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Correlations between environmental factors and CPUEs of blue marlin (*Makaira mazara*) and striped marlin (*Kajikia audax*) caught by Taiwanese longline fishery in the Indian Ocean

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ABSTRACT

This study investigated the correlations between environmental factors (Indian Oscillation Index, Dipole Mode Index, Southern Oscillation Index, sheer currents, amplitude of the shear current, thermocline depth, and temperature at depth of 15/55m and temperature gradient at depth of 15/55m) and nominal CPUEs of blue marlin and striped marlin caught by Taiwanese longline fishery in the Indian Ocean. The results clearly showed that there are significant cycle-patterns between CPUEs and most environmental factors. In addition, this study also suggested the environmental factors with the time-lags for CPUE standardization analyses of blue and striped marlins in the Indian Ocean.

1. INTRODUCTION

The environmental factors were widely adopted for incorporating into the CPUE standardization modeling. However, there are likely the time-lag effects of environmental factors to the nominal CPUE and the time-lag effects may be taken into account when conducting the CPUE standardization model. Nishida et al. (2012) investigated the time-lag effects between environmental factors and Japanese nominal CPUEs of blue marlin (*Makaira mazara*) and striped marlin (*Kajikia audax*) by using simple correlation analyses and they found that there are time-lag effects of 0 to 6 months on nominal CPUEs. In addition, the environmental factor could be treated as continuous variable if there is likely linear relationship between environmental factor and CPUE. Otherwise, the environmental factor may need to be treated as categorical variable by observing the pattern of CPUE on environmental factor. However, these considerations were not taken into account for CPUE standardization conducted in previous Taiwanese studies (Wang and Nishida, 2012; Wang et al., 2012). Therefore, this study attempts to investigate the correlations between environmental factors and nominal CPUEs of blue marlin and striped marlin caught by Taiwanese longline fishery in the Indian Ocean. The results of this study would provide useful information for further analysis of CPUE standardization.

2. MATERIALS AND METHODS

2.1. Catch and Effort data

In this study, daily set-by-set catch and effort data (logbook) of Taiwanese longline fishery with 1x1 degree grid in the period of 1995-2011 are provided by Oversea Fisheries Development Council of Taiwan (OFDC). The CPUE is calculated as number of fish caught per 1000 hooks.

2.2. Environmental data

The environmental effects used in this study are Indian Oscillation Index (IOI), Dipole Mode Index (DMI), Southern Oscillation Index (SOI), moon phase (MP), sheer currents (SC), amplitude of the shear current (AM), thermocline depth (TD), and temperature at depth of 15/55m (T15/T55) and temperature gradient at depth of 15/55m (TG15/TG55).The details of environmental data used in this study were described in the paper of Nishida et al. (2012).

2.3. Relationship between environmental factor and CPUE

The values of environmental factors are rounded to the specified number of decimal places (TD: 0; SC: 1; AM: 1; T55: 1; TG55: 0; DMI: 2; IOI: 2; SOI: 2) and the CPUEs are aggregated into group values of environmental factors by average. Then, a simple scatter plot is adopted for exploring the relationship and linear pattern between environmental factors and CPUE.

2.4. Time-lag correlation analysis

In order to reduce the variation of CPUEs within a month, the CPUEs by sets are aggregated into monthly average values. The cross-correlation analysis is used to conduct the time-lag effects of environmental factors of the CPUEs. The maximum lag of time is set to be 60 months and then cross-correlation with shorter lag of time is extracted from the results with 60 moths time lag. The correlation coefficient (R) and p-value of significance test are also calculated for each time lag.

3. RESULTS AND DISCUSSION

3.1. Relationship between environmental factor and CPUE

Fig. 1 shows the relationship between environmental factors and CPUE of blue marlin. For relationships between CPUE and TD, AM and TG55, the CPUEs are likely slightly higher within specific ranges of these environmental factors, while CPUEs seem to decrease with lower and higher values of these environmental factors but higher variations of CPUEs are also observed. There are relatively obvious linear relationships between CPUEs and SC and T55. However, no significant patterns can be observed between CPUEs and DMI, IOI and SOI.

Similar patterns are shown for the relationship between CPUEs of striped marlin and environmental factors (Fig. 2). However, there is no obvious relationship between CPUE and TG15 as that for blue marlin. In addition, CPUE discontinue the increasing pattern when SC reaches a specific value.

3.2. Time-lag correlation analysis

Figs. 3 and 4 show the patterns of the estimated correlation coefficients based on the cross-correlation analysis with time lags of 0-60 months for blue and striped marlin, respectively. The results clearly show that there are very significant cycle-patterns for TD, SC, AM, T55/15, TG15/TG55 and the time of cycles are general 10-15 months. However, cycle-patterns are relatively obscure for correlations between CPUE and DMI, IOI and SOI. Figs. 5 and 6 show the patterns of correlation coefficients and p-value of significance test based on the results extracted from times-lags of 0-15 months.

