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Standardization of CPUE for striped marlin (*Tetrapturus audax*) of Japanese longline fishery in the Indian Ocean

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Abstract

In order to address stock assessment for striped marlin (*Tetrapturus audax*) in the Indian Ocean, we calculated standardized catch per unit effort (CPUE) of Japanese longline fishery. We supposed four area definitions (North East, North West, South East and South West) that were considered biological informations. We used operational catch and effort data compiled by National Research Institute of Far Seas Fisheries. For the standardization, we addressed data screening to reduce zero-catch ratio of striped marlin and used simple log-normal model. In Addition, we discussed difficulties to treat zero-catch data for a future work.

Introduction

To understand fish stock status, standardized catch per unit effort (CPUE) is the most important information because CPUE is usually considered fish abundance indexes in the stock assessment model (Maunder 2001). In terms of striped marlin (*Tetrapturus audax*) in the Indian Ocean, Working Party on Billfish in 2015 (WPB13) implemented stock assessment using a Bayesian Surplus Production Model (BSPM) (Sharma and Pierre 2015). In this assessment, BSPM used standardized CPUE derived from Japanese and Taiwanese tuna longline fishery (Nishida and Wang 2013). CPUE of Japanese longline fishery was considered core fishing area because catch distribution of striped marlin is limited (include a lot of zero-catch data), operation area and fishing effort are decreasing. However, Working Party on Billfish in 2015 (WPB13) will attempt integrated stock assessment model as Stock Synthesis 3 (SS3) that assumed four area structures. Hence, we recalculated standardized CPUE of Japanese tuna longline fishery for striped marlin that depends on four areas definition. In addition, we addressed to reduce zero-catch data using data screening and discussed some implication to treat zero-catch data of Japanese longline fishery.

Material and Methods

Fishery data and area definition

We followed an area definition of SS3 (North East, North West, South East and South West) (Fig. 1). These areas were considered by biological information. Mainly, striped marlin has been caught in North West area in the Indian Ocean (Fig. 2). Conversely, Japanese tuna longliners has not caught continuously in South East area (Fig. 2).

In this analysis, we used operational data of Japanese tuna longline fishery compiled by National Research Institute of Far Seas Fisheries. This statistics is composed by year, month, day, area (1° × 1°), fleet name (Japanese and call sign), hooks per basket, number of hooks, catch number of each species, and so on. We used this statistics for 1976-2013 because number of hooks per basket has been listed since 1975 and Japanese fleet name has been listed after 1976.

In the Indian Ocean, striped marlin has been caught by secondary target or bycatch in the 1950s and 60s (Uozumi 1998). After early 1970s, Japanese longliners were targeting bigeye, yellowfin and southern bluefin that fishing effort was expanded spatially (Fig. 3). Furthermore, gear configuration (especially hooks per basket) was changed and zero-catch ratio trajectory corresponds to change of hooks per basket (Fig. 5, Fig. 8 and Fig. 11). In terms of nominal CPUE, high density area accompany with high catch area (Fig. 2, Fig. 4).

Data screening

As described above, there are many zero-catch data in operational statistics of Japanese tuna longline fishery. To reduce these zero-catch data, we attempted four step data screening as follows:

1. Removed some operational data (e.g. over 6,000 hooks operation, under 200 hooks operation and no Japanese fleet name data).
2. Aggregate operational data by year, month, Japanese fleet name, number of hooks per basket and 1° × 1° area.
3. Chose 5° × 5° area blocks where fishing was operated over 30 years.
4. Chose 5° × 5° area blocks where no catch data are lower than 5 years.

Consequently, South East area did not satisfy our screening requirement. Hence, we explored CPUE standardization for North East, North West and South West area (Fig. 6a, Fig. 9a and Fig. 12a). In each analysis area, trajectory of nominal CPUE by 5° × 5° areas show similar trends (Fig. 6b, Fig. 9b and Fig. 12b).

