CONSIDERATION OF FACTORS AFFECTING NOMINAL HOOKING RATES OF THE INDUSTRIAL TUNA LONGLINE FISHERIES OF YELLOWFIN TUNA (*THUNNUS ALBACARES*) AND BIGEYE TUNA (*THUNNUS OBESUS*) IN THE INDIAN OCEAN

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ABSTRACT

This paper reviews factors used in the GLM analyses for standardizing nominal hooking rates of the industrial tuna longline fisheries of yellowfin tuna (Thunnus albacares) and bigeye tuna (Thunnus obesus) in the Indian Ocean in the papers presented in the past IPTP and IOTC meetings. Based on the reviews, we will suggest recommendation for the future works.

INTRODUCTION

This paper reviews factors used in the GLM analyses for standardizing nominal hooking rates of the industrial tuna longline fisheries of yellowfin tuna (*Thunnus albacares*) and bigeye tuna (*Thunnus obesus*) in the Indian Ocean in the papers presented in the past IPTP and IOTC meetings. Based on the reviews, we will suggest recommendation for the future works.

INFORMATION

In the review works, we referred to papers presented in the following past five IPTP and IOTC meetings:

1. Second WPTT (2000), Victoria, Seychelles
2. First WPTT (1999), Victoria, Seychelles
3. Seventh expert consultation meeting (1998), Victoria, Seychelles
4. Sixth expert consultation meeting (1995), Colombo, Sri Lanka
5. Fifth expert consultation meeting (1993), Victoria, Seychelles

METHODS AND RESULTS

We carefully examined all factors used in the papers presented in the above-mentioned meetings. We checked their statistical significant levels by referring to probabilities values available in the ANOVA tables in each paper. We also checked additional potential and important factors, which had not yet used in the GLM analyses in the past. We classified factors into five categories, i.e., basic factor, factors related fisheries, economics, ecology, environments and regime shifts.

Table 1 summarizes results. Within each category, factors are listed from the order of importance. Factors we consider that we should include in the future GLM analyses are highlighted by screen tones.

DISCUSSION

Based on the Table 1, we will discuss some of key and important factors by category and other relevant issues:

Fisheries related factors

Skill of skippers

According to the tuna industry in Japan (Japan Tuna Federation) and also from the objective views, nominal hooking rates are affected by the skipper's skill, which may be considered to one of the most significant factors. However, quantification of this factor will be difficult because skipper's skill is the privacy (confidential) issue, hence difficult to collect the information.

However, if compositions of levels of skipper's skills in the past are homogeneous, we don't have to worry about this factor because this factor will relate proportionally to the estimated CPUE and will not produce any biases in the GLM analyses. But, if not, we should work on this topic in the future.

Table 1 Summary of the factors used in the past GLM analyses and potentially important factors (+)

- Classification of resultant significant levels of the GLM factors in the past studies and those for potential important factors (+):

(***) Extremely significant (Pr <0.001); (**) Highly significant (0.001<=Pr<0.01); (*) Significant (0.01<= Pr<0.05); (ns):non-significant

- Factors considered being included in the future GLM analyses are highlighted by screen tones.

Type	Factors	Unit	Ranges of significant levels Aggregated data (1x1 area & month)	Aggregated Coarse-scale data (5x5 area & M/Q)
Basic factors	Year	Number of year	(*)-(**)-(***)	(*)-(**)-(***)
	Season	Number of season	(*)-(**)-(***)	(*)-(**)-(***)
	Sub-area	Sub-area name	(*)-(**)-(***)	(*)-(**)-(***)
Fisheries	(+) Skipper's skill *(not yet applied)*	Class of skill (difficult to evaluate)	(???)	Not adoptable
	Number of hooks per basket	Class of hook range	(**)-(***)	(**)-(***)
	Country	Name	(*)-(**)	(*)-(**)
	(+) Materials of line *(not yet applied)*	Name	(???) data not fully available	(???) data not fully available
	Type of baits	Name	(*)-(**)	(ns) -(*)
	Vessel size	Class of vessel size range	(ns)-(*)	(ns) -(*)
Economics	(+) Fish price *(not yet applied)*	Class of price range	Unknown	Unknown
Ecology	(+) Cryptic biomass *(not yet applied)*	?	(???) difficult to employ	(???)
	(+) Vertical movements *(not yet applied)*	?	(???)1/ difficult to employ	
Physical Environment	Lunar phase	Class of lunar phase index	(***) 1/	Not adoptable
	SST	^{o}C (integer or class of SST range)	(*)-(**)-(***) 2^{nd}–4^{th} power of SST	(*)-(**)-(***) 2^{nd}–4^{th} power of SST
	(+) Bathymetry (sea mount, canyon etc)	Class of steepness range of bathymetry	(???) refer to WPT/ 01/____Nishida et al	(???)
	Depth of thermocline	Class of depth range	(???)	(**) 2/
Regime shift (also related to environment)	El Nino/La Nina (SOI)	Class or integers of SOI	(**)-(***) 1^{st}-2^{nd} power of SOI	(**)-(***) 1^{st}-2^{nd} power of SOI
	Westerly wind index	Class or integers of the WWI index	(**)	(**)
	SST	^{o}C (integer or class of SST range)	(*)-(**)-(***) 2^{nd}–4^{th} power of SST	(*)-(**)-(***) 2^{nd}–4^{th} power of SST