We also explore the correlations between temporal-spatial environmental factors (TD, SC, AM, T55/T15 and TG55/TG15) and the results indicate that there are strong correlation between SC and AM (Fig. 7). Therefore, more considerations may be needed when incorporating SC and AM into CPUE standardization model simultaneously. For temporal environmental factors (DMI, IOI and SOI), there is no obvious correlation between factors.

However, SOI is appropriate to be used to explore the relationship between the environmental index and CPUE for the species in the Pacific Ocean. In addition, IOI and DMI can be represented by temperature (T15 or T55) and thermocline depth (TD). Therefore, we suggest that four environmental effects of TD, SC, T55/T15 and TG55/TG15 may be appropriately adopted for CPUE standardization analysis of blue and striped marlins in the Indian Ocean. Furthermore, biological and environmental behaviors should be taken into account for relationship between CPUE and environmental effects. Therefore, the time-lag of each environmental factor for CPUE standardization analyses of blue and striped marlins in the Indian Ocean is suggested as the value listed in Table 1.

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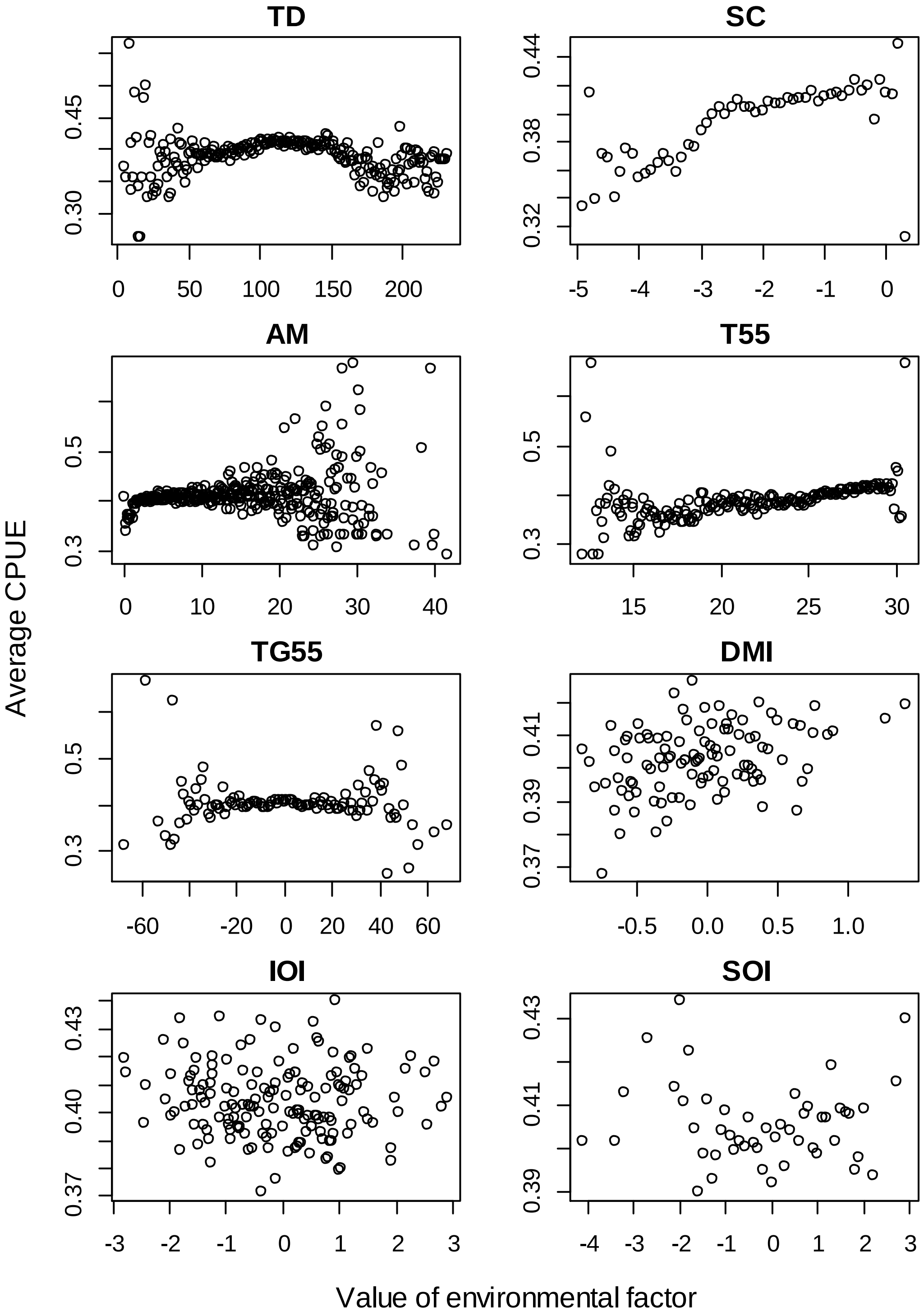

Fig. 1. Relationships between environmental factors and CPUEs of blue marlin caught by Taiwanese longline fleet.

