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Standardization of catch rates for Striped marlin (*Tetrapturus audax*) and Blue marlin (*Makaira nigricans*) in the Indian Ocean based on the operational catch and effort data of the Japanese tuna longline fisheries incorporating time-lag environmental effects (1971-2011)

Tom Nishida (tnishida@affrc.go.jp) and **Yukiko Shiba**
National Research Institute of Far Seas Fisheries (NRIFSF)
Fisheries Research Agency (FRA), Shimizu, Shizuoka, Japan

Horoshi Matsuura
CRI Cygnus Research International (CRI),
Yokosuka, Kangawa, Japan

Sheng-Ping Wang
Department of Environmental Biology and Fisheries Science,
National Taiwan Ocean University, Keelung, Taiwan

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Abstract

Log normal GLMs were applied to estimate STD CPUE for striped and blue marlin. Two GLM models are used, i.e., (1) BASE model (1971-2011) including effects of Y (year), Q (quarter), A (sub-area), G (gear: targeting), Miki+Eda (Materials of main and branch lines), IOI (Indian Ocean Oscillation Index), DMI (Indian Ocean Dipole Mode Index) and MP (Moon Phase) and (2) BASE+NCEP model (1980-2010) include additional effects of T45 (Sea temperature at 45m depth), SC (shear current) and TD (thermocline depth or mixed layer depth).

All the ENV data (IOI, DMI, T45, Shear current, TD and IOI) except MP were examined if there were time-lag effects in 0-6 months to the nominal CPUE for these 2 species in advance. As a result, for striped marlin, it was found that there are 4 months-time lag effects in IOI and DMI, 1 month in TD and no time-lag effect (real time effect) in T45 and Shear current. As for blue marlin, 4 months in TD and no time lag effect in T45 and Shear current. In this study, GLMs incorporating time lag effects were used as a first time and conducted unlike in the past, i.e., we have been using ENV data without considering any time-lag effects and ENV data without the time lag effects showed some levels of statistical significances in GLMs, but the resultant trends of STD CPUE with and without ENV data were not so different.

However, for this time, we applied GLM with ENV data considering time lag effects, then we found that some ENV effects showed large and consistent statistical significances, i.e., for striped marlin, T45 and shear current and for blue marlin, T45 and IOI. Furthermore, their trends of STD CPUE were resulted to be largely different from STD CPUE without ENV data unlike in the past. This suggested that GLM with time-lag effects ENV data likely play an important role to represent more real trends of STD CPUE.

Results of GLMs suggested that STD CPUE of both species showed the decreasing trend since 1971 in general, except a few periods. However during 2011-2012, STD CPUE showed a slight increase trends. This is likely caused by the pirate activities, i.e., fishing efforts by Japanese tuna longline and also other related fisheries have been largely decreased since 2008 due to the piracy activities in the western Indian Ocean, which significantly reduce catch and effort for both species and such reduction likely made recoveries of these 2 species' stocks in very recent 2 years (2010-2011).

Contents

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1. Introduction

In the past, CPUE standardization (hereafter STD CPUE) of swordfish has been actively conducted in the IOTC WPB. However very 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 and Wang et al., 2011).

This is the reason why the last SC recommended conducting on STD CPUE these 5 billfish species in WP10. In Japan, after swordfish, striped and blue marlines 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 (1971-2011) using the operational set by set catch and effort data.

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 are 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. The reason for such decreases in catches is not fully understood.

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.

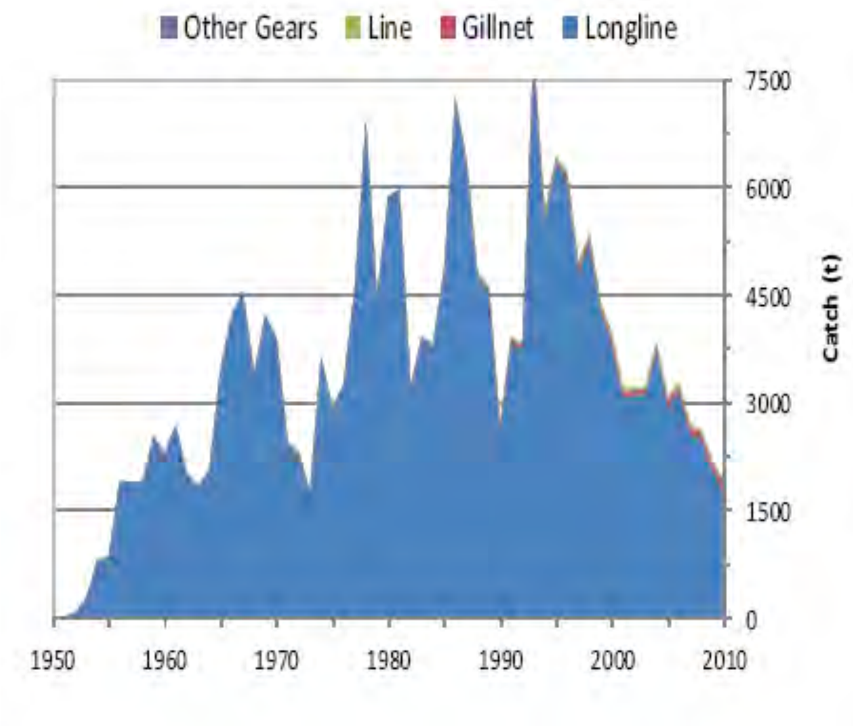


Fig. 1 Catch trend by gear (striped marlin)

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.

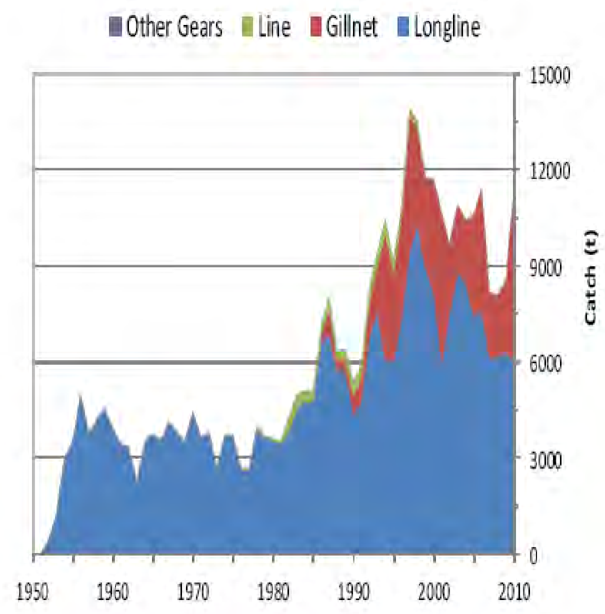
These changes of fishing area and catches over the years are thought to be related to changes in the type of access agreements to EEZs of coastal countries in the Indian Ocean, rather than changes in the distribution of the species over time.

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.



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. Catch and effort data

3.1 Fine scale 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, we used type (a), operational daily set by set fine-scale catch and effort data (1971-2011). The previous works by Uozumi (1998) for STD CPUE for all billfish used type (b), the aggregated operational catch and effort fine scale data.

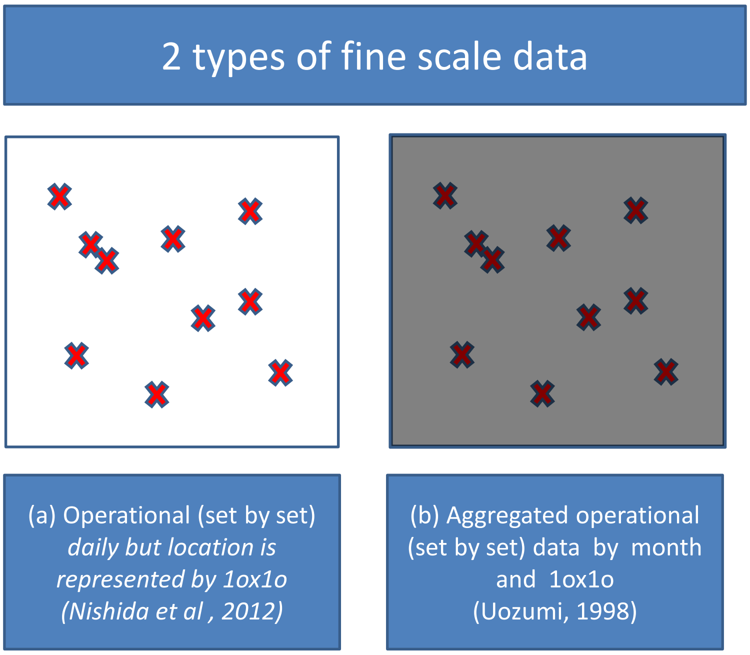


Fig. 3 Definition of 2 different types of fine scale data available in the database of National Research Institute of Far Seas Fisheries (NRIFSF).

3.2 Features of nominal CPUE distribution by decade, recent years and season

To understand features and situation of these 2 species, we made maps showing distribution by decade (1970', 1980's, 1990's and 2000's) with in recent years (2008-2011) and quarterly distribution (Figs. 4-7 for STM and Figs. 8-10 for BLU).

