Received: 8 & 20 September 2013

Standardization of catch rates for striped marlin (*Tetrapturus audax*) and blue marlin (*Makaira mazara*) of the Japanese tuna longline fisheries in the Indian Ocean based the core fishing area approach and the new area effect concept (1971-2012)

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September, 2013

Abstract

We attempted the core fishing area approach and the new area effect concept incorporating environmental data, in order to evaluate standardized catch rates for Striped marlin (*Tetrapturus audax*) and Blue marlin (*Makaira mazara*) in the Indian Ocean. We used operational catch and effort data of the Japanese tuna longline fisheries (1971-2012). We discussed pros and cons on the core fishing area approach and the new area effect concept by comparing results from last year.

Submitted to the IOTC 11th WPB meeting, Sept. 18-22, 2013, La Reunion

1. Introduction

In the past, CPUE standardization (hereafter STD_CPUE) of swordfish has been actively conducted in the IOTC WPB. However limited STD_CPUE works for 5 other billfishes have been implemented i.e., striped marlin, blue marlin, black marine, Indo-Pacific sailfish and Short-billed spearfish (Uozumi, 1998, Wang et al., 2011, Nishida and Wang, 2012 and Wang and Nishida, 2012).

This is the reason why the SC14-SC15 (2011-2012) recommended conducting on STD_CPUE these 5 billfish species in WPB10 (2012) and WPB11 (2013) (this time). In Japan, after swordfish, striped marlin (STM) and blue marline (BLUE) are commercially important in general. Hence in this paper we attempted STD CPUE for these two species exploited by the Japanese tuna longline fisheries operated in the Indian Ocean (1980-2012).

In the last WPB10 (2012), we attempted STM and BLUE STD_CPUE for the major fishing grounds. Then WPB10 (2012) recommended to attempt the core fishing area approach because large area approach produce unstable and unbalanced STD_CPUE and also occasional intensified fishing in EEZ might produce biases in STD_CPUE.

In the Japanese tuna longline fisheries, both striped marlin and blue marlin were targeted in 1950's and 1960's afterward they turned to be bycatch.

2. Catch trends

2.1 Striped marlin

Striped marlin are caught almost exclusively under drifting longlines (98%) with remaining catches recorded under gillnets and troll lines (Fig. 1). Striped marlin is generally considered to be a bycatch of industrial fisheries. Catch trends for striped marlin are variable; however, this may reflect the level of reporting. The catches of striped marlin under drifting longlines have been changing over time, between 2,000 t and 8,000 t (Fig. 1).

Catches under drifting longlines have been recorded under Taiwan,China, Japan, Republic of Korea fleets and, recently, Indonesia and several NEI fleets. Taiwan,China and Japan have reported large drops in the catches of striped marlin for its longline fleets in recent years due to effect by piracy activities.

Between the early-50s and the late-80s part of the Japanese fleet was licensed to operate within the EEZ of Australia, reporting relatively high catches of striped marlin in the area, in particular in waters off northwest Australia. High catches of the species were also reported in the Bay of Bengal during this period, by both Taiwan,China and Japanese longliners.

The distribution of striped marlin catches has changed since the 1980‘s with most of the catch now taken in the western areas of the Indian Ocean. In recent years, the fleets of Taiwan,China (longline) and to a lesser extent Indonesia (longline) are attributed with the highest catches of striped marlin.

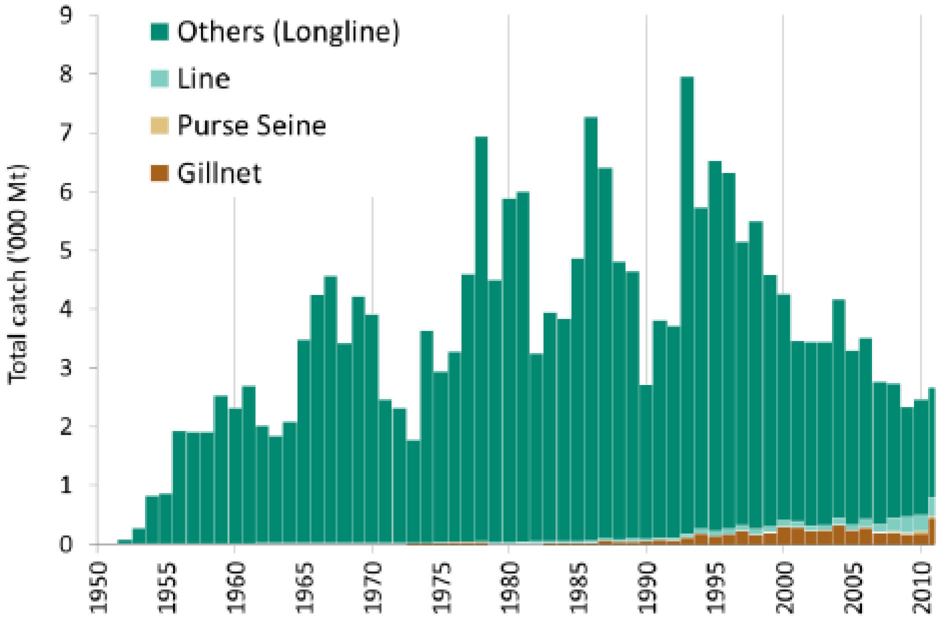

Fig. 1 Catch trend by gear (striped marlin)

In recent years, deep-freezing longliners from Japan and Taiwan,China have reported lower catches of striped marlin, mostly in the northwest Indian Ocean. The minimum average annual catch estimated for the period 2006 to 2010 is around 2,542 t.

These changes of fishing area and catches over the years are thought to be related to changes in the type of access agreements to EEZs of coastal countries in the Indian Ocean, rather than changes in the distribution of the species over time.

Discards are believed to be low although they are unknown for most industrial fisheries, mainly longliners. Discards of striped marlin may also occur in the driftnet fishery of the I.R of Iran, as this species has no commercial value in this country.

2.2 Blue marlin

Catch trends

Indo-Pacific blue marlin are caught mainly under drifting longlines (60%) and gillnets (30%) with remaining catches recorded under troll and hand lines. Indo-Pacific blue marlins are considered to be a bycatch of industrial and artisanal fisheries. The catches of Indo-Pacific blue marlin are typically higher than those of black marlin and striped marlin combined. In recent years, the fleets of Taiwan,China (longline), Indonesia (longline), Sri Lanka (gillnet) and India (gillnet) are attributed with the highest catches of Indo-Pacific blue marlin (Fig. 2). The distribution of Indo-Pacific blue marlin catches has changed since the 1980's with most of the catch now taken in the western areas of the Indian Ocean.