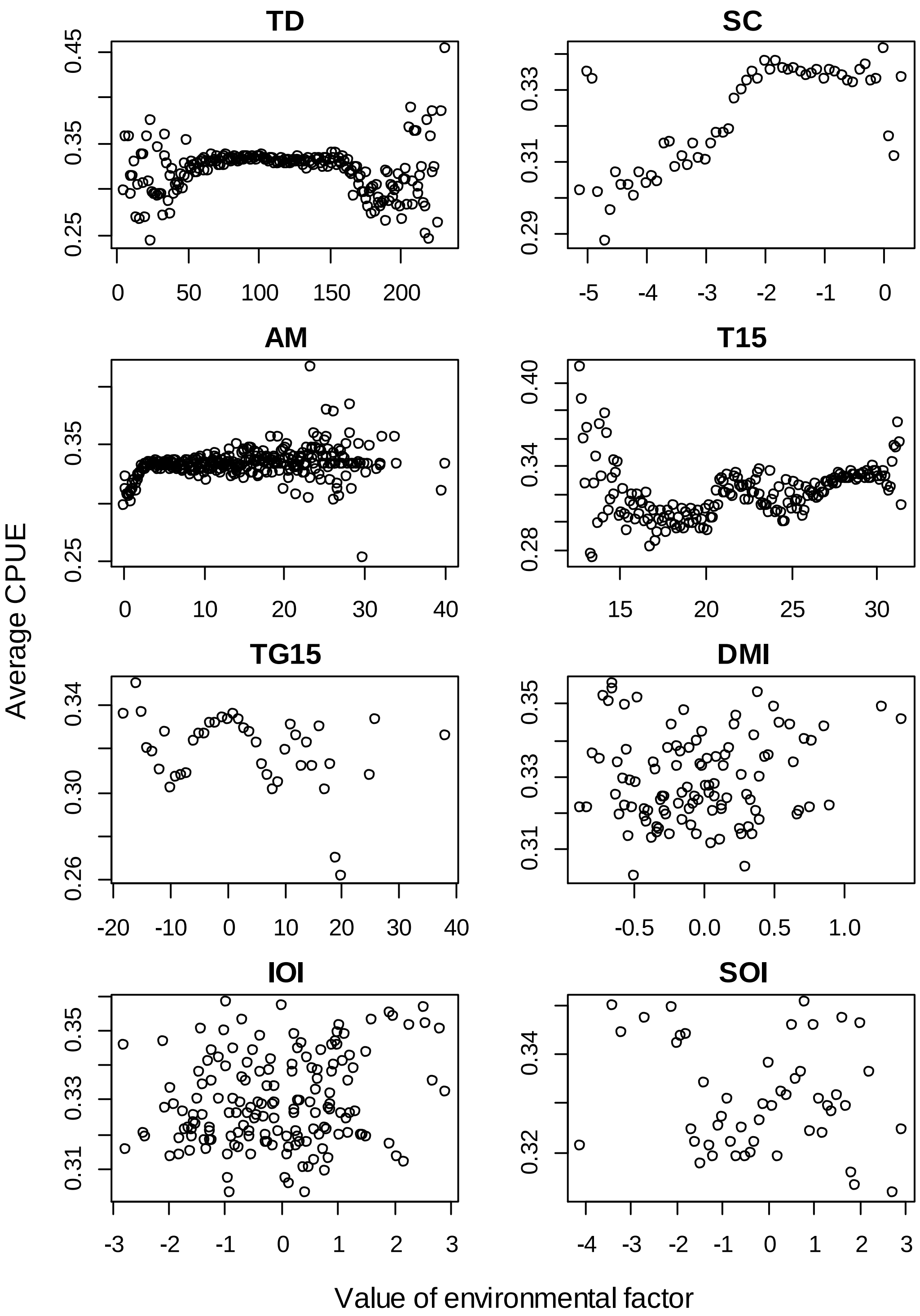

Fig. 2. Relationships between environmental factors and CPUEs of striped marlin caught by Taiwanese longline fleet.