(1) Striped marine

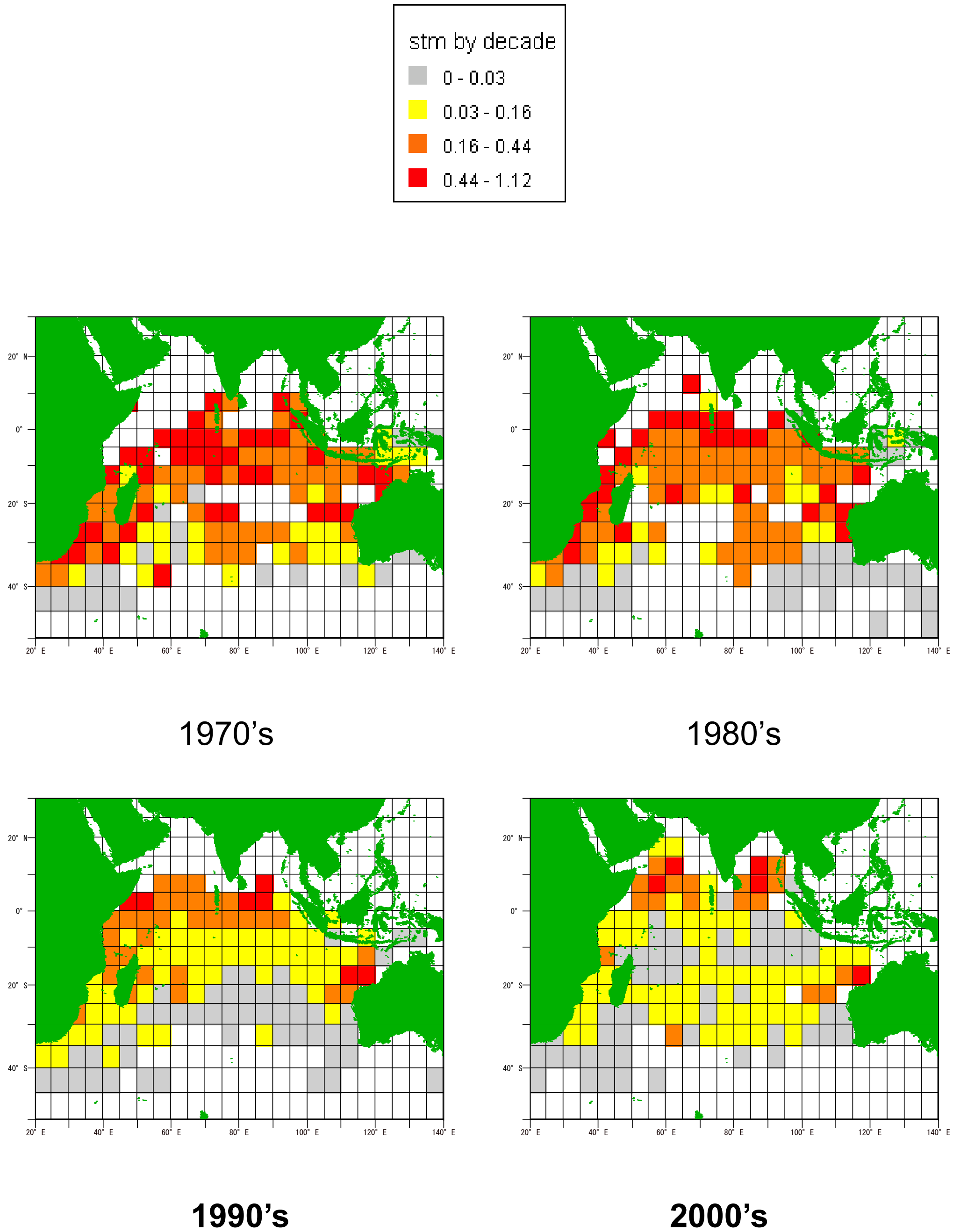


Fig. 4. Distribution of annual average nominal **striped marlin** CPUE (no of fish/1000 hooks) by decade (1970's, 80', 90's and 2000's).

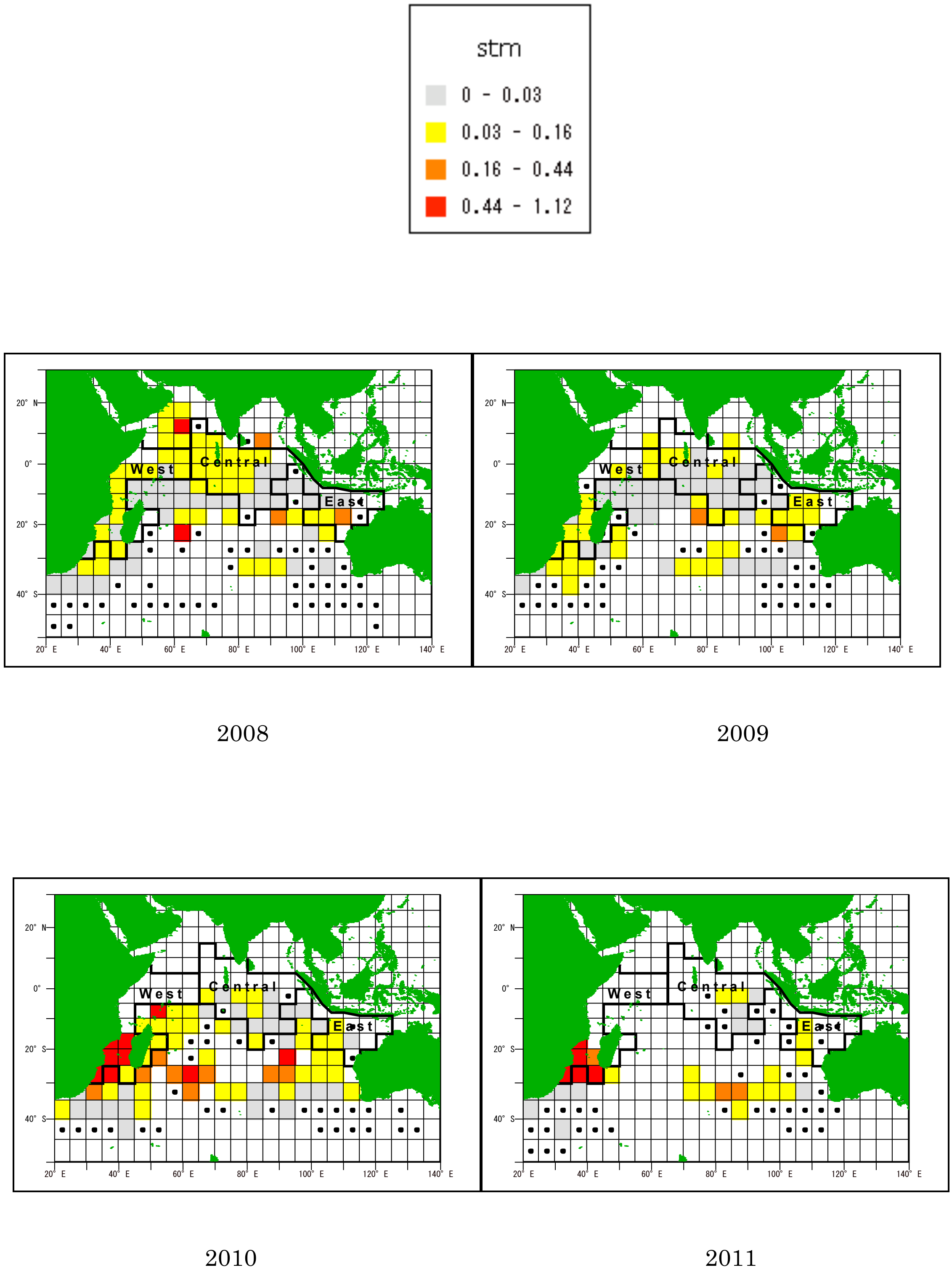


Fig. 5. Distribution of annual nominal **striped marlin** CPUE (no of fish/1000 hooks) in recent 4 years (2008-2011). Black dots represent no catch. Refer to Fig. 10 for 3 sub-areas)

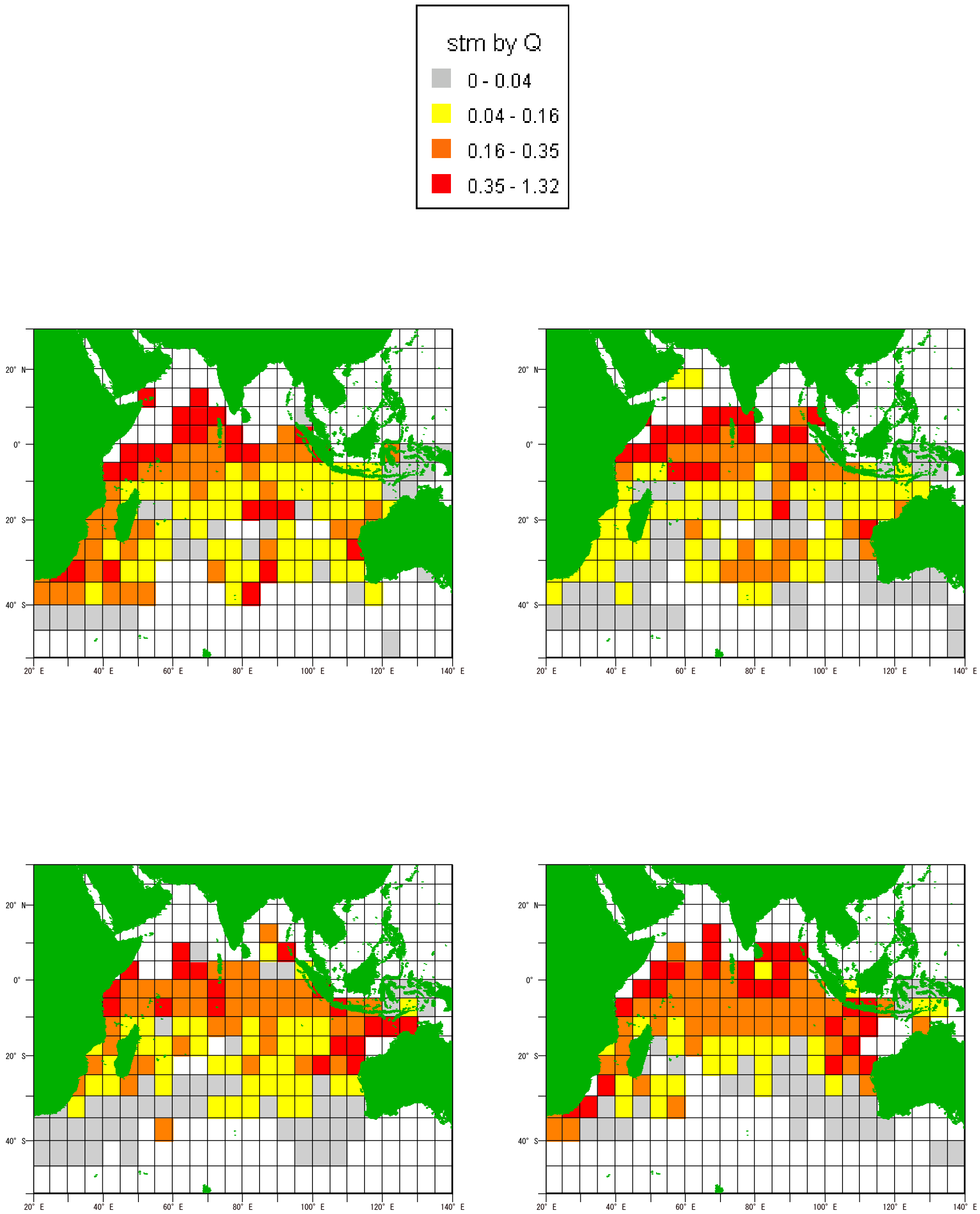
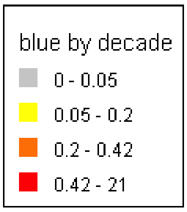
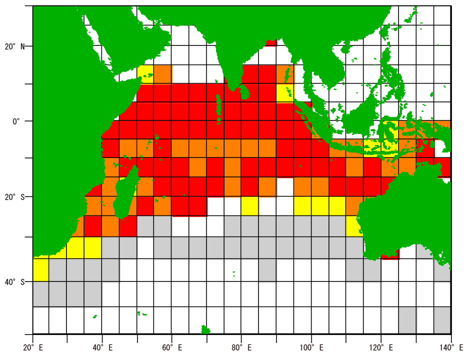


Fig. 6 Distribution of annual average nominal **striped marlin** CPUE (no of fish/1000 hooks) by season (quarter).

