to 2007. It increased from 2007 to 2011 and degreased from 2003 to 2016. Moon phase was observed from the new moon to the full moon in the period of the acoustic survey, because the survey period of the acoustic survey from 1996 to 2006 was longer than the period of trolling survey since 2007.

The differences of weather condition between catch and no-catch in the trolling survey and number of catch versus the weather variables included GTI shown in Fig. 2. There is no difference of weather conditions between at catch and no-catch the trolling survey. The relationship between number of catch and the weather variables were roughly liner regressions except SST and Moon phase. Because the relationship between number of catch and some variables included SST showed slightly a non-liner regression, the fitting model would be better using GAM model. However, we selected GLM for two sub-models in the delta model to make consistent with current GTI. Moon phase in the standardization model was as a factor.

Table 2 showed the results of the estimated values and effect of weather variables on probability of catch. For probability sub-model, a model included factors in current GTI plus minimum and maximum air temperature and maximum wind speed was selected by AIC.

ACI selected probability sub-model

Log(p/(1-p)) ~ year + month + area + Minimum air temperature + Maximum air temperature + Maximum wind speed + offset(log(dist)) + error,

error ~ binomial

For the positive catch sub-model, a model included factors in current GTI plus maximum wind speed was selected by AIC. Table 3 showed the estimated values of positive catch sub-model.

ACI selected positive catch sub-model

Log(catch) ~ year + hour + area + Maximum wind speed + offset(log(dist)) + error,

error ~ gaussian

In both sub-models, while both above two sub-models showed the minimum AIC (Table 6), the effects of all weather variables were negligible on responsible variable in the plots (Table 4 and 5, Fig. 3).

4. Discussion

As a first step to improve the current GTI, we explored the influence of weather condition variables on catch in the trolling survey. As result of standardizing with the delta log normal

GLM model using weather variables to the current GTI, the year trend of GTI including weather variables was very similar trend to the current GTI. Some weather variables such as maximum air temperature, minimum air temperature, and maximum wind speed were selected by AIC, however no significant effect was detected in both sub-models. Therefore, weather variables during the trolling survey had negligible effect on standardization of GTI. In other words, the weather conditions have no major impact on fishing of the trolling survey. GTI is a robust index against weather condition and consistent to year trend.

Further investigation of other variables in the effect on GTI may be warranted. For example, the ocean environments of the spawning ground which may affect egg hatching and growth of juvenile fish resulting the recruitment of SBT would fluctuated. The year trend of recruitment of SBT would be affected by the large scale and medium-and long-term oceanic changes such as Southern Oscillation Index and Dipole Mode Index which is represented by anomalous SST gradient between western and southern Indian ocean. The migration of juvenile from spawning ground to southwestern Australia and residence in survey area also would be affect by the ocean environments. Because the trolling survey is limited by are and periods. further studies would be needed to be substantial index of recruitment of SBT.

References

Anon. 2015. Report of the six Operating Model and Management Procedure Technical Meeting for CCSBT, 30-31 August, Incheon, Korea.

Tsuda, Y. and T. Itoh. 2017. Trolling indices for age-1 southern bluefin tuna: update of the piston line index and the grid type trolling index. CCSBT-ESC/1708/23.

Table 1. Average weather conditions during the trolling survey by year

Year	Air Temperature (℃)		Rainfall	Maximum wind speed	Solar exposure	SST	Moon phase
	minimum	maximum	(mm)	(km/h)	(MJ/m2)	(℃)	(1:new-5:full)
1996	15.6	27.1	0.1	44.6	26.6	20.2	3.3
1997	14.7	27.0	1.0	45.2	21.4	20.7	3.1
1998	13.9	24.2	0.1	44.7	26.2	20.3	2.6
1999	15.3	24.0	1.2	45.2	21.7	20.5	3
2000	15.3	24.7	2.0	42.4	22.8	21.0	3.1
2001	15.8	24.9	0.9	43.9	19.6	20.2	3.2
2002	13.8	25.5	0.1	46.0	22.9	19.1	2.8
2003	13.9	26.1	0.2	47.8	27.0	18.7	3.1
2005	14.4	24.1	0.5	45.1	23.7	20.2	3.1
2006	13.9	23.1	0.9	43.1	24.7	19.3	3
2007	15.7	25.8	0.1	47.1	26.3	19.4	2.9
2008	15.4	23.5	0.4	47.2	22.4	19.9	4
2009	15.6	24.5	4.3	43.3	21.2	20.5	1.8
2010	16.0	24.1	0.5	45.3	23.0	20.0	3.9
2011	17.2	25.6	2.4	43.4	17.9	20.9	2.2
2012	15.3	26.3	0.5	43.3	22.0	20.8	3.5
2013	14.2	25.0	0.1	40.8	28.0	20.9	3.9
2014	16.0	25.0	0.8	42.3	19.0	20.5	2.4
2016	15.9	26.7	0.1	39.5	23.6	19.8	2.4
2017	14.5	24.6	2.9	40.6	18.1	19.6	2.9