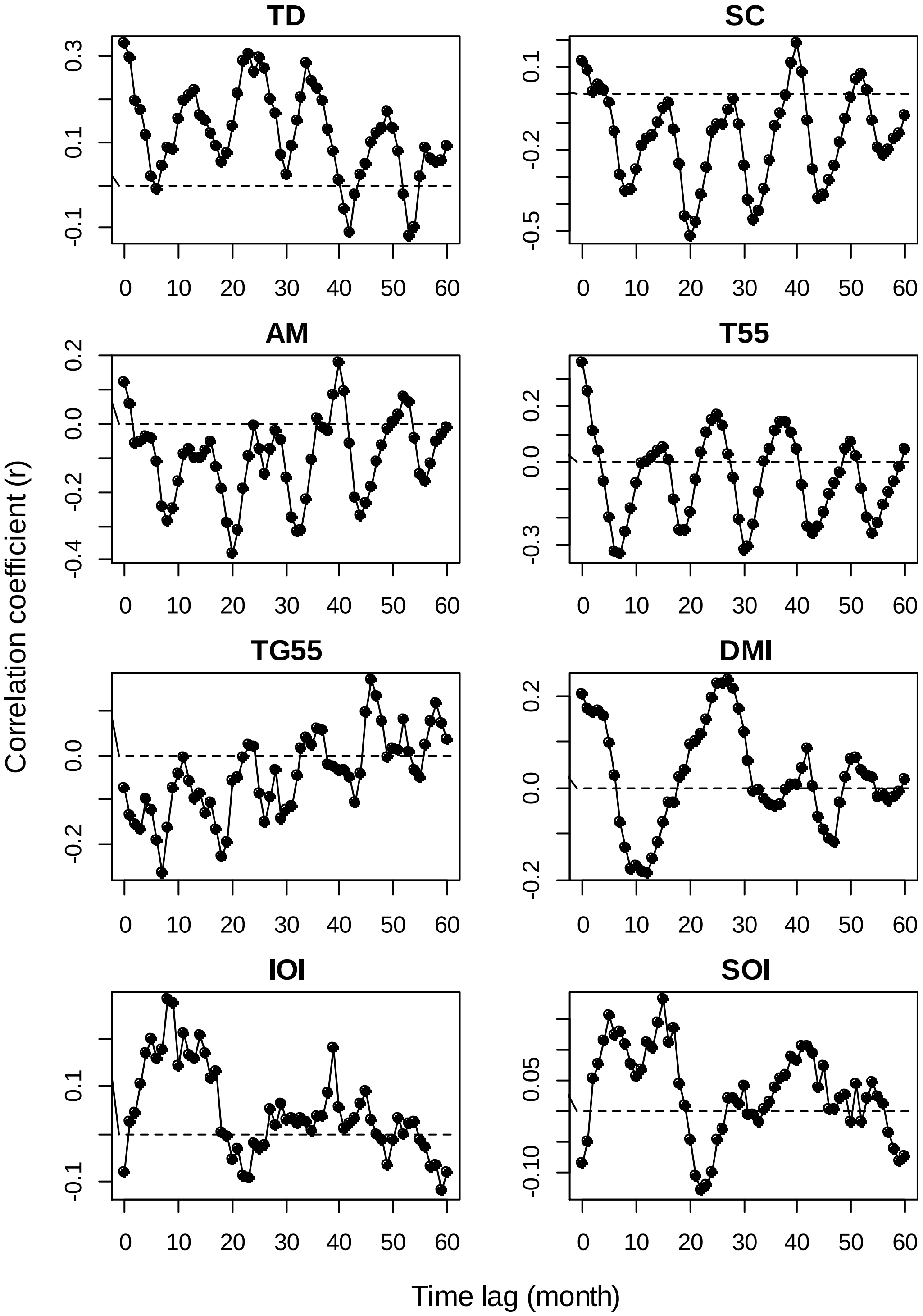

Fig. 3. Correlation coefficients against various time-lags based on time-lag analysis of cross-correlation between environmental factors and CPUE of blue marlin caught by Taiwanese longline fleet.