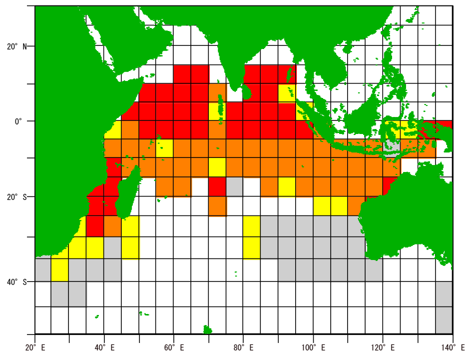
Received: 6, 11 and 14 September, 2012

(2) Blue marlin

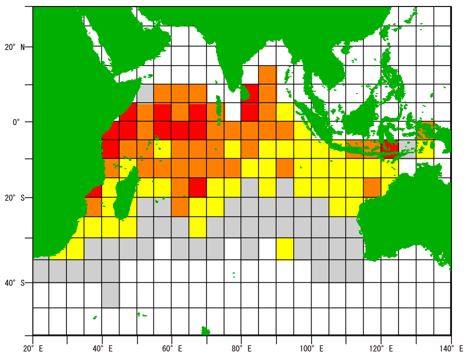




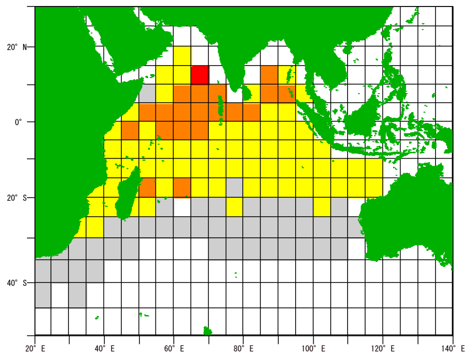
1970's



1980's



1990's



2000's

Fig. 7. Distribution of annual average nominal **blue marlin** CPUE (no of fish/1000 hooks) by decade (1970's, 80', 90's and 2000's).

Received: 6, 11 and 14 September, 2012

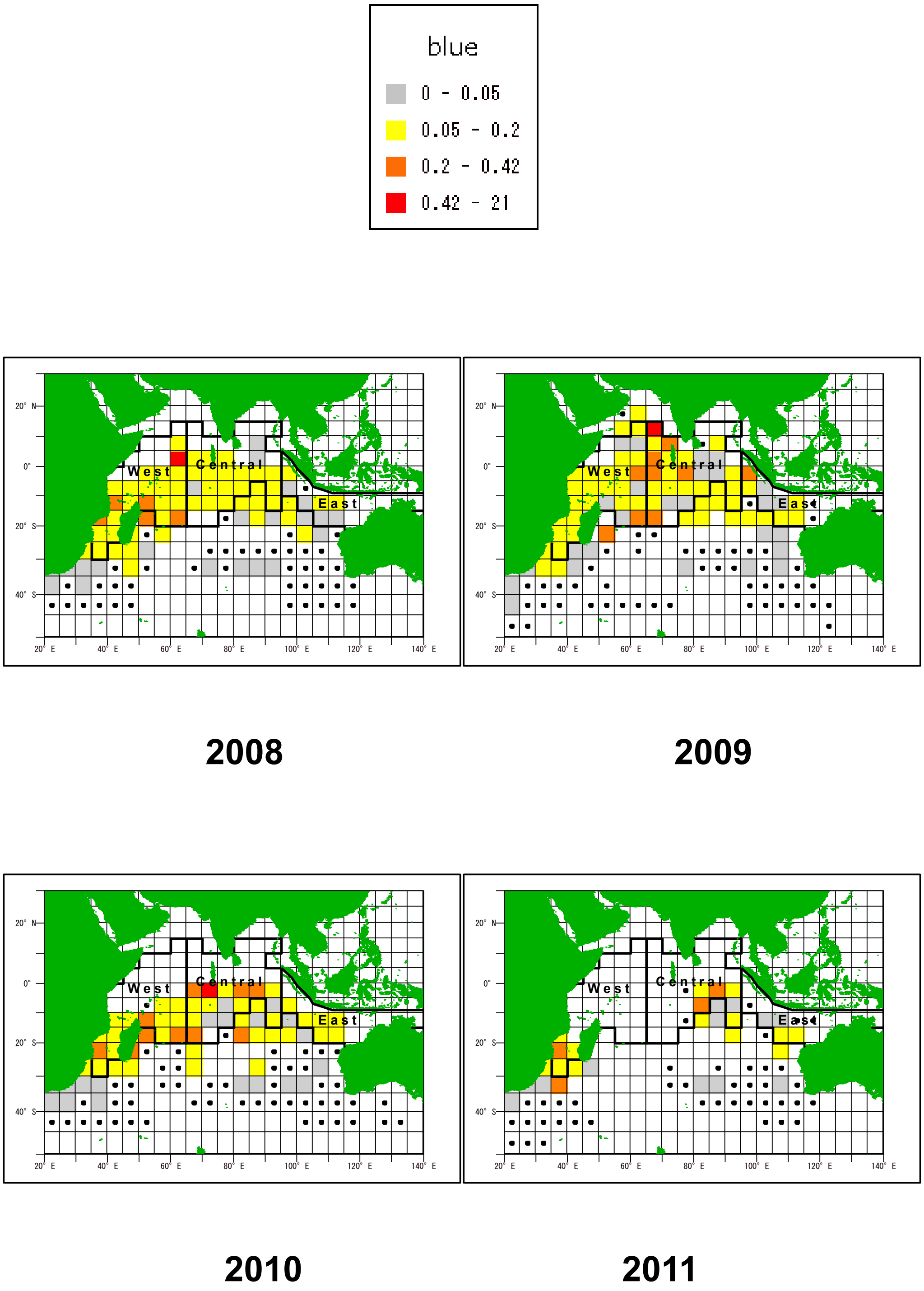


Fig.8 Distribution of annual nominal blue marlin CPUE (no of fish/1000 hooks) in recent 4 years (2008-2011). Black dots represent no catch. Refer to Fig. 11 for 3 sub-areas)

Received: 6, 11 and 14 September, 2012
IOTC–2012–WPB10–19 Rev_2

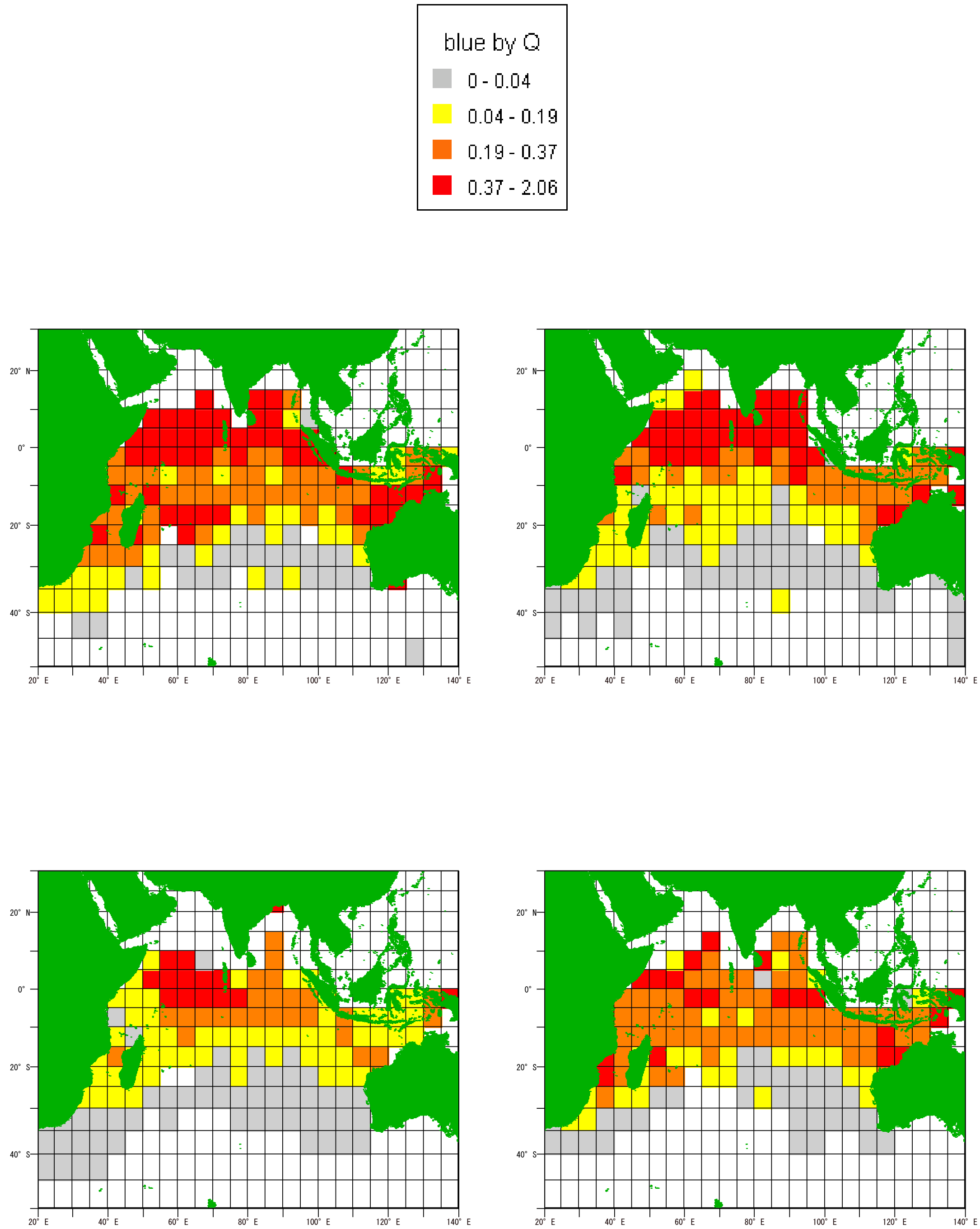


Fig. 9 Distribution of annual average nominal **blue marlin** CPUE (no of fish/1000 hooks) by season (quarter).