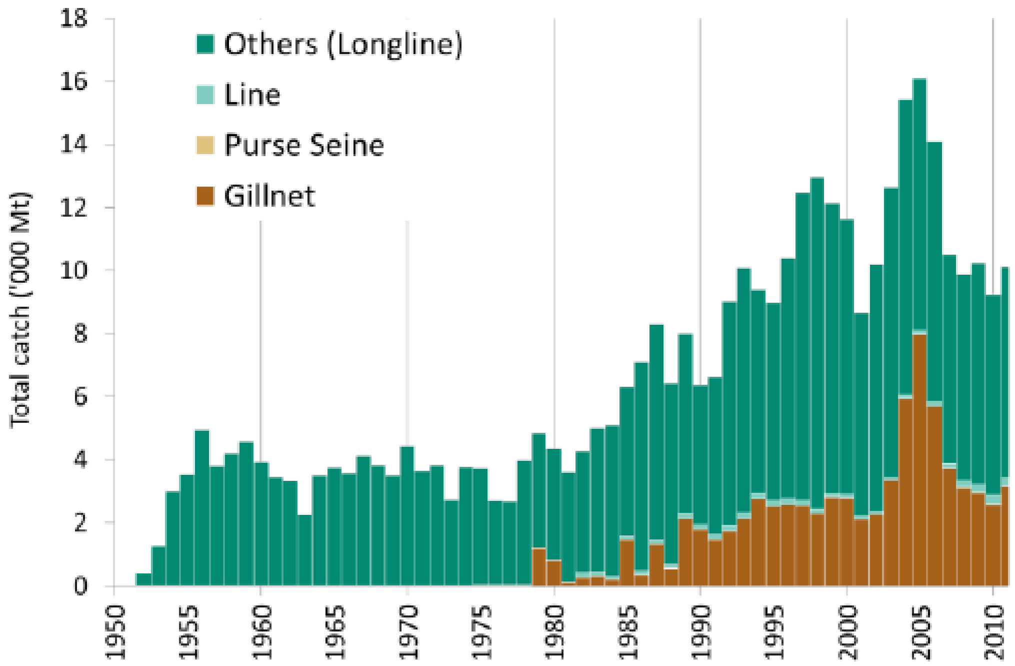

Fig. 2 Catch trend by gear (Blue marlin)

Catch trends for Indo-Pacific blue marlin are variable; however, this may reflect the level of reporting. The catches of Indo-Pacific blue marlin under drifting longlines were more or less stable until the mid-80's, at around 3,000 t, steadily increasing since then. The largest catches were recorded in 1997 (~14,000 t). Catches under drifting longlines have been recorded under Taiwan,China and Japan fleets and, recently, Indonesia and several NEI fleets. In recent years, deep-freezing longliners from Japan and Taiwan,China have reported most of the catches of Indo-Pacific blue marlin in waters of the western and central tropical Indian Ocean and, to a lesser extent, the Mozambique Channel and the Arabian Sea.

3. Fine scale Catch and effort data

2 types of fine scale data are available in the database of National Research Institute of Far Seas Fisheries (NRIFSF) as shown in Fig. 1. For this paper, in order to make statistically stable STD_CPUE we used type (b), aggregated catch and effort data (1971-2011). The previous works by Uozumi (1998) for STD CPUE for all billfish used type (b).

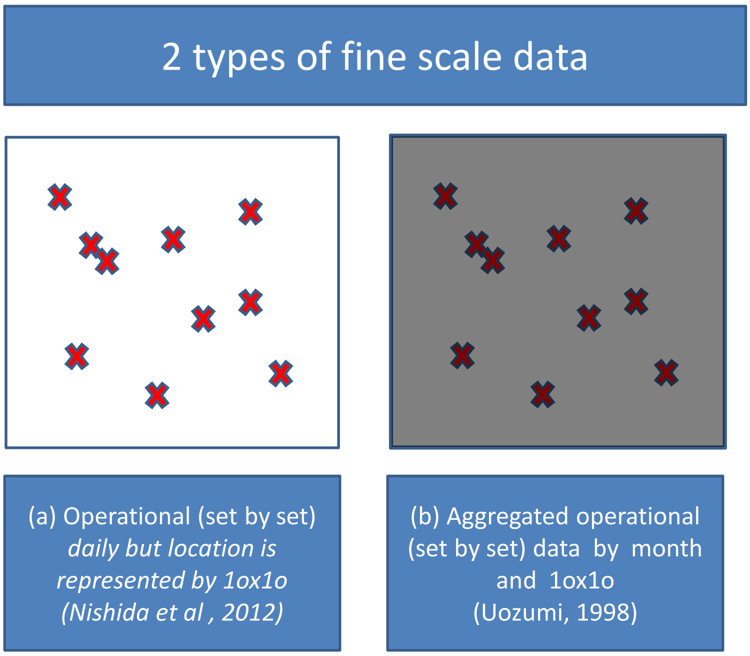

Fig. 3 Definition of 2 different types of fine scale data available in the database of National Research Institute of Far Seas Fisheries (NRIFSF).

4. Core fishing area approach

In the last WPB10 (2012), we attempted STM and BLUE STD_CPUE based on three major fishing grounds. Then WPB10 (2012) recommended to attempt the core fishing area approach because large area approach produce unstable and unbalanced STD_CPUE and also occasional intensified fishing in EEZ might produce biases in STD_CPUE. Fig. 12 and Fig. 13 which shows distribution of number of years with positive STM catch by quarter for STM and BLUE, i.e., yellow and red shows positive catch for 10-14 years and for 15 years or more respectively in 32 years (1971-2012).