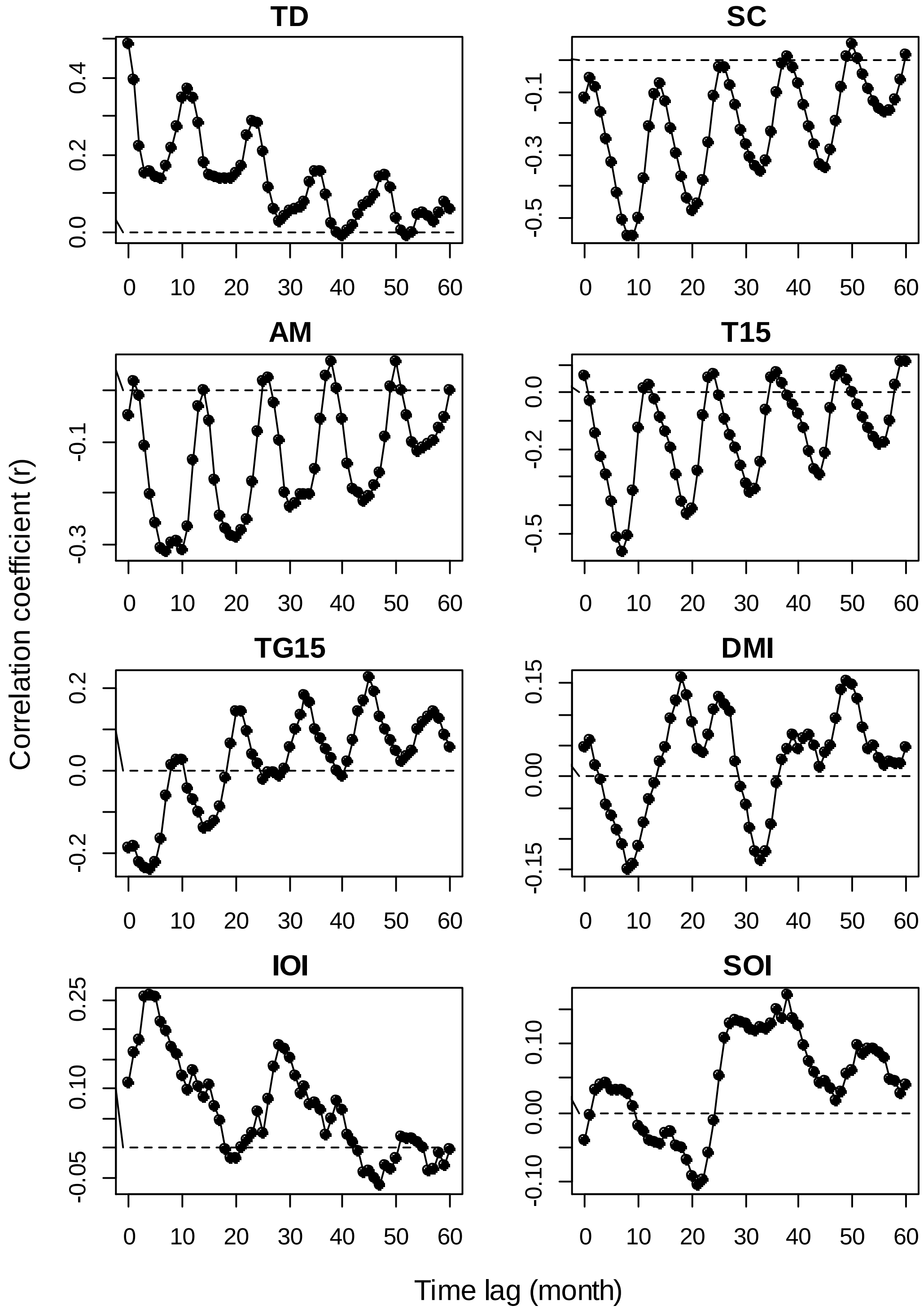

Fig. 4. Correlation coefficients against various time-lags based on time-lag analysis of cross-correlation between environmental factors and CPUE of striped marlin caught by Taiwanese longline fleet.