Received: 6, 11 and 14 September, 2012

3.3 Sub areas

Sub areas for STD CPUE are defined by the core fishing area method, i.e., we defined 3 high nominal CPUE areas (East, Central and West) each for striped marlin (Fig. 10) and blue marlin (Fig. 11).

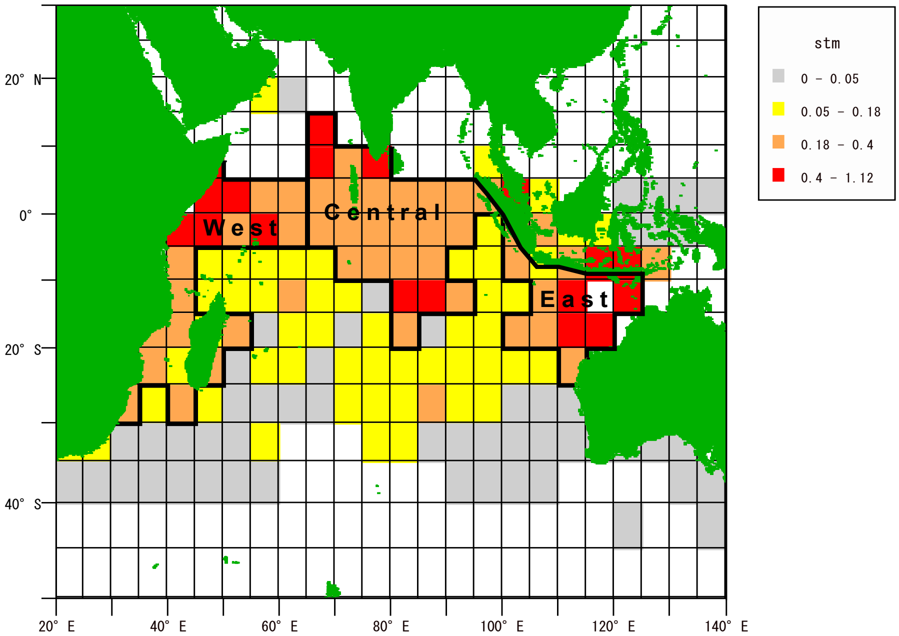


Fig.10 3 sub-areas defined by the core fishing area for STD CPUE of striped marlin.

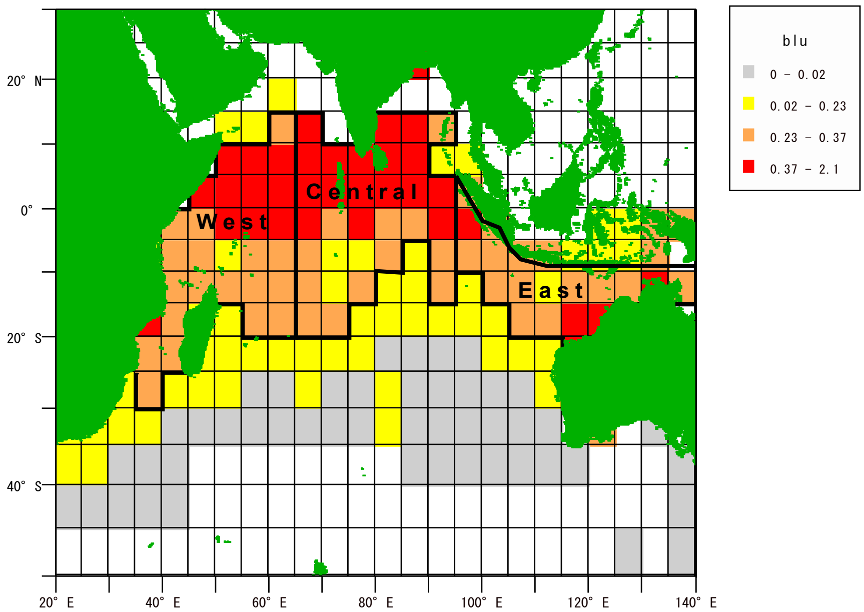


Fig.11 3 sub-areas defined by the core fishing area for STD CPUE of blue marlin.

4. Environmental (ENV) data

4.1 Basic data

As in the past, we used various ENV data which are explained as below and Table 1 show the summary.

(1) IOI (Indian Ocean Index)

Dr Marsac (IRD, France) provided us the monthly IOI data (1971-2010). IOI is the alternate indicator of the SOI (El Nino and La Nina events) in the Indian Ocean, is the difference of the atmospherics pressure (SLP series) between Agalega and Darwin (Australia).

(2) DMI index (Indian Ocean Dipole Mode Index) (DMI)

Dr Marsac (IRD, France) also provided us the monthly DMI data (1971-2011). DMI is the different anomaly of SST between two zone (Z1 and Z2) in the eastern and western IO respectively, i.e., Z1 (Western IO) : 50°E-70°E / 10°N-10°S and Z2 (Eastern IO) : 90°E-110°E / 0°-10°S.

(3) MP (Moon phase)

Daily moon phase data (1971-2011) are downloaded from the web site of the Japan Metrological Agency. MP ranges from 0 (new moon) to 29.7 (full moon).

(4) Oceanographic conditions (GODAS-NCEP data)

Based on suggestion made in the validation works of the GODAS (NCEP) data (Nishida, *et al,* 2011), we will not use the salinity data for this time until the estimation method is replaced by the next generation (better) method.

To make the above mentioned ENV data affecting STM and BLU habitat we applied depth specific temperature and current data available the NCEP Global Ocean Data Assimilation System monthly data (GODAS; http://cfs.ncep.noaa.gov/cfs/godas/monthly). The Original data include temperature, salinity and current (u, v) digital data for 28 depth layers, i.e., every 5 m starting from 5m depth to 225m with extra 4 deeper depth layers, i.e., 5m, 15m, 25m, 35m, 45m, 55m ,65m, 75m, 85m, 95m, 105m, 115m, 125m, 135m, 145m, 155m, 165m, 175m, 185m, 195m, 205m, 215m, 225m, 238m, 262m, 303m, 366m and 459m.

These data are available globally for 28 years from 1980 – 2010 with the resolution of (1/3) degrees in latitude and 1 degree in longitude. These depth specific data were estimated by the spatial models developed by the NCEP. For details refer to the above mentioned web site. Using these original NCEP data we made the following 1x1 and month based oceanographic condition data sets in the Indian Ocean for 31 years (1980-2010) used to estimate STD (standardized).

We used following 4 ENV (TD, T45, TG45, SC and AM) data utilizing the GODAS (NCEO) data. Details are described as below:

TD (Thermocline depth) (mixed layer depth)

Using the NCEP data we estimated TD at 20^{o}C defined by Mizuno, Marsac and others.

T45 (temperature at the 45 m depth)

Instead of normally used the SST or salinity at surface we used T45. This is because Oliveira et al (2005) (submitted as the INFO paper in this WPB7 meeting) suggests that marlin are most frequently exploited by the LL at the depth range from 40-50m. Since temperature data at the 45 m in depth are available in the NCEP data set we directly used such INFO.

TG45 (temperature gradient at 45 m depth)

SWO and tuna are sensitive for changes temperature changes (Bigelow and many others). Thus we use temperature gradients at the depths of 45 m. To represent the ocean currents we compute the maximum gradients per 100km in eight directions around each pixel (Fig. 12). After we select the maximum gradient per 100km we made average gradient by 1x1 and month at 5m depth data available in the NCEP data set.

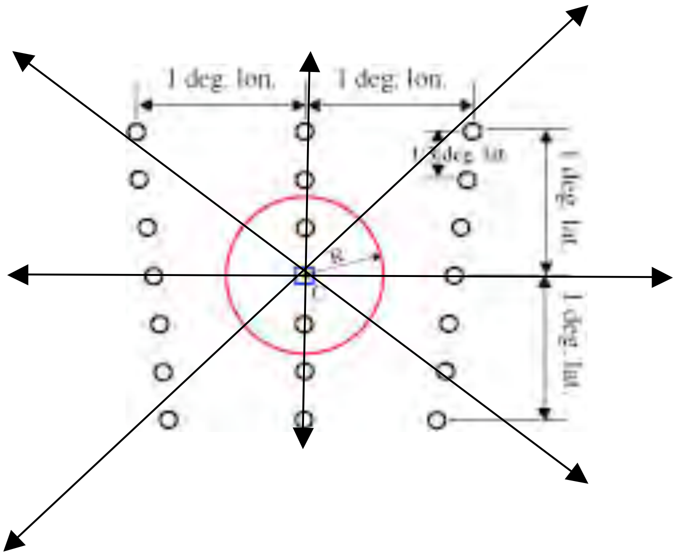


Fig. 12 Searching directions for TG45

Shear currents (SC) and its amplitude (AM)

The current shear, as defined by Bigelow et al (2006), is calculated throughout the water column, as an integration of the horizontal current ($\vec{u}$) from the near-surface to a given depth (Z), usually defined as the maximum depth reached by the hooks of the longline gear :

$$K = \log\left(\frac{\int_0^z \left\|\frac{\partial \vec{u}}{\partial z}\right\| dz}{Z}\right)$$

that can be approximated by :

$$\widetilde{K} = \log\left\{\frac{\sum_{n=1}^{N}\left[\left(\frac{u_{n+1}-u_n}{z_{n+1}-z_n}\right)^2+\left(\frac{v_{n+1}-v_n}{z_{n+1}-z_n}\right)^2\right]^{1/2}(z_{n+1}-z_n)}{\sum_{n=1}^{N}(z_{n+1}-z_n)}\right\}$$

where $\widetilde{K}$ is the log-transformed vertical shear, u_n the zonal velocity component of layer n, v_n the meridional velocity component of layer n and z_n is the depth of layer n. vertical shear was estimated from the NCEP model by integrating from 5 to 205 m. Values found for this factor in the study area range between -4.65 and -0.09.