Generalized linier model

We used generalized linear model (GLM) for CPUE standardization of striped marlin by three areas defined above. The GLM includes five main effects (year, quarter, 5° × 5° area and fishing gear). We assumed quarter as the effect of fishing season. We assumed 5° × 5° areas for area effect, which trajectory are not large differences (e.g. time lag trend) (Fig. 6, Fig. 9 and Fig. 12). Number of hooks per basket was assumed for a fishing gear effect. The GLM for standardization of CPUE was,

$$\ln\left(CPUE_{i,j,k,l} + const\right) = X + yr_i + qtr_j + area_k + gear_l + \varepsilon_{i,j,k,l},$$

where $CPUE_{i,j,k,l}$ is the catch in number of the fish per 1,000 hooks in year *i*, fishing quarter *j*, fishing area *k* and fishing gear *l*. *const* is 10% value of overall nominal CPUE, *X* is the intercept, yr_i is the effect of year, qtr_j is the fishing quarter effect, $area_k$ is the fishing area effect, $gear_l$ is fishing gear effects and $\varepsilon_{i,j,k,j}$ is the random error term that was assumed the normal distribution $\varepsilon_{i,j,k,l} \sim N(0, \sigma^2)$. We treated all data sets as categorical data in this GLM. In the model selection, we changed categorized range of hooks per basket and compared each models using AIC and p value. As a result, range of hooks per basket were chose into four or three revels (5-8, 9-13, 14-18 and 19-21 for North East and North West area, 5-7, 8-10 and 11-21 for South West area). Finally, we calculated standardized annual CPUE that was obtained by the least squares means. All standardization analysis results were provided by software of R-3.0.3.

Result and discussion

In the all area, annual trajectory was approximately similar between nominal CPUE and standardized CPUE (Fig. 7a, Fig. 10a, Fig. 13a). In terms of data fitting, residual trend (residual histogram, QQ plots and residual plots) did not show normal distribution pattern in the North East and South West area (Fig. 7b-d, Fig. 13b-d). By contrast in the North West area, residual trend showed normal distribution pattern (Fig. 10b-d).

It is thought that the effect of hooks per basket is the most important factor to standardize CPUE of striped marlin, because trajectory of zero catch ratio accompany with change of hooks per basket (Fig. 5bc, Fig8bc, Fig11bc). This phenomenon is obvious because longline gear configuration change means operational change (shallow-sets to deep-sets). In general, striped marlin distributes sallow water. Hence, we might underestimate Japanese longline CPUE during deep-sets operation period (after middle of 1990s). From these considerations, we attempted alternative analysis using zero-inflated negative binomial model (ZINB). However, ZINB did not convergence. The reason is thought that there is a lack of deep-sets information during shallow-sets operation period. Furthermore, it is thought that catchabilty of shallow-sets are higher than deep-sets. To address these difficulties, we suggest that fishery definition would divide between shallow-sets period and deep-sets period. This methodology was accepted in North Pacific albacore stock assessment (Ijima et al).

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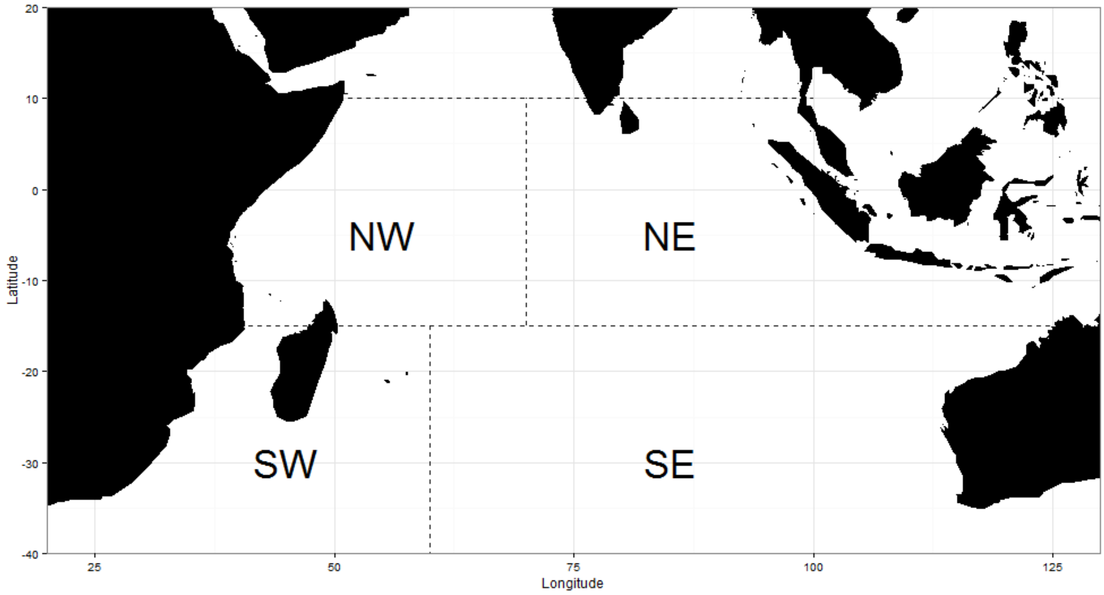

Fig. 1 Spatial structure of Stock Synthesis 3 for striped marlin in the Indian Ocean.