Table 2. Parameter values estimated for the probability sub-model for full GLM model

Item	Estimate	Std. Error	z value	Pr (>| z |)	Significance
(Intercept)	-1.95170	1.68119	-1.16090	0.2457	
fyear1997	0.42208	0.27775	1.51962	0.1286	
fyear1998	0.38971	0.27266	1.42928	0.1529	
fyear1999	0.51654	0.27905	1.85108	0.0642	
fyear2000	-0.90303	0.33714	-2.67847	0.0074	**
fyear2001	-0.88768	0.32298	-2.74838	0.0060	**
fyear2002	-1.71866	0.41916	-4.10023	0.0000	***
fyear2003	-0.73872	0.35414	-2.08592	0.0370	*
fyear2005	-0.02796	0.25701	-0.10879	0.9134	
fyear2006	0.73217	0.25163	2.90974	0.0036	**
fyear2007	1.08991	0.30526	3.57041	0.0004	***
fyear2008	1.08462	0.28812	3.76448	0.0002	***
fyear2009	0.78702	0.29995	2.62380	0.0087	**
fyear2010	0.91288	0.27556	3.31288	0.0009	***
fyear2011	1.01840	0.27901	3.65008	0.0003	***
fyear2012	0.49735	0.29341	1.69505	0.0901	
fyear2013	1.02582	0.28521	3.59667	0.0003	***
fyear2014	0.64951	0.27786	2.33750	0.0194	*
fyear2016	1.25996	0.27006	4.66551	0.0000	***
fyear2017	-0.01447	0.31836	-0.04544	0.9638	
fmonth2	0.06591	0.09288	0.70963	0.4779	
fmonth3	-0.88448	0.25514	-3.46667	0.0005	***
fhour7	-0.30214	0.17137	-1.76302	0.0779	
fhour8	-0.34088	0.17471	-1.95112	0.0510	
fhour9	-0.43503	0.17846	-2.43762	0.0148	*
fhour10	-0.42235	0.17878	-2.36241	0.0182	*
fhour11	-0.57429	0.18227	-3.15070	0.0016	**
fhour12	-0.42796	0.17675	-2.42123	0.0155	*
fhour13	-0.59948	0.18277	-3.28005	0.0010	**
fhour14	-0.30525	0.17640	-1.73043	0.0836	
fhour15	-0.41285	0.18894	-2.18507	0.0289	*
fhour16	-0.38176	0.20075	-1.90165	0.0572	
fhour17	-0.81810	0.24972	-3.27602	0.0011	**
fhour18	-1.09041	0.60789	-1.79376	0.0729	
fareaLump	1.54979	0.33825	4.58184	0.0000	***
fareaMaudaReef	1.34735	0.36311	3.71063	0.0002	***
fareaOffshore	-2.31575	0.36561	-6.33400	0.0000	***
fareaOnShore	0.22741	0.29927	0.75988	0.4473	
fareaShelfedge	-0.02667	0.31761	-0.08396	0.9331	
minT	0.01515	0.02283	0.66361	0.5069	
maxT	-0.01054	0.01260	-0.83644	0.4029	
rainfall	0.00368	0.01278	0.28794	0.7734	
sunshine	-0.00538	0.00868	-0.61998	0.5353	
sst	-0.10677	0.07292	-1.46428	0.1431	
max.w .spd	0.00839	0.00613	1.36981	0.1707	
fmoon2	0.12175	0.13346	0.91222	0.3617	
fmoon3	0.04732	0.13203	0.35838	0.7201	
fmoon4	-0.08172	0.14223	-0.57458	0.5656	
fmoon5	-0.05638	0.16194	-0.34815	0.7277	