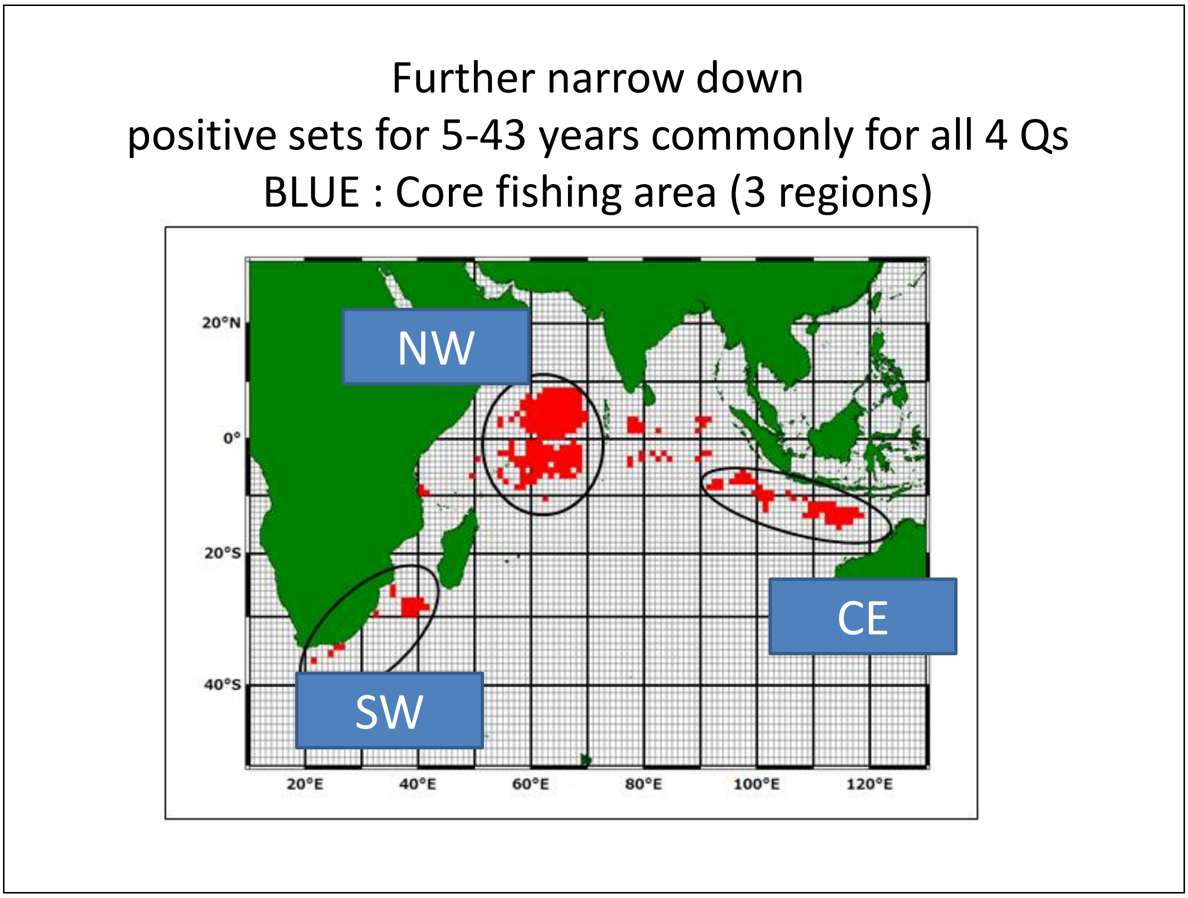

Fig 4 Distribution of number of years with positive striped marlin catch by quarter, i.e., yellow and red shows positive catch for 10-14 years and for 15 years or more respectively in 32 years (1971-2012).

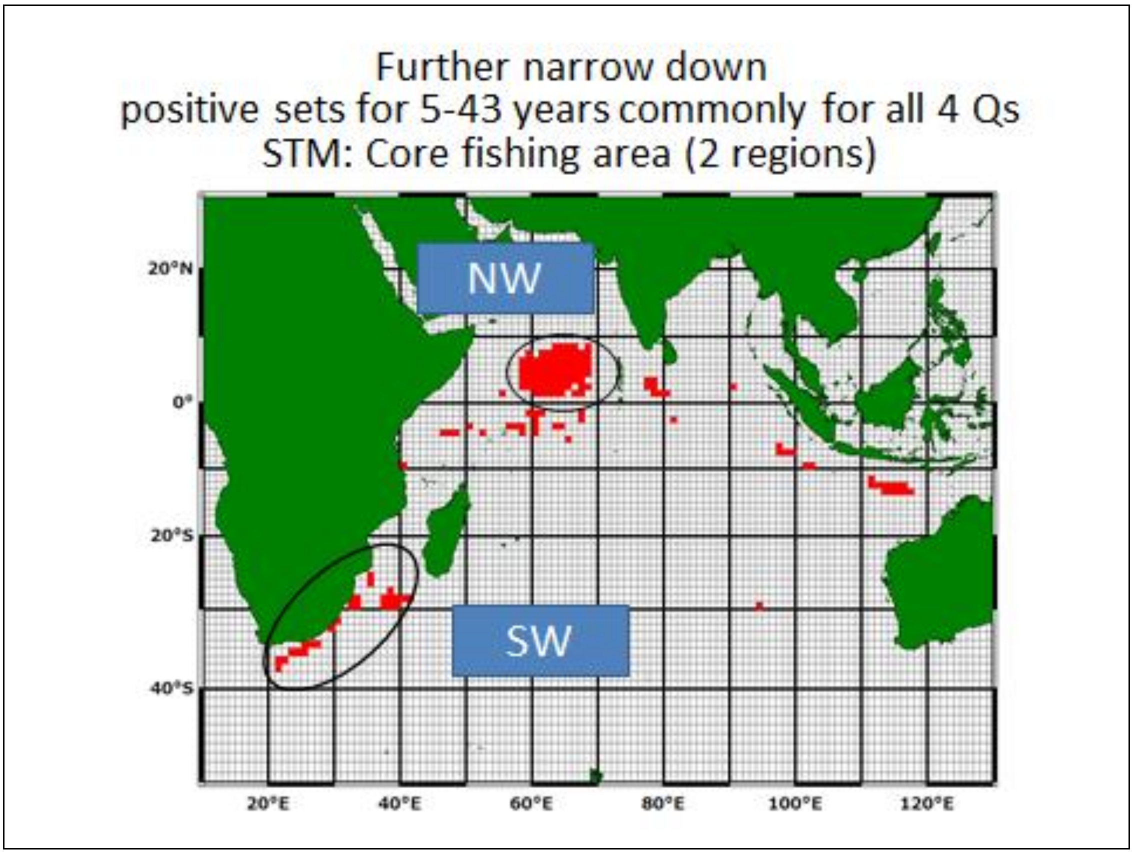

Fig 5 Distribution of number of years with positive blue marlin catch by quarter, i.e., yellow and red show positive catch for 10-14 years and for 15 years or more respectively in 32 years (1971-2012).

5. New area effect concept reflecting real time environmental anomalies

Normally we use large regions as area effects, which can take care of the anomalies of environment, recruitments etc., (personal communication with Dr Dale Kolody). But they cannot reflect fine scale changes. To solve this problem, Matsumoto et al (2012) use the 5x5 area effect in the GLM. In this way, small 5x5 area can take care of fine scale anomalies producing biases to nominal CPUE.