Note 1/ *Possible to adopt if the fine scale (operation by operation) data are used..*

2/ *Studied in the western Pacific Ocean.*

3/ *Three factors may be auto -correlated. Thus, one factor need to be used (see text detail discssion)*

??? *We have not used these factors yet, but we consider that they are statistically significant factors.*

Country as a GLM factor

Two papers by Hsu and Chang (1993) and Nishida (1995) used longline data of three countries (Korea, Japan and China (Taiwan)). The trends of the standardized hooking rates were resulted as similar but the levels were different due to the different targeting species by country, i.e., due to heterogeneity of q (catchability) among three countries. Hsu and Chang (1993) demonstrated the heterogeneity by the non-parametric statistical test. Nishida (1995) included 'country' as one of GLM factors, which resulted as the significant level. We need to further investigate if we include all longline data of three countries in the GLM analyses in order to improve accuracy of the estimation.

Ecological factors

Vertical movements

Tuna frequently moves vertically even within one day, which obviously affects the longline fishing catch. Thus, this factor is considered to be also important in the GLM analyses. But, there are no fine-scale spatial and temporal digital data to examine this factor. Average time-space information obtained by the archival tag, pinger tracking experiments or the data loggers of the longliners (SBT500) might be subscribed. This issue needs to be more explored.

Cryptic biomass

This is the hypothesis proposed by Fonteneau (1995). The cryptic biomass is defined as a fraction of stock which is not available to any fishery (because of the gear used or because of its geographical distribution); thus biomass will remain unavailable (or cryptic) as long as it shows no mixing (or very little mixing) with the main stock which is fully available to the fisheries.

Cryptic biomass (if it were true), may be able to explain some of the problem on the longline standardization. One example is explained as follows: Hooking rates of some of tuna species caught by longline tuna fisheries in three Oceans have been stable at the low level in recent years and there are no decreasing signs, although there have been large and strong fishing pressures by both industrial longline and purse seine fisheries. This strange phenomenon may be well explained by the cryptic biomass if it were actually existed.

There have been criticisms that hooking rates of the longliners cannot represent tuna abundance. This might be partially due to the existence of the cryptic biomass. However, at present, there are no concrete ideas on this issue. Therefore, we need to do further research on this topic.

Physical environmental factors

Bathymetry

This factor is not used in any papers in the past. The recent study by Nishida *et al* (WPT/01/___) suggested that fine-scale steep bathymetry strongly affect the hooking rates. Thus we consider that this factor should be incorporated to the GLM analyses. The numerical approach was developed in this study to employ the fine-scale bathymetry slope data to the aggregated fisheries data.

Regime shift related factors

In the past, southern oscillation index (SOI) and westerly wind index (WWI) have been used in the GLM analyses, which were always resulted as highly significant factors (for example, Nishida, 1995). However, these factors were not used in papers presented last three meetings. Thus, inclusions of these environmental factors are essential for the future GLM analyses. However, it is consider that SOI and WWI and also SST are correlated factors. Thus, if we include all three factors, we will face the auto-correlation problem in the GLM analyses, which violates the statistical assumption. Thus, we need to carefully select one meaningful factor from thee factors to represent the regime-shift factor.

Okamoto *et al* (2001) discussed about the sudden jumps of the standardized LL CPUE of BET in the Indian

Ocean. This unrealistic phenomenon is also consistently observed in other tuna species in all three Oceans and also in the other Asian tuna longline GLM analyses. Because it is likely the global event, thus we need considering to include the regime shift related factor in the future GLM analyses.

Other issues

- Data type

In the tropical tuna longline fisheries, the aggregate and coarse–scale data are satisfactory to apply for the standardization of the nominal hooking rates, i.e., the 5x5 based information.

- Year Interaction term

To include the year interaction is the difficult issue. If the fishing patterns are homogenous throughout the analyzing years, this term needs not be included. If not, we need to concern this term in the GLM analyses. In such case, we will face the missing data problem, which may be solved by the random effect in the SAS GLM procedure. There is another option using the regression tree model. We need to work on this issue further.

RECOMMENDATIONS

In the past GLM analyses, some of factors listed in Table 1 had been used, but not all factors were included. As we consider that those with highlighted factors are important, we recommend to conduce the integrated GLM analyses by including as many as meaningful factors as possible based on the careful evaluation (for example, to select one regime related factor). In such way, we might be able to solve various problems discussed in this paper.

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REFERENCES

Refer to WPM/01/___ (Nishida) that lists papers cited in this document. The Title is ‘Review on “CPUE standardization of the industrial longline tuna fisheries” and “Production model analyses” for yellowfin tuna (*Thunnus albacares*) and bigeye tuna (*Thunnus obesus*) resources in the Indian Ocean’.