We also estimate the amplitude of the current in the water column where the shear is calculated. To do so, we calculate the difference between minimal and maximal current velocities found in the column sampled. This complements the shear current factor by providing a more direct value (in cm.s^{-1}) of the heterogeneity of current. Values found for this factor in the study area range between 0.31 and 168.9. Following the original resolution of the NCEP model output selected, both shear current and amplitude are given by 1/3° latitude and 1° longitude box and month. Then 1x1 and month data set are created.

(5) Summary of the ENV data (Table 1)

Table 1 Summary of the ENV data

Code	Meanings	Resolution (period used)	Unit	Sources
IOI	Indian Ocean Index (difference of the atmospheric pressure between Agalega and Darwin)	Month (1971-2011)	hPa (hect pascal)	Marsac (IRD, France)
DMI	Different anomaly of SST between two zone (Z1 and Z2) in the eastern and western IO, i.e., Z1: 50°E-70°E / 10°N-10°S and Z2: 90°E-110°E / 0°-10°S.	Month (1971-2011)	^{o}C	
MP	Moon Phase	Day (1971-2011)	Index: 0 (new moon) & 29.7(full)	Japan Metrological Agency
T45	Temperature at 45 m depth	1x1 & month	^{o}C	NCEP
SC	Shear current (currents integrated from 5 to 205 m)		cm/second	
AM	Amplitudes of the SC (different between mini & max water column sampled)		cm/second (0.31 - 168.9)	
TG45	Temperature gradient		Max ^{o}C /100 km	

4.2 Time lag effect

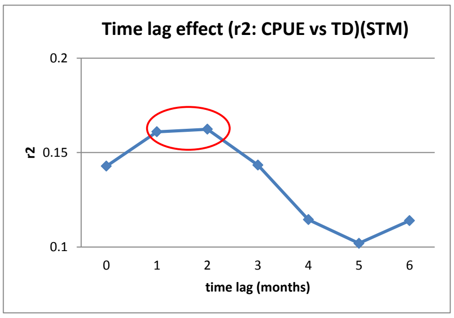
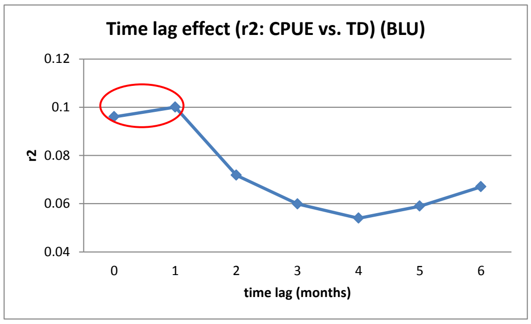
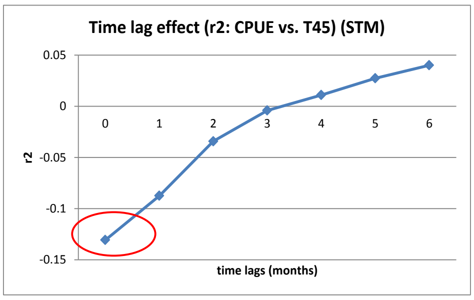
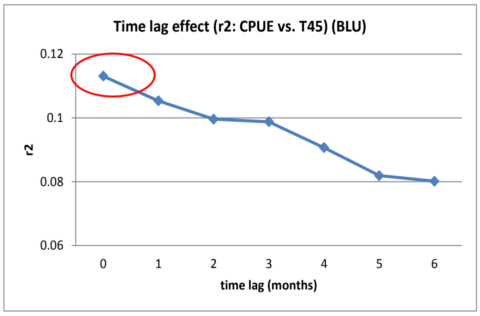
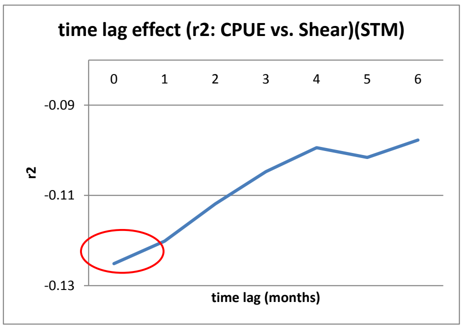
As discussed in the last WPB and WPTP, there are likely the time-lag effects of ENV to the nominal CPUE, e.g., blooming of primary products affected nominal CPUE of yellowfin tuna in 3 month later in the Arabian Sea (Wang and Nishida, 2011). For this time we investigate the time-lag effects by simple correlation analyses between nominal CPUE v. ENV factors with the time-lag of 0, 1, --- 6 months (for some parameters to 7 months). Table 1 and Figs. 13-14 show the results.

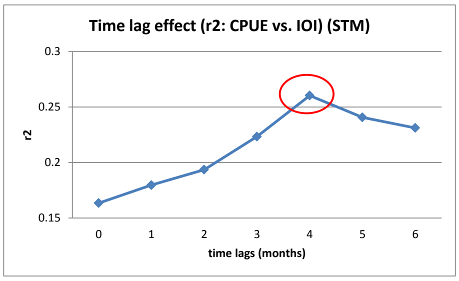
Table 2 Summary of the time-lag effect between nominal CPUE vs. ENV with 0-6 months lags.

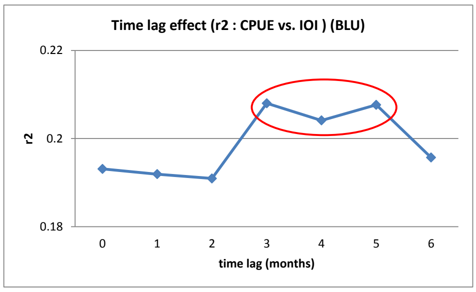
Core fishing area ➔	Striped marlin	Blue marlin
Type of ENV	Time lag period when higher correlation observed	
IOI (Indian Ocean Index)	4 months	3-5 months
MDI (Indian Ocean Dipole Mode Index) (all sub-areas)	no correlations	1 and 4 months
	Note : time lag period may be different by sub-area (W+C+E) as MDI affect CPUE by different timing by sub-area (future work)	
TD (Thermocline depth)	1-2 months	0-1 Months
T45 (Sea temperature at 45 m depth)	0 (same) month (no time lag) Negative CORR	0 (same) month (no time lag)
TG45 (Sea temperature gradient at 45m depth)	no correlations	no correlations
SC (Shear Current)	0 (same) month (no time lag) Negative CORR	no correlations
AM (amplitude of the shear current)	no correlations	no correlations

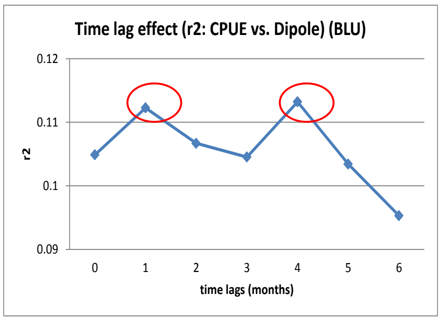
Received: 6, 11 and 14 September, 2012

Fig 13 Time lag effect of oceanographic factors (NCEP) on nominal CPUE (STM and BLU)

	Striped marlin	Blue marlin
TD	 time lag (1-2 months)	 time lag (0-1 months)
T45	 No time lag (real time) effect	 No time lag (real time) effect
Shear	 No time lag (real time) effect	no correlations
Shear (Amp)	no correlations	no correlations

<table>
<tr><th></th><th>Striped marlin</th><th>Blue marlin</th></tr>
<tr><td>IOI</td><td>

time lag (4 months)</td><td>

time lag (3-5 months)</td></tr>
<tr><td>IO Dipole index</td><td>

time lag (1 and 4 months)</td><td>no correlations</td></tr>
</table>

Fig 14 Time lag effect of climate indices on nominal CPUE (STM and BLU)

We could observe time lag effects in majority of ENV data. Thus, we need to use these ENV data incorporating the time lags in the GLM analyses, so that we can expect more ecologically and statistically meaningful results. However all correlations between nominal CPUE and various ENV data were very low (0.1-0.3). Thus in the GLM, even we newly use ENV data with the time lag effect, it is likely that trends of STD CPUE may not be significantly different from those without ENV data as in the past. Table 3 shows list of ENV data to be used in the GLM for STM and BLU.

Table 3 List of ENV data with time lag to be used in the GLM for STM and BLU.

<table>
<tr><th></th><th>IOI</th><th>DMI</th><th>TD</th><th>T45</th><th>Shear current</th><th>Shear Amplitude</th></tr>
<tr><td>STM</td><td rowspan="2">4 months</td><td>4 months</td><td rowspan="2">1 month</td><td rowspan="2">Real time (No time lag)</td><td>Real time (No time lag)</td><td rowspan="2">Excluded</td></tr>
<tr><td>BLU</td><td>Excluded</td><td>Excluded</td></tr>
</table>

Received: 6, 11 and 14 September, 2012

5. STD CPUE

We applied the log normal (LN) GLM for STD CPUE for both species for 2 periods (Table 4). These analyses were conducted using SAS 9.3.