Table 3. Parameter values estimated for catch sub-model for full GLM model

Item	Estimate	Std. Error	t value	Pr (>| t |)	Significance
(Intercept)	-1.27485	1.23347	-1.03355	0.3017	
fyear1997	-0.10539	0.19057	-0.55304	0.5804	
fyear1998	0.02114	0.17722	0.11928	0.9051	
fyear1999	0.16785	0.17999	0.93254	0.3513	
fyear2000	0.26084	0.22911	1.13848	0.2553	
fyear2001	-0.32959	0.21955	-1.50121	0.1337	
fyear2002	0.13309	0.28575	0.46577	0.6415	
fyear2003	0.05046	0.23252	0.21701	0.8283	
fyear2005	0.14182	0.16999	0.83427	0.4044	
fyear2006	0.12805	0.16073	0.79670	0.4259	
fyear2007	0.11723	0.18953	0.61855	0.5364	
fyear2008	0.50874	0.18094	2.81174	0.0050	**
fyear2009	0.08737	0.19438	0.44947	0.6532	
fyear2010	0.16479	0.17386	0.94787	0.3435	
fyear2011	0.28749	0.18462	1.55721	0.1198	
fyear2012	-0.04283	0.19221	-0.22283	0.8237	
fyear2013	0.18029	0.18758	0.96115	0.3368	
fyear2014	-0.07618	0.18395	-0.41416	0.6789	
fyear2016	0.08841	0.17357	0.50933	0.6107	
fyear2017	-0.07396	0.20764	-0.35618	0.7218	
fhour7	0.04894	0.10517	0.46530	0.6418	
fhour8	0.01344	0.10663	0.12607	0.8997	
fhour9	-0.00027	0.11037	-0.00241	0.9981	
fhour10	0.09914	0.11025	0.89923	0.3688	
fhour11	-0.13704	0.11275	-1.21541	0.2246	
fhour12	-0.08232	0.10908	-0.75464	0.4507	
fhour13	0.17369	0.11407	1.52262	0.1282	
fhour14	0.06088	0.10794	0.56404	0.5729	
fhour15	0.02046	0.11681	0.17515	0.8610	
fhour16	-0.10283	0.12713	-0.80881	0.4189	
fhour17	0.04093	0.16200	0.25268	0.8006	
fhour18	-0.18137	0.41559	-0.43642	0.6626	
fareaLump	0.59750	0.22072	2.70710	0.0069	**
fareaMaudaReef	0.55727	0.23076	2.41491	0.0160	*
fareaOffshore	0.49892	0.24530	2.03387	0.0423	*
fareaOnShore	0.27613	0.19788	1.39543	0.1633	
fareaShelfedge	0.92868	0.20911	4.44121	0.0000	***
minT	-0.01202	0.01474	-0.81568	0.4149	
maxT	0.00763	0.00817	0.93391	0.3506	
rainfall	-0.01157	0.00848	-1.36432	0.1728	
sunshine	-0.00864	0.00545	-1.58601	0.1131	
sst	0.03413	0.05533	0.61681	0.5375	
max.w.spd	-0.00694	0.00416	-1.66922	0.0955	
fmoon2	-0.03026	0.08558	-0.35352	0.7238	
fmoon3	-0.08725	0.08656	-1.00806	0.3137	
fmoon4	-0.07796	0.09204	-0.84704	0.3972	
fmoon5	-0.03504	0.10317	-0.33964	0.7342	

Table 4. Results of StepAIC function: AIC and Deviance explained

Probability sub-model

Model	Explanatory variables	AIC	Deviance explained
GTI	GTI	5199.84	15.63
Full model	GTI + *Min.Temp* + *Max.Temp* + *Rainfall* + *Solor exposure* + *SST* + *Max wind spd* + *Moon*	5079.55	16.04
AIC selected model	GTI + *Min.Temp* + *Max.Temp* + *Max wind spd*	5067.83	15.59

Positive catch sub-model

Model	Explanatory variables	AIC	Deviance explained
GTI	GTI	1908.52	14.51
Full model	GTI + *Min.Temp* + *Max.Temp* + *Rainfall* + *Solor exposure* + *SST* + *Max wind spd* + *Moon*	1875.70	15.93
AIC selected model	GTI + *max wind spd*	1863.89	15.32

Table 5. Parameter values estimated for the probability sub-model for AIC selected model