For our case, we use the 1x1 area. As our case use small core areas, there are not too many 1x1 areas that create over-parameterization problems. However, if large areas are used, there will be too many 1x1 areas like the other work by Wang et al (2013). In such case, 2x2 or 5x5 areas should be used. Plates 1-4 summarizes the area effect concept reflecting real time environmental anomalies

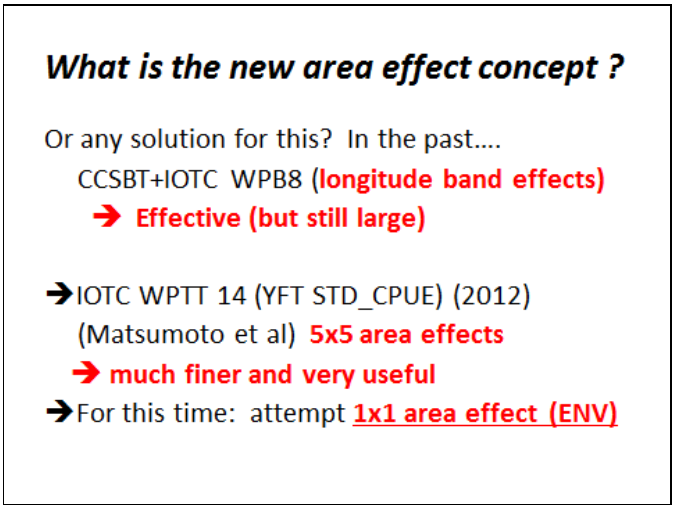

Plate 1 New area effect concept (1)

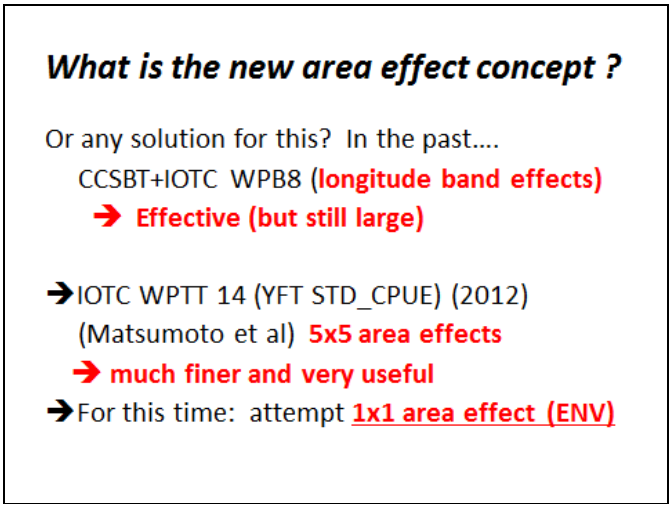

Plate 2 New area effect concept (2)

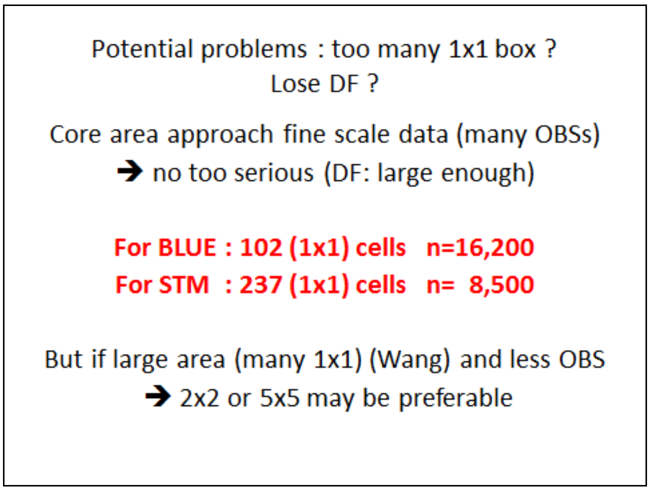

Plate 3 New area effect concept (3)

However, the time lag environmental effects cannot be taken care of by this concept. Thus we still need the environmental data. This will be discussed later (Plate 4). However, we cannot use both large area and fine scale area (1x1, 2x2, 5x5 areas). This is because both are area effects, which create auto correlation problems. Then we evaluate these two area effects by running GLM. Plate 5 shows the results. Based on r2, 1x1 area performed better than the large area. We used r2 but AIC is more appropriate criteria.