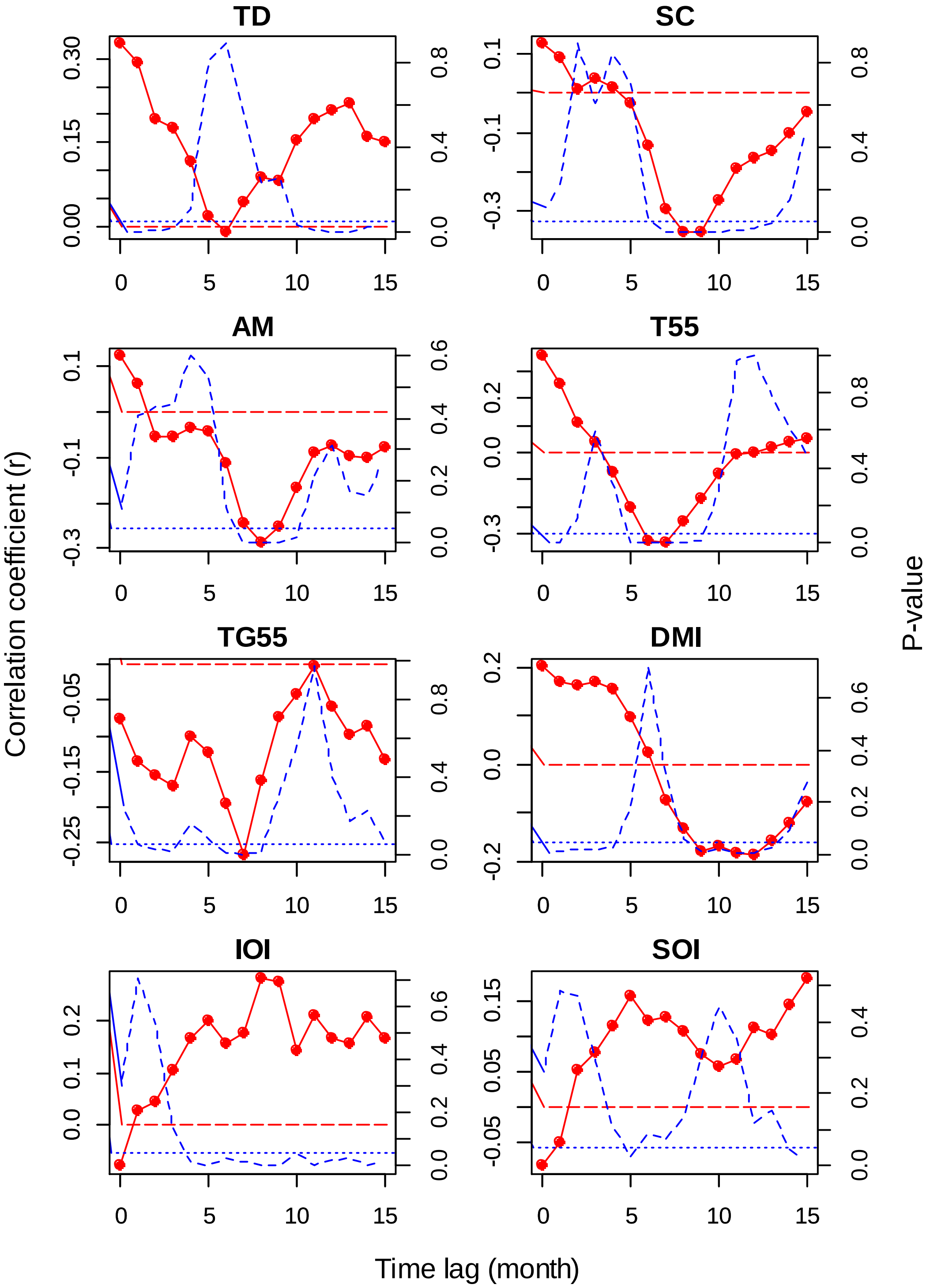

Fig. 5. Correlation coefficients against various time-lags based on the results extracted from the analysis of time-lag cross-correlation with time-lags of 0-15 months between environmental factors and CPUE of blue marlin caught by Taiwanese longline fleet .

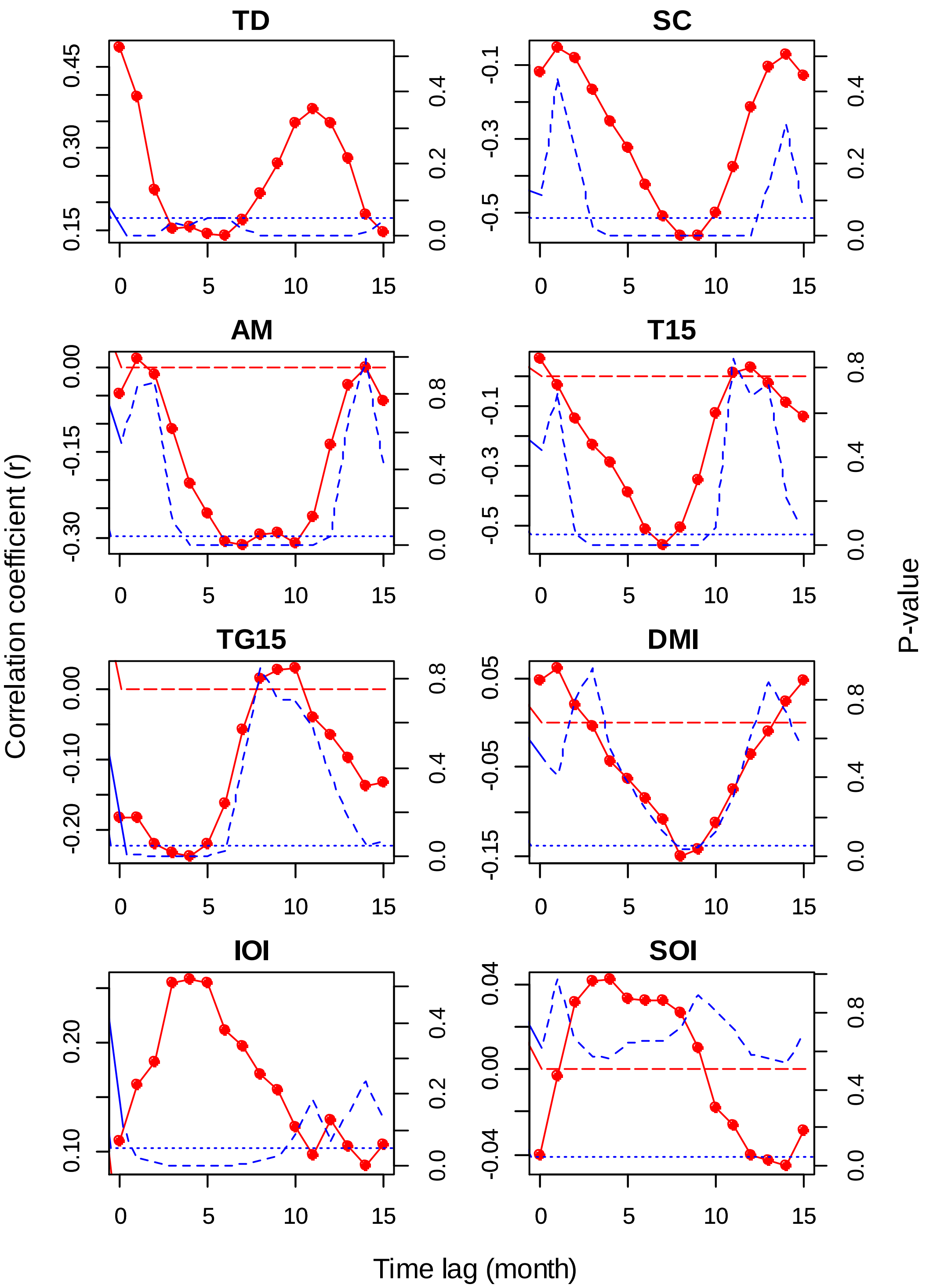

Fig. 6. Correlation coefficients against various time-lags based on the results extracted from the analysis of time-lag cross-correlation with time-lags of 0-15 months between environmental factors and CPUE of striped marlin caught by Taiwanese longline fleet .