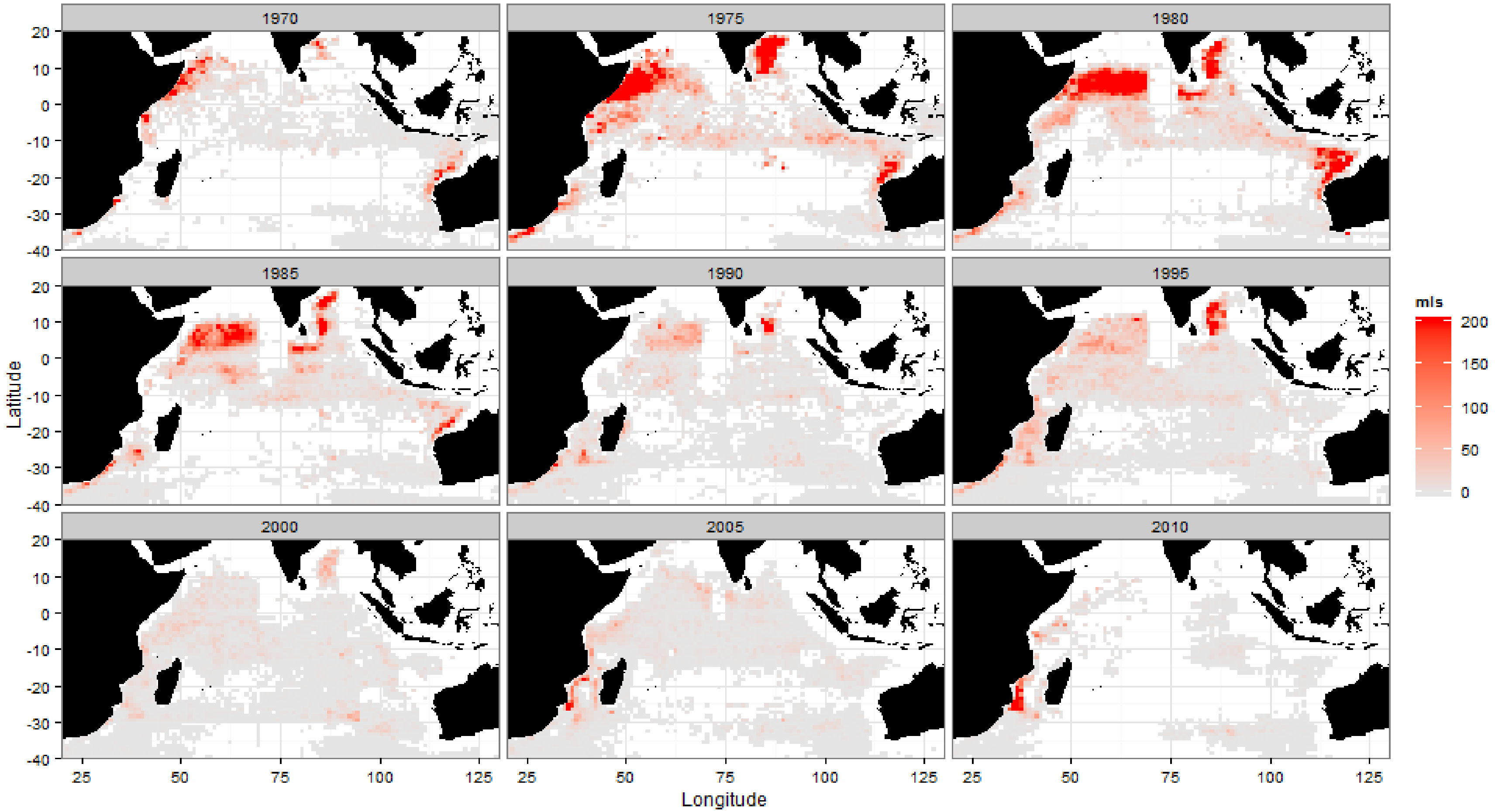

Fig. 2 Time spatial distribution of catch for striped marlin by 5 years.