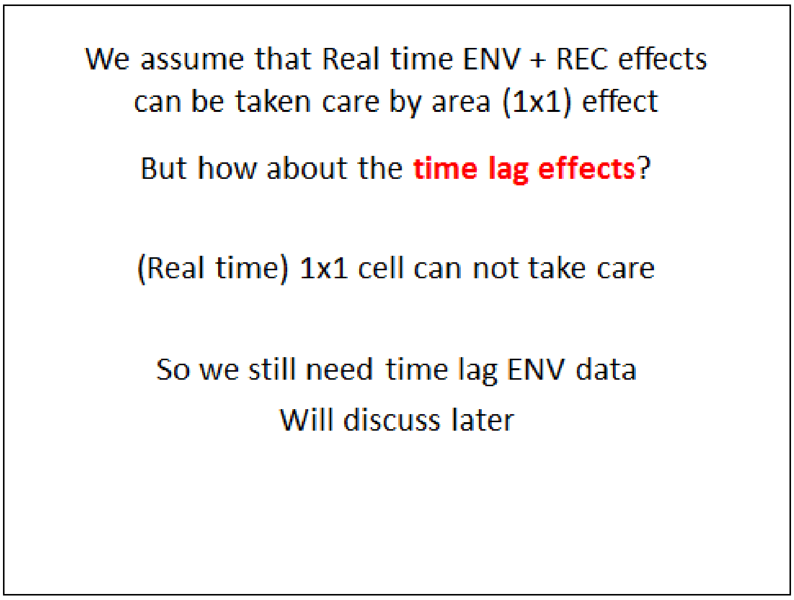

Plate 4 Need the time-lag environmental effects

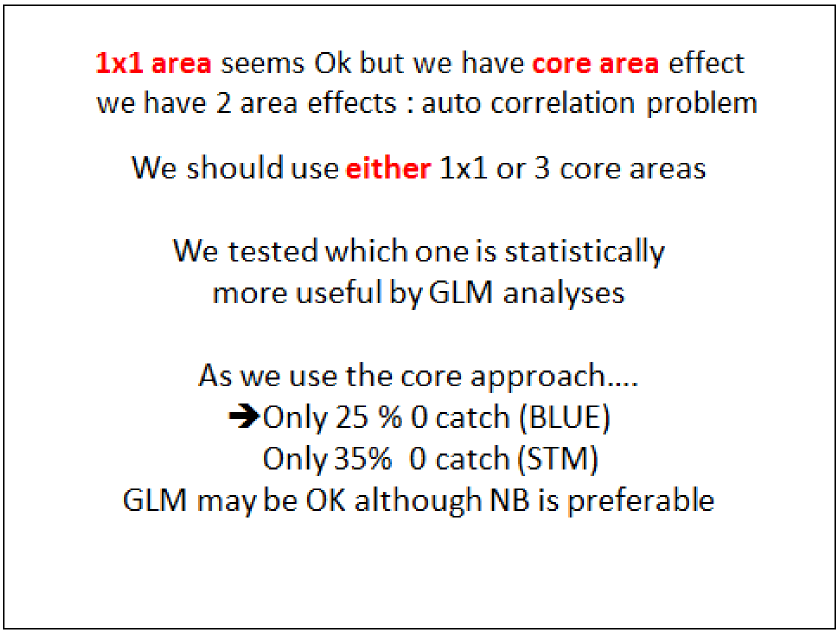

Plate 5 Evaluation of 2 area factors

The GLM Procedure STM with 1x1 effect

Dependent Variable: lncpue

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	568	7727.11898	13.60408	14.25	<.0001
Error	7845	7491.67427	0.95496		
Corrected Total	8413	15218.79325			

R-Square	Coeff Var	Root MSE	lncpue Mean
0.507735	-49.79036	0.977221	-1.962672

Source	DF	Type III SS	Mean Square	F Value	Pr > F
yr	41	1541.775038	37.604269	39.38	<.0001
q	3	315.602858	105.200953	110.16	<.0001
g	3	36.859233	12.286411	12.87	<.0001
yr*q	123	477.687742	3.883640	4.07	<.0001
q*box	297	616.276155	2.075004	2.17	<.0001
box	99	711.132661	7.183158	7.52	<.0001
eda	1	0.185613	0.185613	0.19	0.6593
miki	1	1.829057	1.829057	1.92	0.1664

The GLM Procedure with area effect STM

Dependent Variable: lncpue

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	176	6826.27598	38.78566	38.07	<.0001
Error	8237	8392.51726	1.01888		
Corrected Total	8413	15218.79325			

R-Square	Coeff Var	Root MSE	lncpue Mean
0.448543	-51.42968	1.009396	-1.962672

Source	DF	Type III SS	Mean Square	F Value	Pr > F
yr	41	1614.727961	39.383609	38.65	<.0001
q	3	490.843138	163.614379	160.58	<.0001
a	1	305.054665	305.054665	299.40	<.0001
g	3	51.754369	17.251456	16.93	<.0001
yr*q	123	545.368002	4.433886	4.35	<.0001
q*a	3	175.604896	58.534965	57.45	<.0001
eda	1	0.079295	0.079295	0.08	0.7803
miki	1	0.390963	0.390963	0.38	0.5356

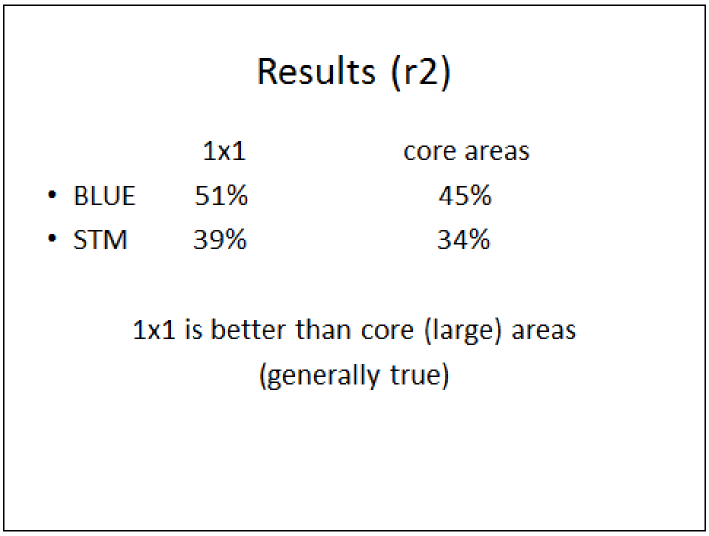

Plate 6

6. Time-lag ENV affects

As discussed in the previous section, we need to use time lag effect as they cannot be taken care of the 1x1 area factors which can handle the real time effect. In the past we use the climate factors such as IOI, SOI, and Dipole index in the STD_CPUE. But they will be reflected by anomaly of temperature and thermocline depth with some time lags. Thus we will use the limited ENV data such as T15 (temperature at 15 m depth) for Striped marlin and T55 for blue marlin. These depths are where these 2 species are exploited. In addition we will use the shear currents and TG (temperature gradient) which are also considered to affect nominal CPUE with some time lags (Plate 7).

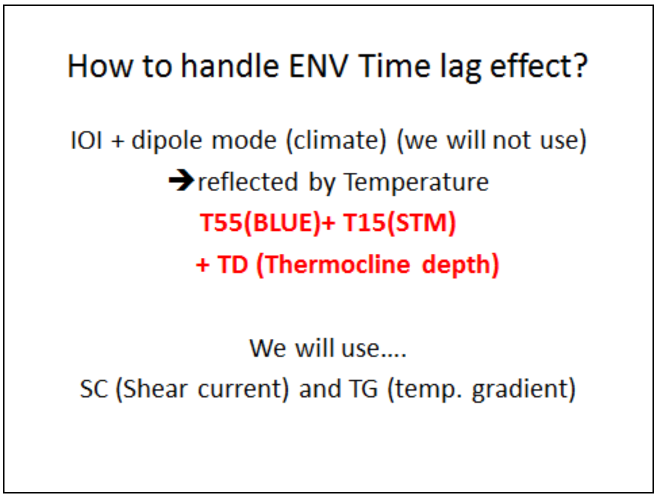

Plate 7 Time lag effect of ENV data

Then we investigate cross correlations between N_CPUE and ENV factors to evaluate time lag effects. Plates 8-11 show the results for Blue and Striped marlin. We use rather strict selection criteria, i.e., r2 is more than 40%. As a result, we use TD (Q-2), T55 (Q-1), T55 (Q-2) and T55 (Q-3).for blue marlin and nothing for striped marlin.