Table 4 Summary of effects used in the GLM model by period

<table>
<tr><th rowspan="2">Model</th><th colspan="2">Effect</th><th colspan="2">Period</th></tr>
<tr><th>Effect type</th><th>Effect elements</th><th>1971-2011</th><th>1980-2010</th></tr>
<tr><td rowspan="3">Base</td><td>Basic effect</td><td>Year, Quarter, sub-area, target, material (main and branch line)</td><td rowspan="3"></td><td rowspan="4"></td></tr>
<tr><td rowspan="2">Moon Phase and climate effect</td><td>Moon phase</td></tr>
<tr><td>IOI and DMI</td></tr>
<tr><td>Base +NCEP</td><td>NCEP (Oceanographic) effect</td><td>NCEP(TD, T45 and SC)</td><td>(na)</td></tr>
</table>

$$\ln(CPUE+const)= \mu + Y_i + Q_j + A_k + G_l + Q_j{*}A_{jk} + Q{*}G_{jl} + Y_i {*}Q_j +B+M+MP+ENV+ e_{ijkl} \text{ ---------------- } (1)$$

where Y_i*: effect of year in year i*

Q_j*: effect of quarter in quarter j*

A_k*: effect of subarea in area k (see Figs 2 and 3)*

G_l*: effect of gear in gear l*

if 4<=hpb<=7 then G=1(shallow LL);

if 8<=hpb<=11 then G=2(regular LL);

if 12<=hpb<=15 then G=3(deep LL);

if 16<=hpb<=21 then G=4 (ultra deep LL);

hpb: number of hooks per (between) baskets (floats)

$Q_j{*}A_{jk}$*: interaction term between quarter and area in quarter j and area k*

$Q_j{*}G_{jl}$*: interaction term between quarter and gear in quarter j and gear l*

$Y_i {*}Q_j$*: interaction term between year and quarter in year i and quarter j*

B: materials of branch line

M: materials of main line

ENV : Environmental effect (See Table 3)

e_{ijkl} *: error term (normal distribution)*

Standardized CPUE for LN model was calculated as follows:

Standardized $CPUE_i$= EXP (LSM(Y_i)) – C

where LSM(Y_i): least square mean of year effect in year i

MSE: Mean square error

C: constant (10% of mean CPUE)

5.1 Results for striped marlin

Box 1 shows results of 2 GLM runs. Base model suggested that year, quarter and quarter*gear effects affect nominal CPUE significantly, while for the BASE+NCEP model, year, quarter, T45 and Shear current. Fig 15 shows the annual trend of the estimated STD CPUE (BASE, BASE+NCEP and nominal). It suggested that STD CPUE of striped marlin generally shows the decreasing trend except very high jumps in the middle of 1970's and the recent slight increase trend in 2010-2011. It also suggested that BASE+NCEP model leveled up the trends of BASE and nominal CPUE. Performances of both GLM models (goodness-of-fitness) are almost same level (Table 5)

BOX 1 Results of 2 GLM runs (STM)

BASE model

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	70	212524.0152	3036.0574	2469.46	<.0001
Error	341482	419832.0378	1.2294		
Corrected Total	341552	632356.0529			

R-Square	Coeff Var	Root MSE	lncpue Mean
0.336083	-40.31308	1.108802	-2.750476

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Y	40	61046.83318	1526.17083	1241.35	<.0001
q	3	13699.86376	4566.62125	3714.39	<.0001
a	2	99.84657	49.92328	40.61	<.0001
g	3	2949.93790	983.31263	799.80	<.0001
q*a	6	6492.99977	1082.16663	880.21	<.0001
q*g	9	14207.97241	1578.66360	1284.05	<.0001
miki	2	350.48122	175.24061	142.54	<.0001
eda	2	16.77774	8.38887	6.82	0.0011
mp	1	193.18505	193.18505	157.13	<.0001
dmi	1	184.35388	184.35388	149.95	<.0001
ioi	1	21.29877	21.29877	17.32	<.0001

BASE+NCEP model

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	63	131677.1680	2090.1138	2034.92	<.0001
Error	305179	313456.5834	1.0271		
Corrected Total	305242	445133.7514			

R-Square	Coeff Var	Root MSE	lncpue Mean
0.295815	-35.20437	1.013471	-2.878822

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Y	30	36275.37702	1209.17923	1177.25	<.0001
q	3	4904.42719	1634.80906	1591.64	<.0001
a	2	42.39625	21.19812	20.64	<.0001
g	3	1353.78524	451.26175	439.35	<.0001
q*a	6	3997.34257	666.22376	648.63	<.0001
q*g	9	3849.47508	427.71945	416.42	<.0001
miki	2	344.92430	172.46215	167.91	<.0001
eda	2	13.71407	6.85704	6.68	0.0013
mp	1	185.38476	185.38476	180.49	<.0001
dmi	1	1.94176	1.94176	1.89	0.1691
ioi	1	8.62451	8.62451	8.40	0.0038
td	1	5.23084	5.23084	5.09	0.0240
t45	1	1389.74332	1389.74332	1353.04	<.0001
sc205	1	1362.05696	1362.05696	1326.09	<.0001

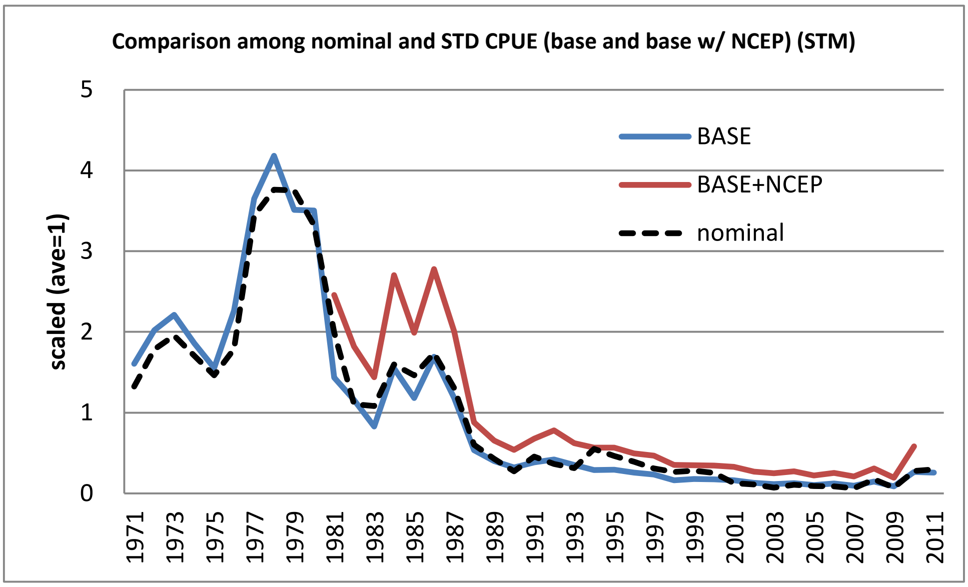
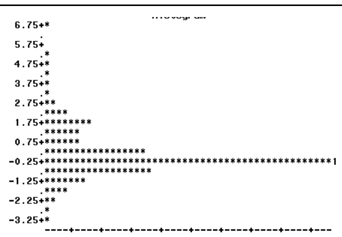
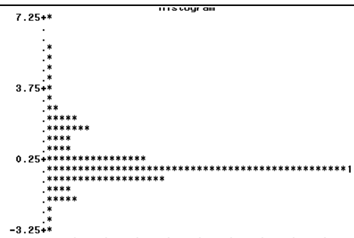
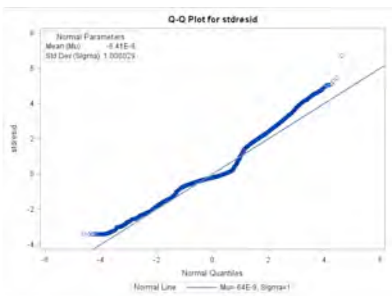
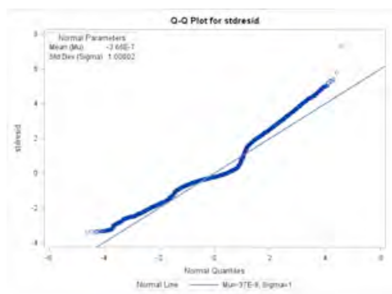


Fig. 15 Estimated STD CPUE (BASE and BASE+NCEO) and nominal CPUE for striped marlin

Table 5 Comparison of STD CPUE between BASE and BASE+NCEP model

	BASE	BASE+NCEP
Period	1971-2011	1980-2010
Effect	Y+Q+A+G+IOI+Dipole+MP+Matearials	Base with TD+T45+Shear
Significant effect (4 tops)	(1) Q, (2) Y, (3) Q*G and (4) Q*A	(1) Q, (2) T45, (3) Shear and (4) Y
R2	34%	30%
CV	-40%	-35%
Root MSE	1.11	1.01
Residual		
QQ plot		
Performance	Similar performance. In BASE+NCEP model, T45 and Shear current significantly affect nominal CPUE	

5.2 Results for Blue marlin

Box 2 shows results of 2 GLM runs. Base model suggested that quarter, area, gear (targeting) and IOI affect nominal CPUE significantly, while for the BASE+NCEP model, T45, Shear current, IOI and year (T45 was extremely significant). Fig 16 shows the annual trend of the estimated STD CPUE (BASE, BASE+NCEP and nominal). It suggested that STD CPUE of blue marlin generally shows the decreasing trend except very a few jumps and the recent slight increase trend in 2010-2011. It also suggested that BASE+NCEP model leveled up the trends of BASE. Performances of the BASE+NCEP model (goodness–of-fitness) is better than in the BASE model (Table 6). IOI plays an important role for both models.