Item	Estimate	Std. Error	z value	Pr (>| z |)	Significance
(Intercept)	-4.85334	0.54964	-8.83010	0.0000	***
fyear1997	0.39774	0.26948	1.47596	0.1400	
fyear1998	0.44318	0.27000	1.64142	0.1007	
fyear1999	0.50328	0.27600	1.82350	0.0682	
fyear2000	-0.94375	0.33122	-2.84934	0.0044	**
fyear2001	-0.82159	0.32060	-2.56267	0.0104	*
fyear2002	-1.51296	0.40679	-3.71927	0.0002	***
fyear2003	-0.51683	0.33921	-1.52360	0.1276	
fyear2005	0.02370	0.25463	0.09307	0.9258	
fyear2006	0.87340	0.24335	3.58907	0.0003	***
fyear2007	1.22172	0.29878	4.08906	0.0000	***
fyear2008	1.08140	0.28522	3.79149	0.0001	***
fyear2009	0.87209	0.29032	3.00394	0.0027	**
fyear2010	0.96225	0.27271	3.52850	0.0004	***
fyear2011	1.11425	0.26800	4.15764	0.0000	***
fyear2012	0.51205	0.28560	1.79291	0.0730	
fyear2013	0.97648	0.27523	3.54788	0.0004	***
fyear2014	0.76327	0.27000	2.82694	0.0047	**
fyear2016	1.43846	0.26098	5.51176	0.0000	***
fyear2017	0.17201	0.30462	0.56467	0.5723	
fmonth2	0.04829	0.09013	0.53583	0.5921	
fmonth3	-0.87735	0.24716	-3.54970	0.0004	***
fareaLump	1.54563	0.32608	4.74001	0.0000	***
fareaMaudaReef	1.43599	0.35105	4.09059	0.0000	***
fareaOffshore	-2.23601	0.35139	-6.36332	0.0000	***
fareaOnShore	0.27861	0.28700	0.97077	0.3317	
fareaShelfedge	0.02712	0.30279	0.08958	0.9286	
minT	0.02778	0.01835	1.51395	0.1300	
maxT	-0.01633	0.01073	-1.52158	0.1281	
max.w.spd	0.01013	0.00603	1.67927	0.0931	

Table 6. Parameter values estimated for the catch sub-model for AIC selected model

Item	Estimate	Std. Error	t value	Pr (>| t |)	Significance
(Intercept)	-0.84496	0.31661	-2.66876	0.008	**
fyear1997	-0.03292	0.17601	-0.18702	0.852	
fyear1998	0.06632	0.17341	0.38242	0.702	
fyear1999	0.18292	0.17413	1.05048	0.294	
fyear2000	0.31265	0.22604	1.38314	0.167	
fyear2001	-0.26924	0.21431	-1.25630	0.209	
fyear2002	0.15666	0.27465	0.57041	0.569	
fyear2003	0.01674	0.22111	0.07570	0.940	
fyear2005	0.16465	0.16487	0.99868	0.318	
fyear2006	0.12690	0.15510	0.81817	0.413	
fyear2007	0.07722	0.18459	0.41832	0.676	
fyear2008	0.51669	0.17653	2.92690	0.004	**
fyear2009	0.11538	0.18255	0.63205	0.528	
fyear2010	0.16430	0.17074	0.96228	0.336	
fyear2011	0.35666	0.16935	2.10613	0.035	*
fyear2012	0.00780	0.18360	0.04249	0.966	
fyear2013	0.19557	0.17464	1.11985	0.263	
fyear2014	-0.00093	0.17326	-0.00535	0.996	
fyear2016	0.13916	0.16736	0.83149	0.406	
fyear2017	-0.04085	0.19792	-0.20639	0.837	
fhour7	0.04900	0.10448	0.46893	0.639	
fhour8	0.00263	0.10594	0.02481	0.980	
fhour9	-0.01231	0.10958	-0.11238	0.911	
fhour10	0.10151	0.10942	0.92775	0.354	
fhour11	-0.13383	0.11224	-1.19230	0.233	
fhour12	-0.08164	0.10853	-0.75223	0.452	
fhour13	0.17064	0.11339	1.50497	0.133	
fhour14	0.06146	0.10761	0.57110	0.568	
fhour15	0.00837	0.11583	0.07223	0.942	
fhour16	-0.09728	0.12632	-0.77010	0.441	
fhour17	0.02027	0.16093	0.12598	0.900	
fhour18	-0.18838	0.41282	-0.45631	0.648	
fareaLump	0.58787	0.20964	2.80413	0.005	**
fareaMaudaReef	0.56030	0.21929	2.55503	0.011	*
fareaOffshore	0.49440	0.23546	2.09971	0.036	*
fareaOnShore	0.26707	0.18655	1.43163	0.153	
fareaShelfedge	0.92263	0.19735	4.67498	0.000	***
max.w.spd	-0.00725	0.00403	-1.80037	0.072	