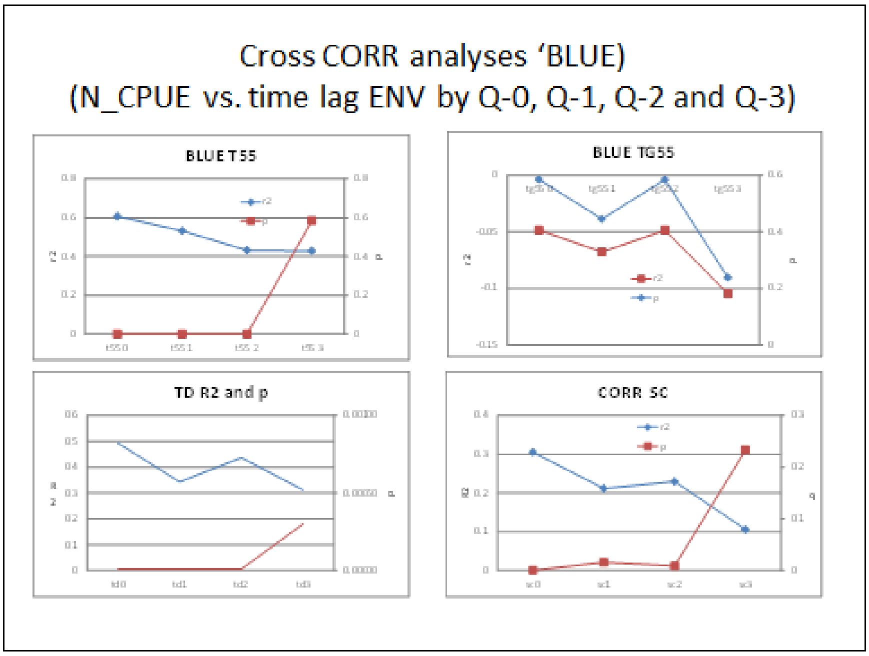

Plate 8 Cross correlation analyses between N_CPUE vs. time-lag ENV data.(BLUE)

Results (BLUE)

We use ENV (40% < r2)

TD(Q-2) and T55(Q-1 , Q-2 and Q-3)

(real time 0Q : we will not use)

	Time lags			
	0 Q (real time)	1Q	2Q	3Q
TD	49% (0.00)	34% (0.00)	44% (0.00)	31% (0.00)
SC	30% (0.00)	21% (0.02)	23% (0.01)	11% (0.23)
T55	61% (0.00)	53% (0.00)	43% (0.00)	43% (0.00)
TG55	-5% (0.59)	-7% (0.45)	-5% (0.59)	-10% (0.24)

Plate 9 Selection of time lag effect ENV data (BLUE)

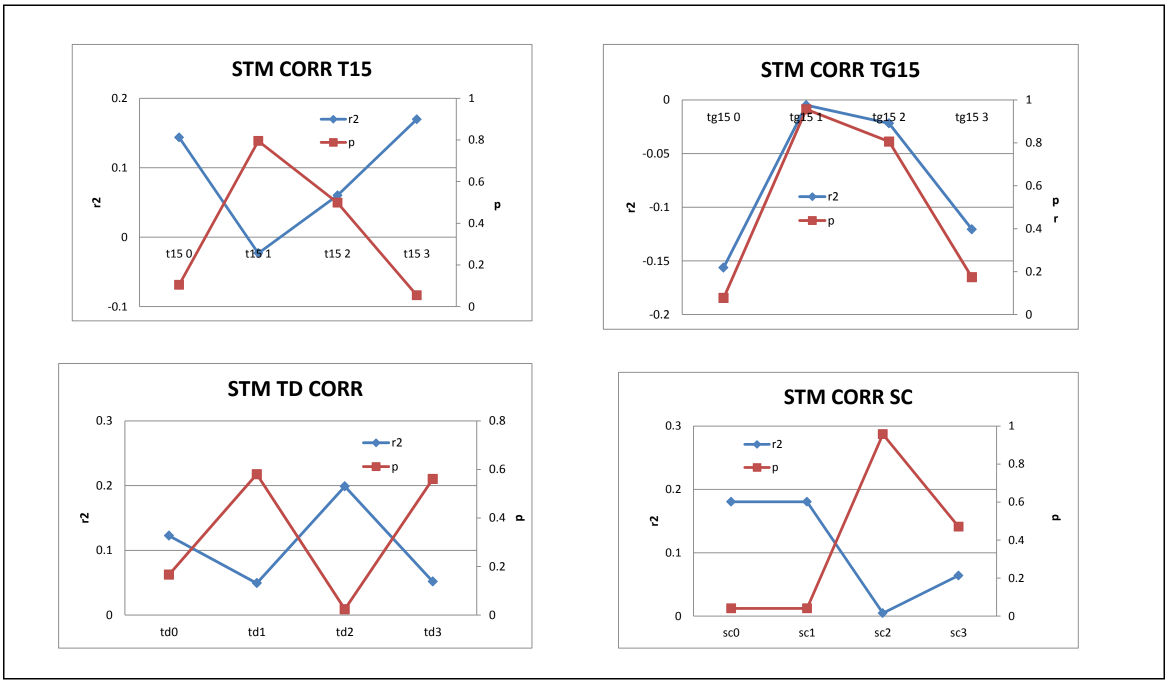

Plate10 Cross correlation analyses between N_CPUE vs. time-lag ENV data (STM).

Results (STM)

We use ENV (40% < r2)

NONE: We will not use any ENV (time lag)

	0 Q (real time)	1Q	2Q	3Q
TD	12% (0.17)	5% (0.58)	20% (0.02)	5% (0.56)
SC	18% (0.04)	18% (0.04)	0% (0.96)	6% (0.47)
T15	14% (0.10)	-2% (0.80)	6% (0.50)	17% (0.05)
TG15	-15% (0.08)	0% (0.96)	-2% (0.81)	-12% (0.17)

Plate 11 Selection of time lag effect ENV data (STM)

Using these ENV factors and also gear (number of hooks between floats), we make the categorical data as shown in Plate 12 so that we can perform the robust STD_CPUE by GLM.

Continuous data ➔ Categorical data
(for robust GLM)

Gear (NHF): 4 category
➔ shallow, regular and deep and ultra deep
TD (Q-2) 4 category
➔ very shallow, shallow, deep and vey deep
T55(Q-1, Q-2 and Q-3) 4 category
➔ very cool, cool, warm and vey warm

Plate 12 Creation of categorical data

7 STD_CPUE (BLUE)

Plate 13 shows the final GLM formulation and Plates 14-16 (BLUE) show results.