BOX 2 Results of 2 GLM run (BLU)

BASE

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	69	192768.289	2793.743	1498.17	<.0001
Error	437330	815519.637	1.865		
Corrected Total	437399	1008287.925			

R-Square	Coeff Var	Root MSE	lncpue Mean
0.191184	-57.14689	1.365566	-2.389571

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Y	40	66109.81847	1652.74546	886.30	<.0001
q	3	11253.54245	3751.18082	2011.61	<.0001
a	2	7185.34831	3592.67415	1926.60	<.0001
g	3	8456.11386	2818.70462	1511.56	<.0001
q*a	6	7093.66646	1182.27774	634.01	<.0001
q*g	9	1992.85200	221.42800	118.74	<.0001
miki	2	132.45682	66.22841	35.52	<.0001
eda	2	80.76383	40.38191	21.66	<.0001
mp	1	485.78885	485.78885	260.51	<.0001
ioi	1	1475.84210	1475.84210	791.43	<.0001

BASE+NCEP

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	58	175450.1638	3025.0028	1817.37	<.0001
Error	342006	569268.3477	1.6645		
Corrected Total	342064	744718.5115			

R-Square	Coeff Var	Root MSE	lncpue Mean
0.235593	-51.84851	1.290154	-2.488315

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Y	30	32540.56328	1084.68544	651.66	<.0001
q	3	1667.87997	555.95999	334.01	<.0001
a	1	391.84824	391.84824	235.42	<.0001
g	3	258.35045	86.11682	51.74	<.0001
q*a	3	3107.57686	1035.85895	622.33	<.0001
q*g	9	2028.52072	225.39119	135.41	<.0001
miki	2	517.26319	258.63159	155.38	<.0001
eda	2	325.45366	162.72683	97.76	<.0001
mp	1	162.50581	162.50581	97.63	<.0001
ioi	1	1261.84866	1261.84866	758.10	<.0001
td	1	583.10745	583.10745	350.32	<.0001
t45	1	11986.96055	11986.96055	**7201.55**	<.0001
sc205	1	2395.08371	2395.08371	1438.92	<.0001

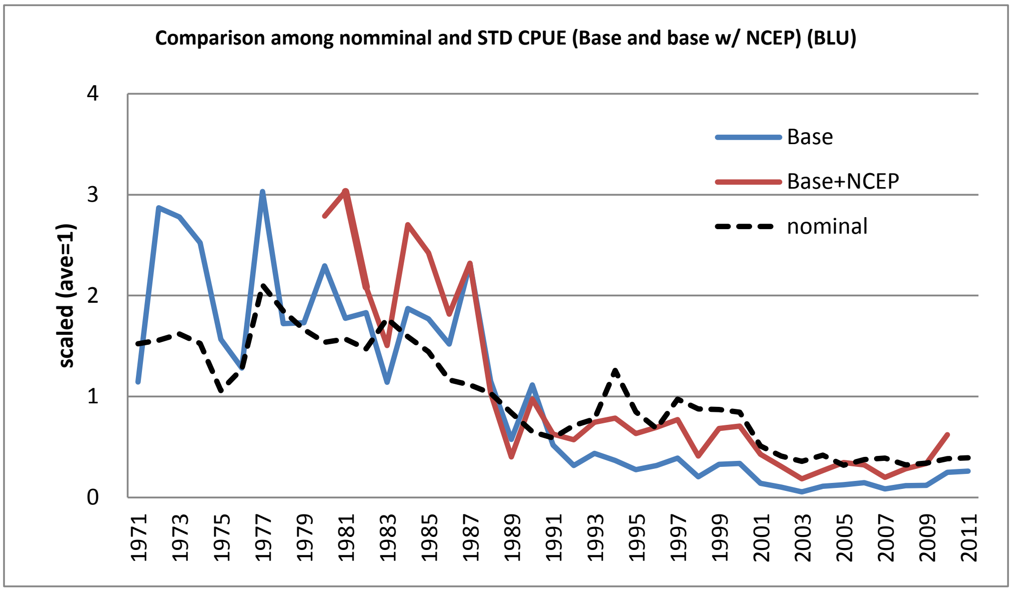
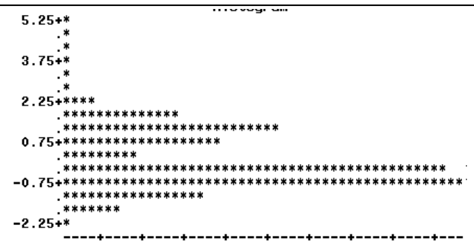
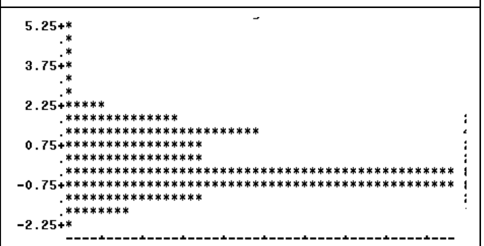
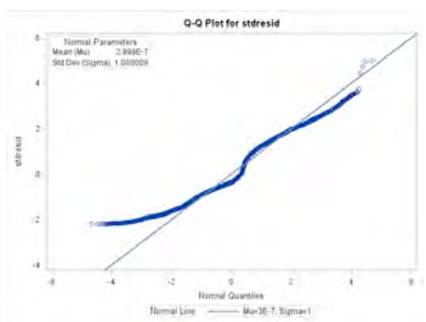
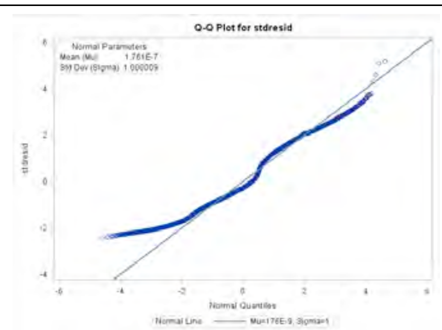


Fig. 16 Trend of nominal CPUE and STD CPUE (base and base with NCEP) (blue marlin)

Table 6 Comparison of STD CPUE between BASE and BASE+NCEP model

	BASE	BASE+NCEP
Period	1971-2011	1980-2010
Effect	Y+Q+A+T+IOI+MP+Matearials	Base with TD+T45+Shear
Significant effect (4 tops)	(1) Q, (2) A, (3) G and (4) IOI	(1) T45, (2) Shear , (3) IOI and (4) Y
R2	19%	24%
CV	-57%	-52%
Root MSE	1.37	1.29
Residual		
QQ plot		
Performance	Fitness of BASE+NCEP model is slightly better than BASE model. IOI affect significantly for both model. In BASE+NCEP model, T45 is highly significant and others (T45 and Shear current) are also significant.	

6. Summary

Log normal GLMs were applied to estimate STD CPUE for striped and blue marlin. Two GLM models are used, i.e., (1) BASE model (1971-2011) including effects of Y (year), Q (quarter), A (sub-area), G (gear: targeting), Miki+Eda (Materials of main and branch lines), IOI (Indian Ocean Oscillation Index), DMI (Indian Ocean Dipole Mode Index) and MP (Moon Phase) and (2) BASE+NCEP model (1980-2010) include additional effects of T45 (Sea temperature at 45m depth), SC (shear current) and TD (thermocline depth or mixed layer depth).

All the ENV data (IOI, DMI, T45, Shear current, TD and IOI) except MP were examined if there were time-lag effects in 0-6 months to the nominal CPUE for these 2 species in advance. As a result, for striped marlin, it was found that there are 4 months-time lag effects in IOI and DMI, 1 month in TD and no time-lag effect (real time effect) in T45 and Shear current. As for blue marlin, 4 months in TD and no time lag effect in T45 and Shear current. In this study, GLMs incorporating time lag effects were used as a first time and conducted unlike in the past, i.e., we have been using ENV data without considering any time-lag effects and ENV data without the time lag effects showed some levels of statistical significances in GLMs, but the resultant trends of STD CPUE with and without ENV data were not so different.

However, for this time, we applied GLM with ENV data considering time lag effects, then we found that some ENV effects showed large and consistent statistical significances, i.e., for striped marlin, T45 and shear current and for blue marlin, T45 and IOI. Furthermore, their trends of STD CPUE were resulted to be largely different from STD CPUE without ENV data unlike in the past. This suggested that GLM with time-lag effects ENV data likely play an important role to represent more real trends of STD CPUE.

Results of GLMs suggested that STD CPUE of both species showed the decreasing trend since 1971 in general, except a few periods. However during 2011-2012, STD CPUE showed a slight increase trends. This is likely caused by the pirate activities, i.e., fishing efforts by Japanese tuna longline and also other related fisheries have been largely decreased since 2008 due to the piracy activities in the western Indian Ocean, which significantly reduce catch and effort for both species and such reduction likely made recoveries of these 2 species’ stocks in very recent 2 years (2010-2011).

Acknowledgments

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

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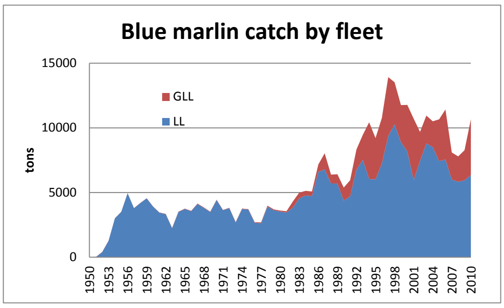
IOTC–2012–WPB10–19 Rev_2

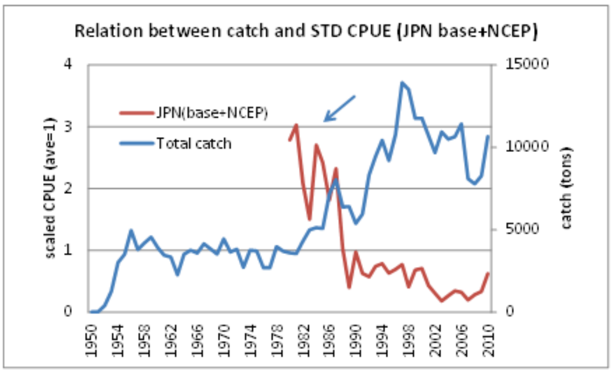
Appendix A Stock assessment of blue marlin by ASPIC (Fox model) (from PowerPoint)

Input data

- 2 fleet model : LL and GILL (1950-2010)
- Catch



STD CPUE (Japan :Base+NCEP)



Results

With STD CPUE : Japan (base+NCEP)(1980-2010)

Problem: TBmsy < MSY (unrealistic)

same problems in other single STD CPUEs

Japan BASE (1971-2010)

Taiwan (1980-2010)

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2nd attempt to solve this problem

Use 2 STD CPUEs of JPN (Base+NECP) +TWN

This problem was solved

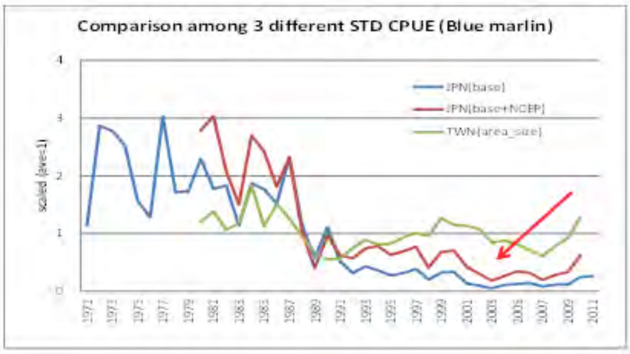
ASPIC model with 2 STD CPUEs (JPN+TWN)
Independently used
(not averaged)

Why one CPUE model failed ?