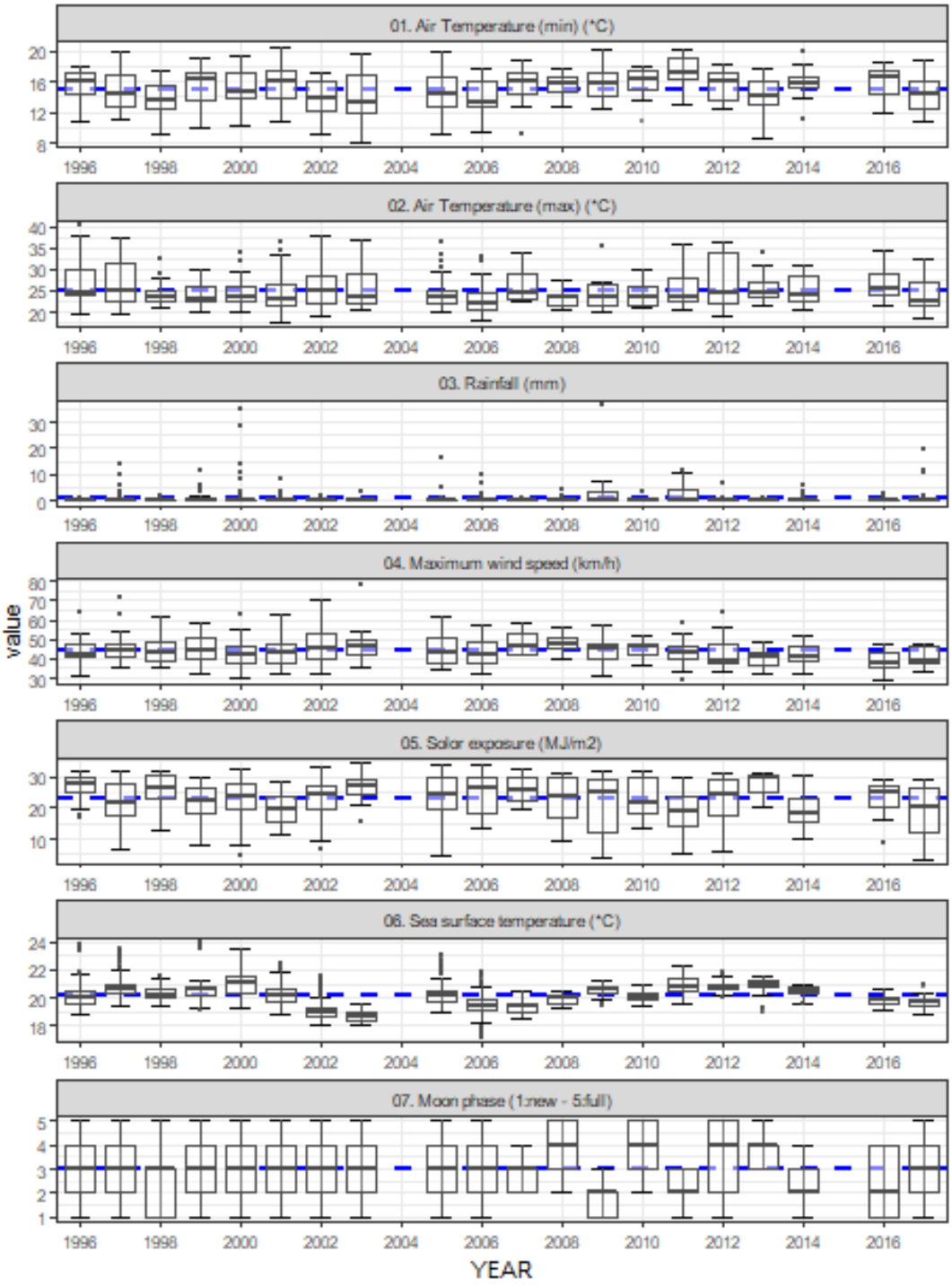

Fig. 1. Boxplot summarizing the environmental conditions. The thick horizontal band through a box indicates the median, the length of a box represents the inter quartile range, and vertical lines extend to the minimum and maximum values. The dashed blueline running across each plot shows the average across all years.