STD_CPUE (BLUE) GLM (1980-2012)

log (CPUE + c)
= [Ave] + [Y] + [Q] + [1x1]+[Q*1x1] +[Y *Q]
+ TD(Q-2)+T55(Q-1)+T55(Q-2)+T55(Q-3)
+[MIKI]+[EDA]+ error

C: 10% of ave nominal CPUE

Plate 13 Final GLM (BLUE)

R2=38%

Year+ Box (1x1) contribute very high while time lag ENV none

Partial Variation Accounted For

Source	Partial Eta-Square	Partial Omega-Square	95% Confidence Limits	
yr	0.0780	0.0705	0.0626	0.0788
q	0.0031	0.0026	0.0013	0.0047
box	0.1089	0.0877	0.0788	0.0971
g	0.0043	0.0037	0.0020	0.0061
yr*q	0.0300	0.0213	0.0166	0.0267
q*box	0.0808	0.0302	0.0229	0.0381
eda	0.0001	0.0001	0.0000	0.0008
miki	0.0009	0.0008	0.0002	0.0020
td2	0.0008	0.0006	0.0001	0.0019
t551	0.0014	0.0012	0.0004	0.0027
t552	0.0002	0.0001	0.0000	0.0009
t553	0.0001	0.0000	0.0000	0.0007

No big contribution

Plate 14 Results of GLM (STM)

Remarks : normally SS3 (F is relative)

Source	DF	Type III SS	Mean Square	F Value	Pr > F
yr	41	1183.340435	28.861962	28.25	<.0001
q	3	78.263243	26.087748	25.53	<.0001
box	236	2554.999227	10.826268	10.60	<.0001
g	3	42.077472	14.025824	13.73	<.0001
yr*q	123	552.850069	4.494716	4.40	<.0001
q*box	708	1313.618947	1.855394	1.82	<.0001
eda	1	1.407859	1.407859	1.38	0.2405
miki	1	15.970684	15.970684	15.63	<.0001

Partial Variation Accounted For partial Eta-square

To evaluate absolute contribution of effect (comparable)

```
CLASS yr q box g a ;
   MODEL lncpue= yr q box g yr*q  q*box eda miki /* yr*a */
  / solution  ss3 effectsize;
```

Plate 15 Eta-square (SAS output) to evaluate absolute (comparable) effects (STM)

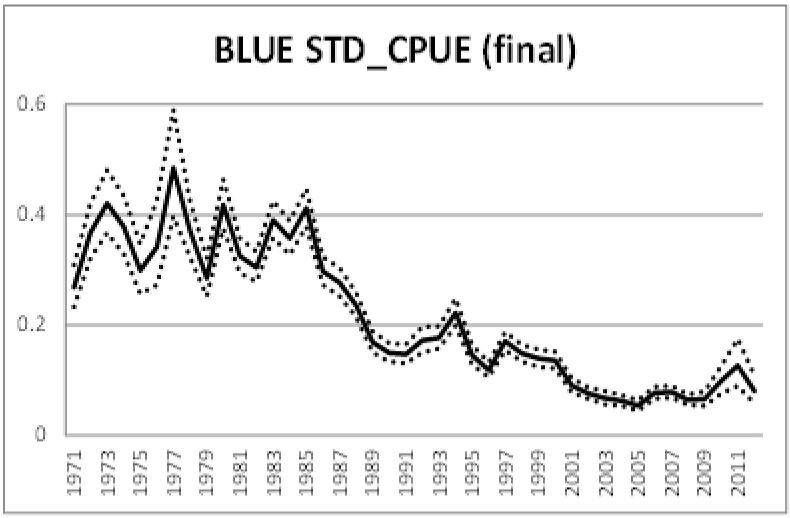

Plate 16 Estimated STD_CPUE (BLUE)

8. STD_CPUE(STM)

Plate 17 shows the final GLM (STM) formulation and Plates 18-20 results (STM).

STD_CPUE (BLUE) GLM final model (1971-2012)

log (CPUE + c)
= [Ave] + [Y] + [Q] + [1x1]+[Q*1x1] +[Y *Q]
[MIKI]+[EDA]+ error

C: 10% of ave nominal CPUE

Plate 17 Final GLM (STM)

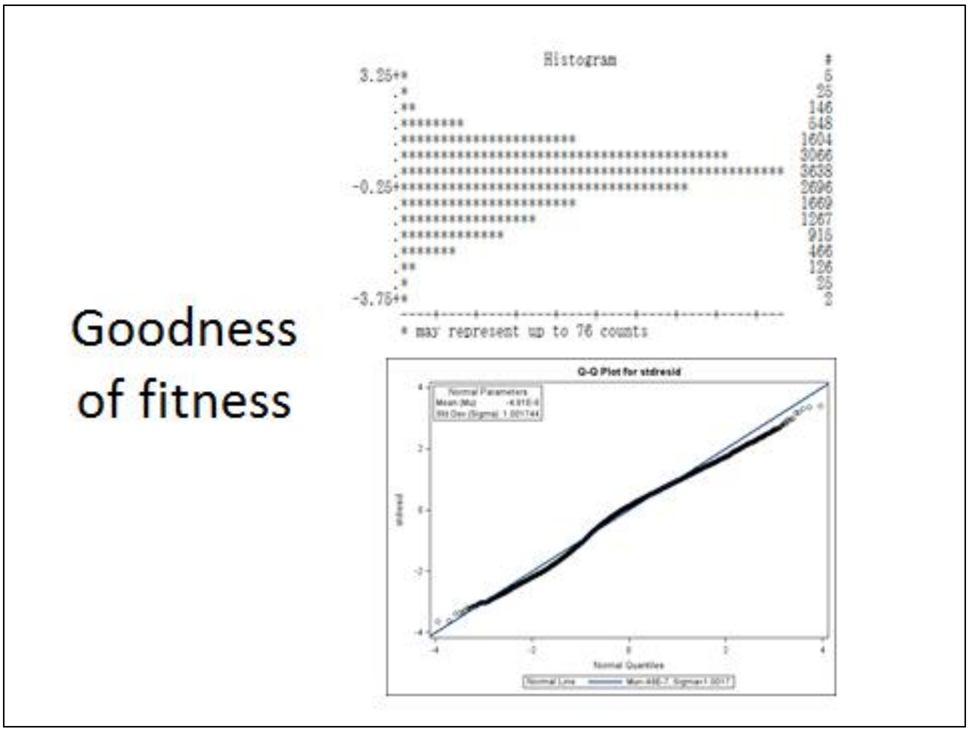

Plate 18 Goodness of fitness for GLM (STM)

R2=50%
Year and Box contribute very high.