Real abundances may be in between JPN + TWN.

➔ 1 CPUE can not explain mechanism (pop Dynamics)

➔ 2 CPUE together may reflect real pop. dynamics



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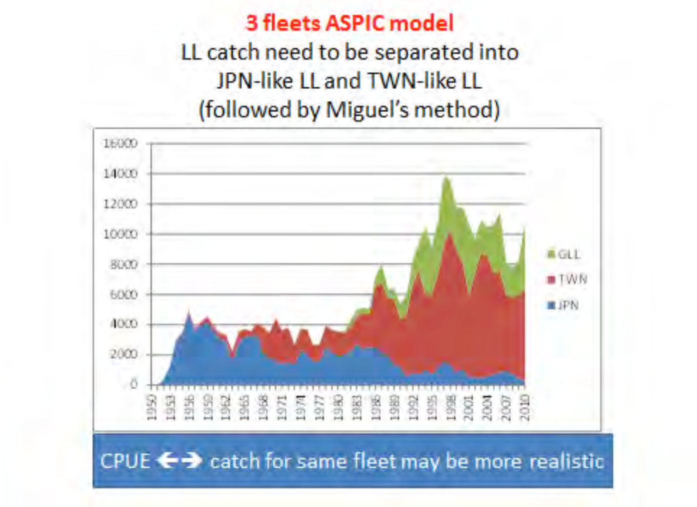
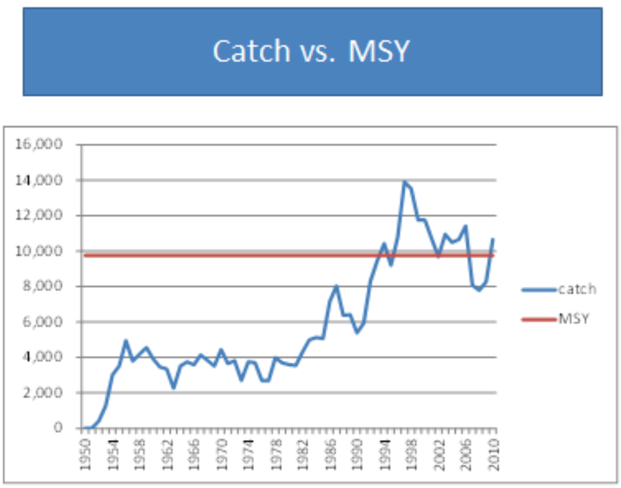


Results (3 fleets model)



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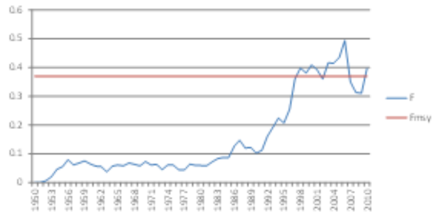
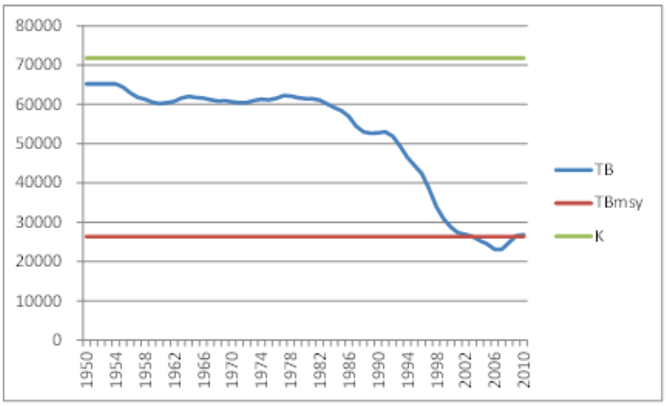
F vs. Fmsy

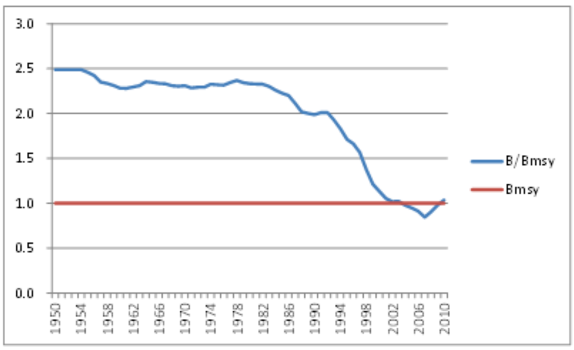
F/Fmsy



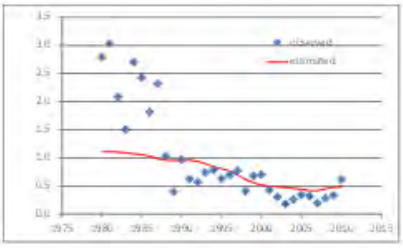
TB vs. K vs. TBmsy



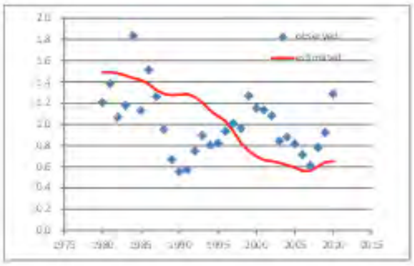
TB/TBmsy



Residuals (STD CPUE Japan: base+NCEP)



Residuals (STD CPUE Taiwan)



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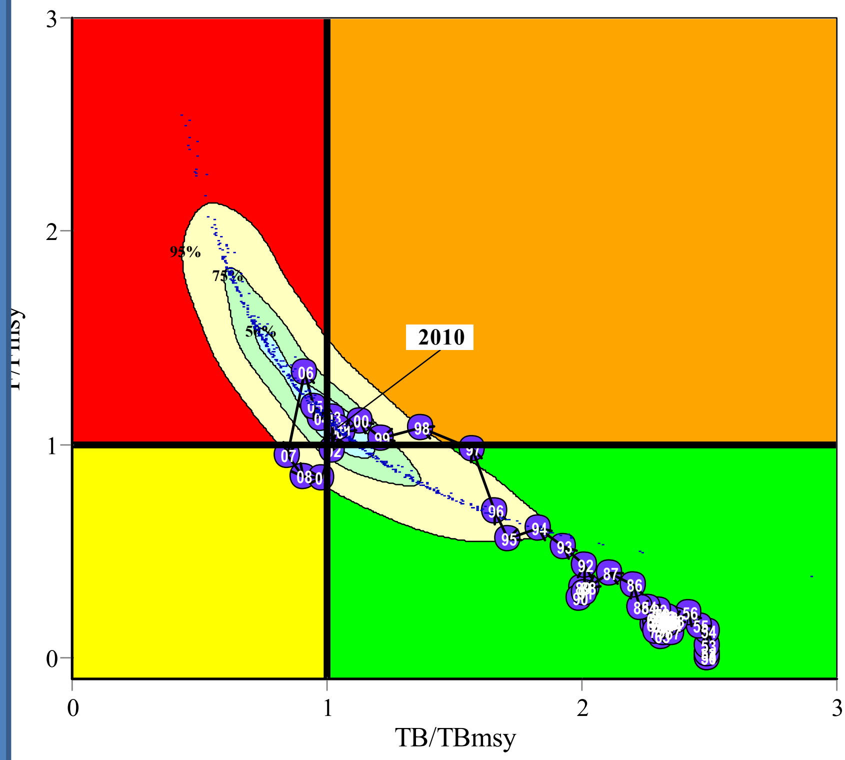

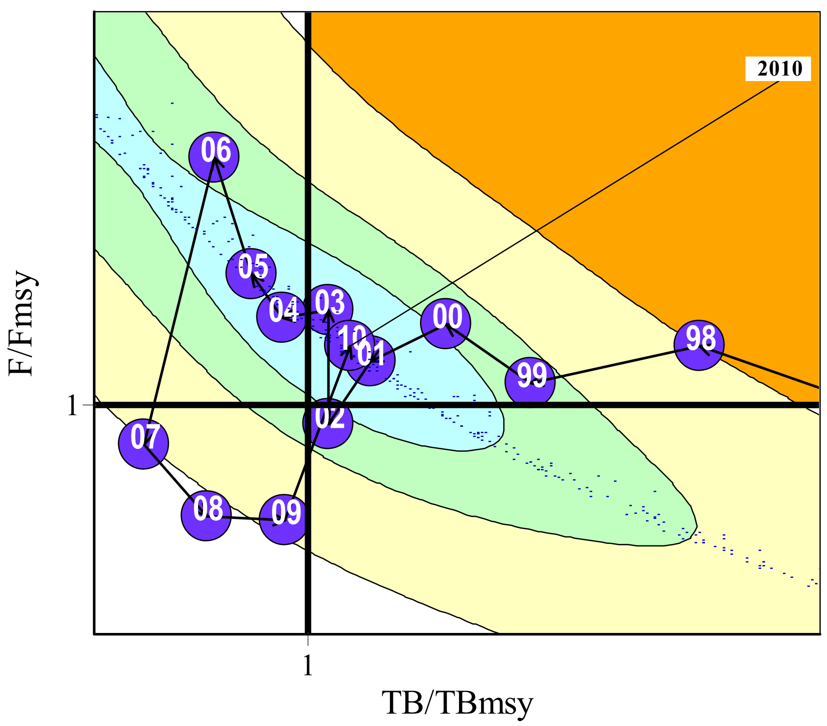

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Indian Ocean blue marlin stock status summary

Management Quantity	Results based on ASPIC (Fox) 3 fleets model (LL: JPN, LL:TWN and GILL)
Most recent catch estimate (t) (2010)	10,662
Mean catch over last 5 years (t) (2006-2010)	92,467
MSY (1,000 t) (80% CI)	97,530 (8,341-13,510)
Current Data Period (catch)	1950-2010
STD CPUE (annual)	Japan (Base+NCEP) + Taiwan (size_area) Independently used (1980-2010)
F(Current)/F(MSY) (80% CI)	1.08 (0.73-1.65)
SSB(2010)/SSB(MSY) (80% CI)	(NA)
TB(2010)/TB(MSY) (80% CI)	1.04 (0.69-1.35)
SSB(2010)/SSB(0) (80% CI)	(NA)
TB(2010)/TB(0)	0.48
SSB(2010) /SSB(Current, F=0)	(NA)