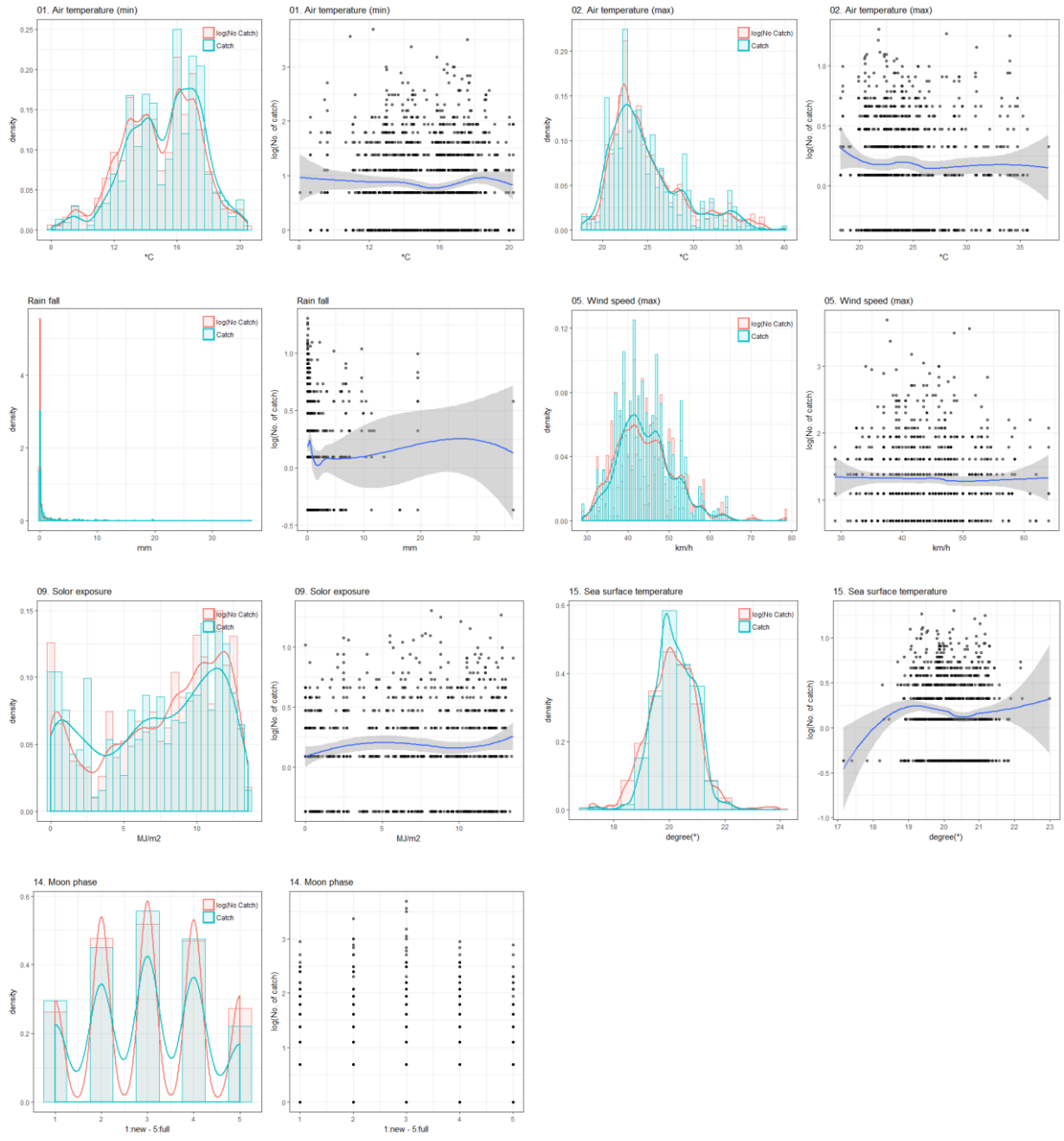

Fig. 2. Difference in weather conditions between catch and no catch in trolling survey. It compares when SBT age-1 were caught (green color) and not caught (red color) on left side. Right side panels show the relationship between number of fish caught and value of each weather variables.