Partial Variation Accounted For

Source	Partial Eta-Square	Partial Omega-Square	95% Confidence Limits	
yr	0.1707	0.1575	0.1439	0.1716
q	0.0404	0.0375	0.0300	0.0458
box	0.0867	0.0713	0.0608	0.0825
g	0.0049	0.0042	0.0019	0.0076
yr*q	0.0599	0.0429	0.0343	0.0525
q*box	0.0760	0.0398	0.0304	0.0500
eda	0.0000	-0.0001	0.0000	0.0007
miki	0.0002	0.0001	0.0000	0.0013

Plate 19 Eta-square (SAS output) to evaluate absolute (comparable) effects (STM)

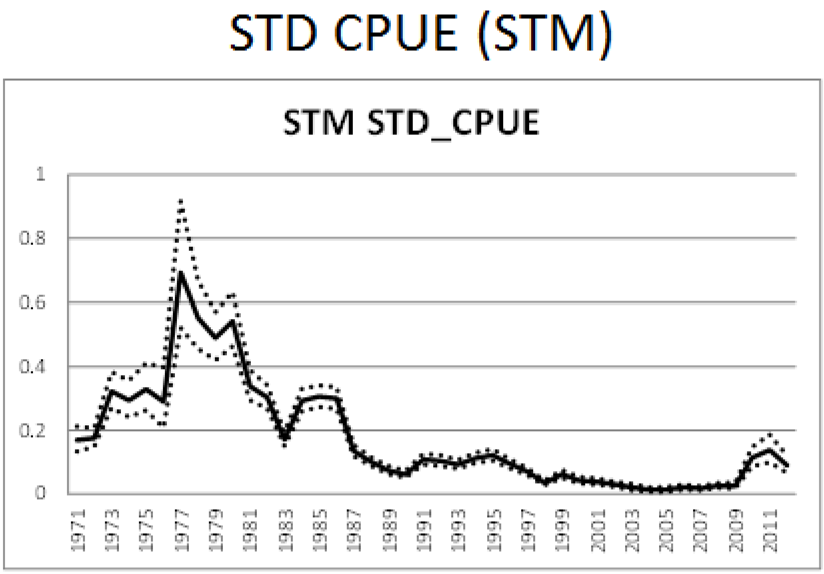

Plate 20 Estimated STD_CPUE (STM)

9. **Summary** (Plates 21-22)

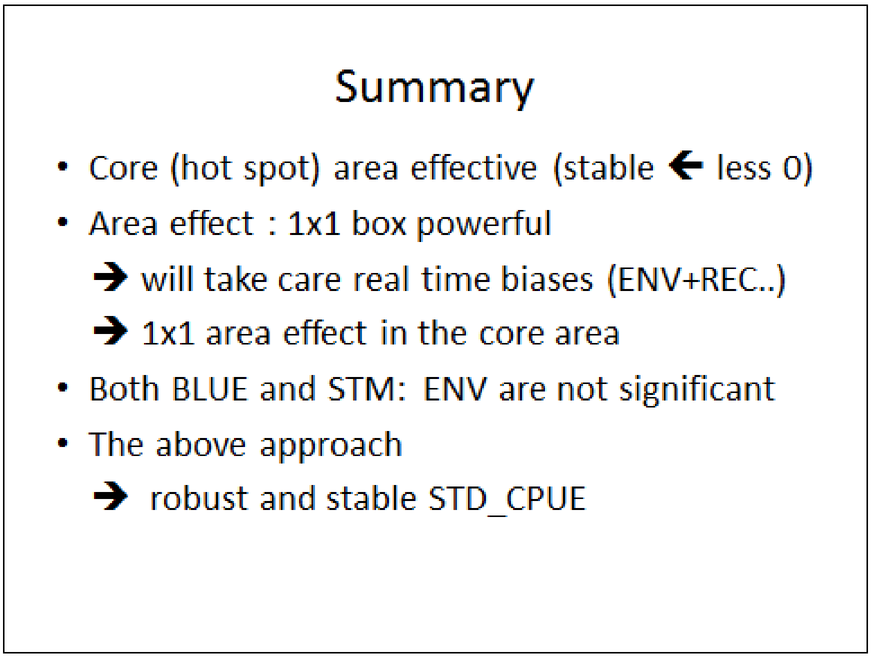

Plate 21 Summary 1

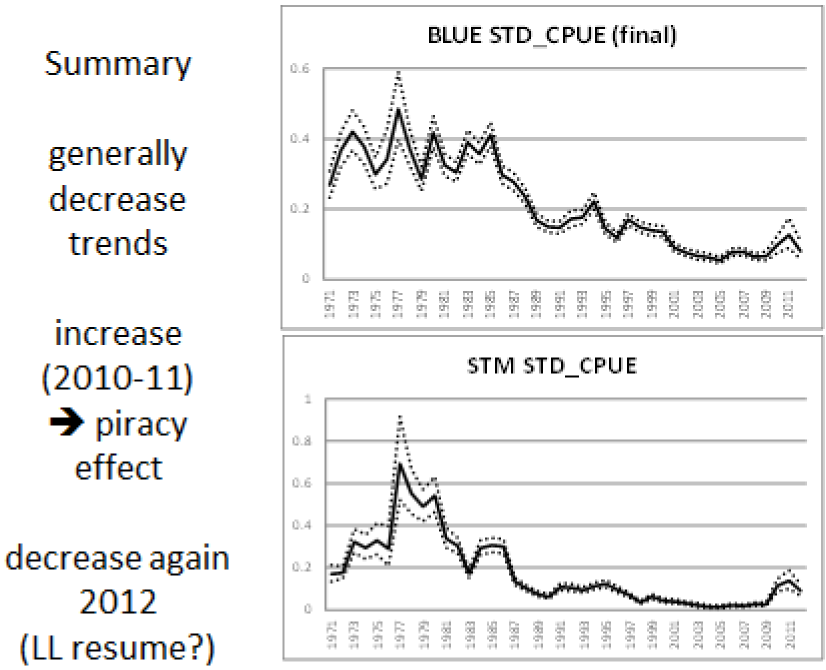

Plate 22 Summary (2)

Acknowledgments

We thank Dr. Marsac (IRD, France) providing the IOI and IO dipole mode index data and also Dr. Hiroshi Shono (Kagoshima University) for the technical suggestions.

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