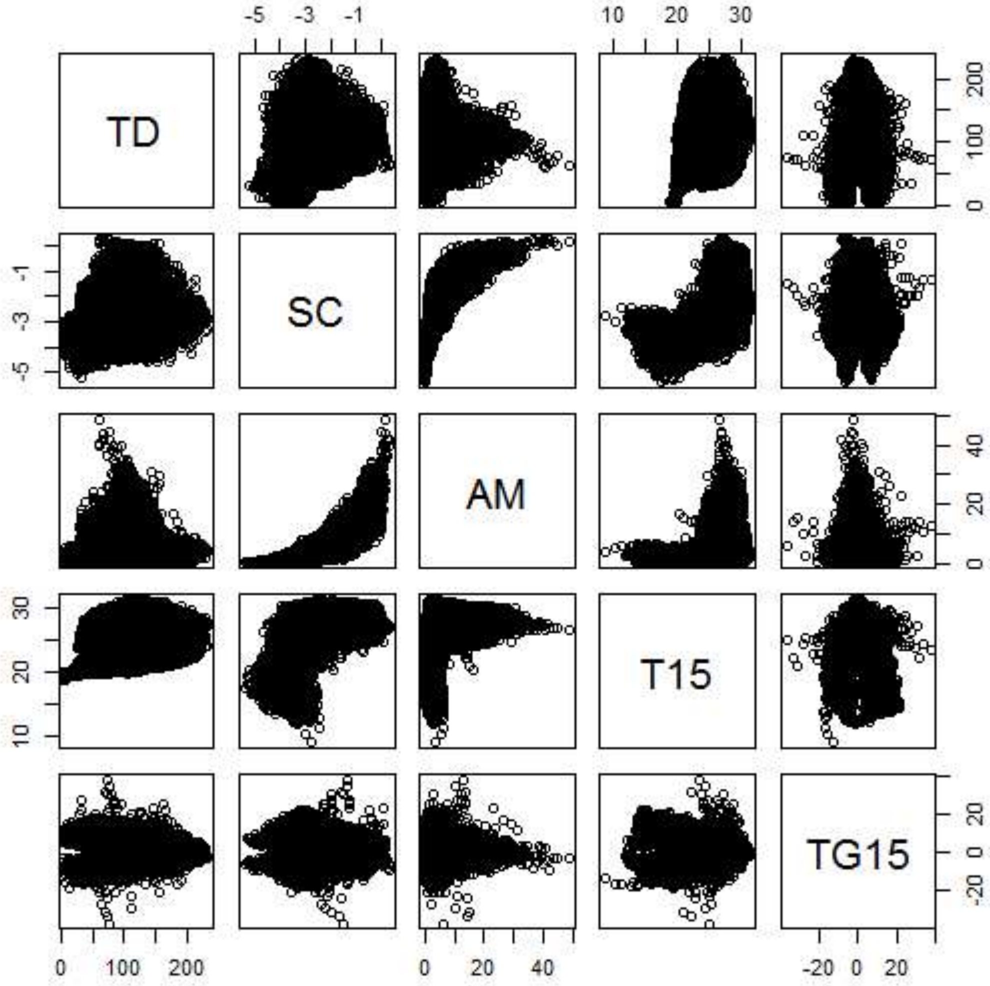

Fig. 7. Pairs plot for the relationship between temporal-spatial environmental factors.