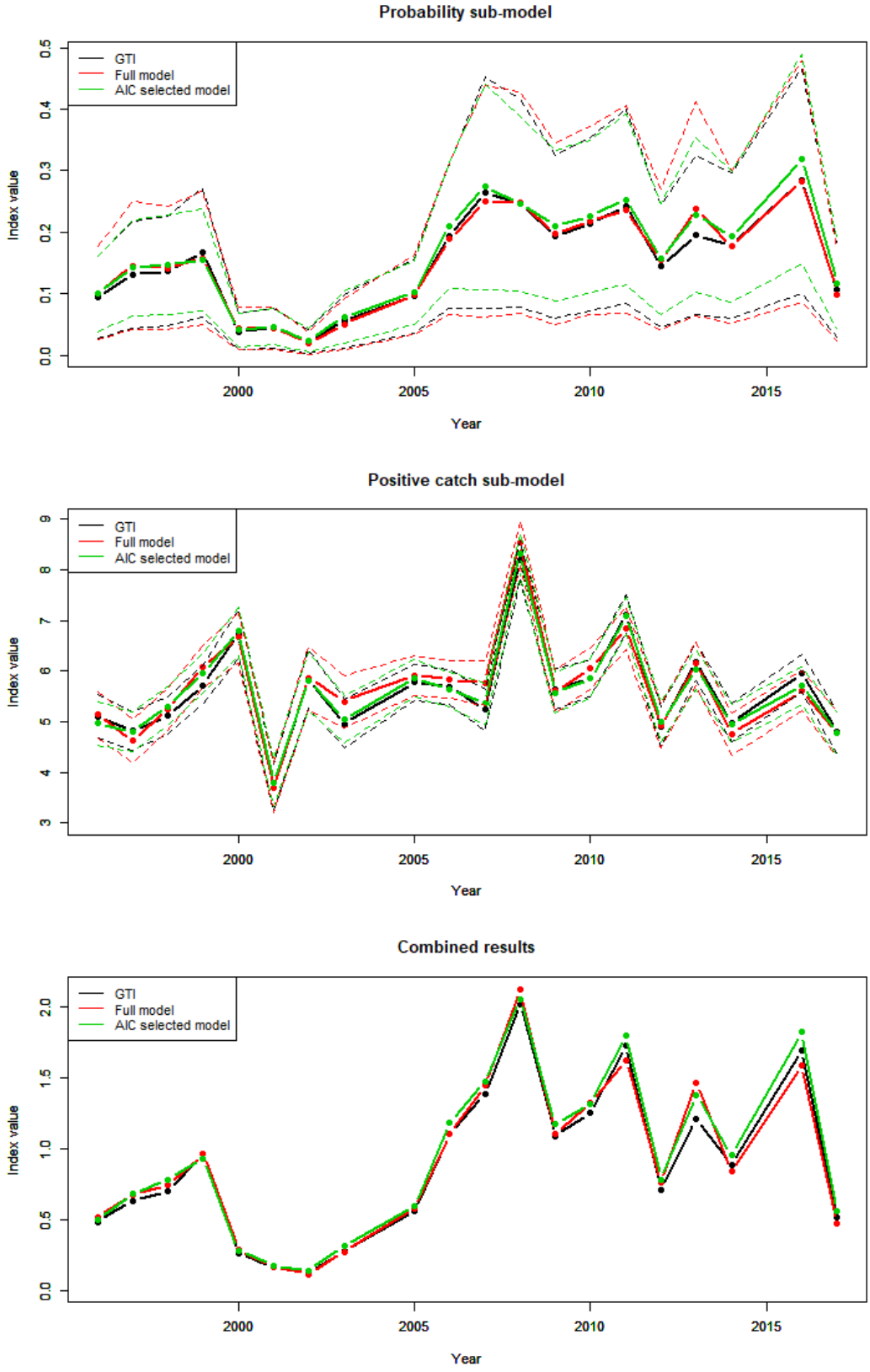

Fig. 3 Comparison of year trends among three models: current GTI model, Full model and AIC selected model that included weather variables.