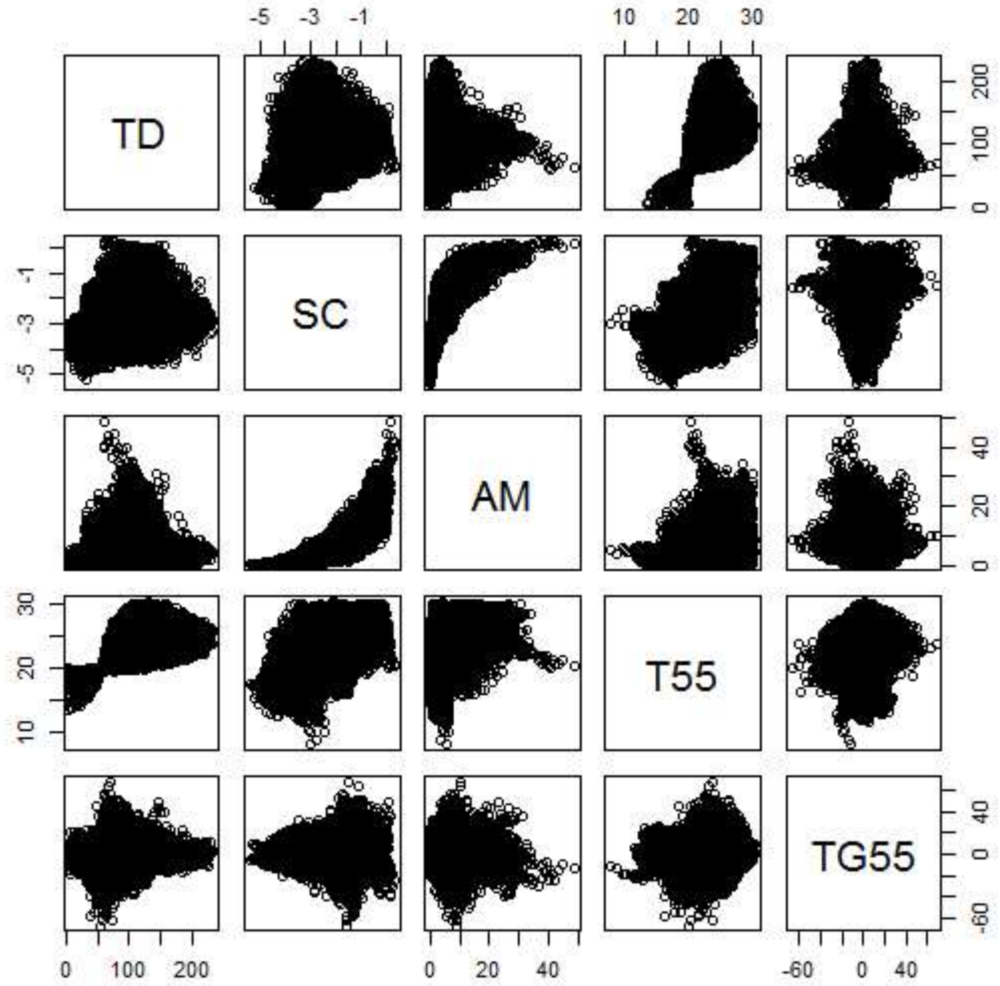

Fig. 7. (continued).

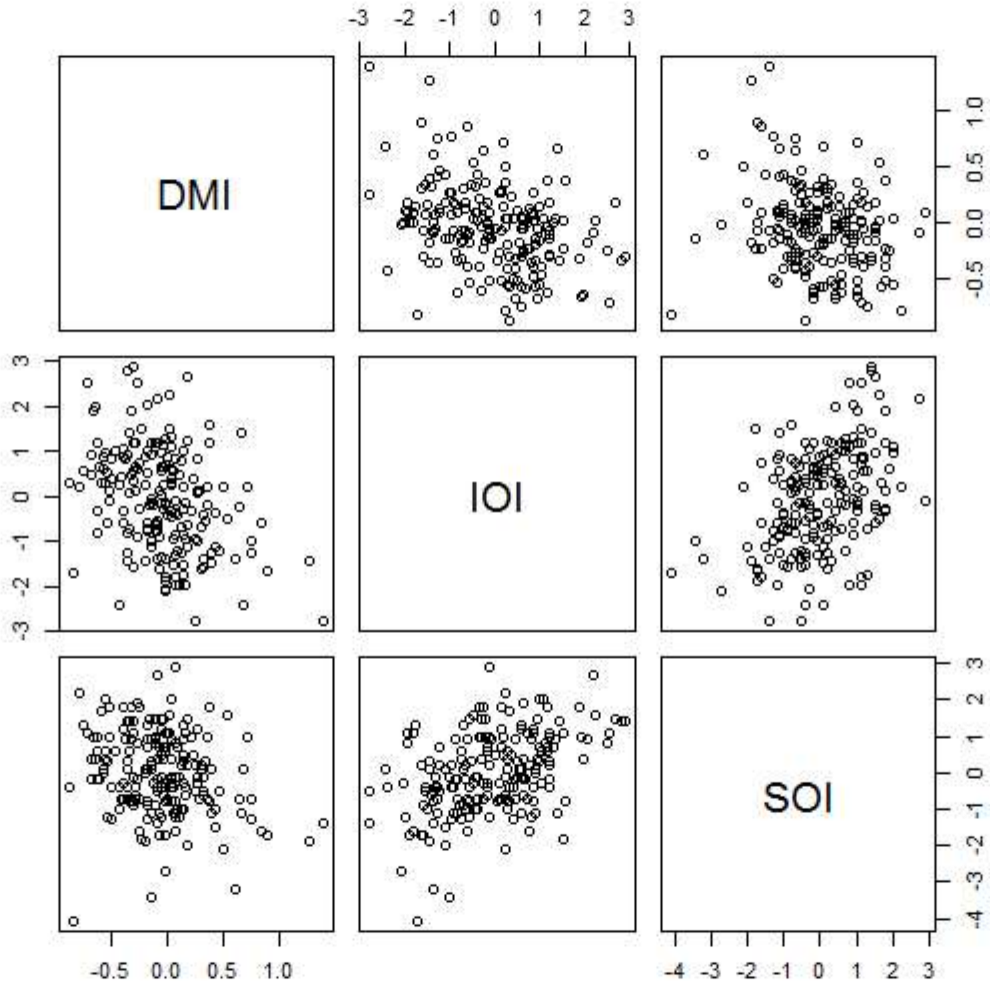

Fig. 8. Pairs plot for the relationship between temporal environmental factors.

Table 1. The time-lag of each environmental factor suggested for CPUE standardization analyses of blue and striped marlins in the Indian Ocean.

	Blue marlin	Striped marlin
TD	0	0
SC	0	4
T55/T15	0	4
TG55/TG15	3	4