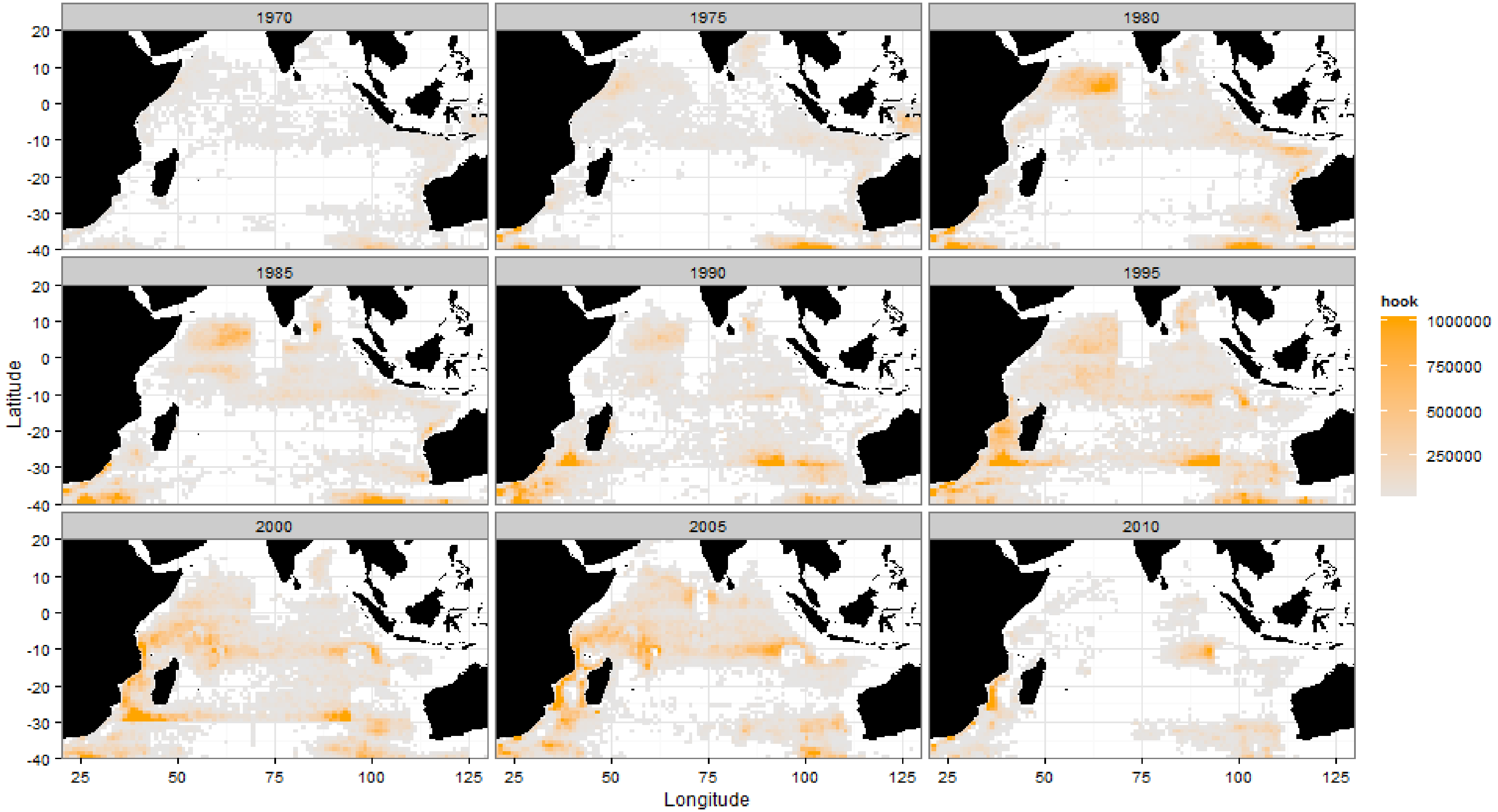

Fig. 3 Time spatial distribution of fishing effort for striped marlin by 5 years.

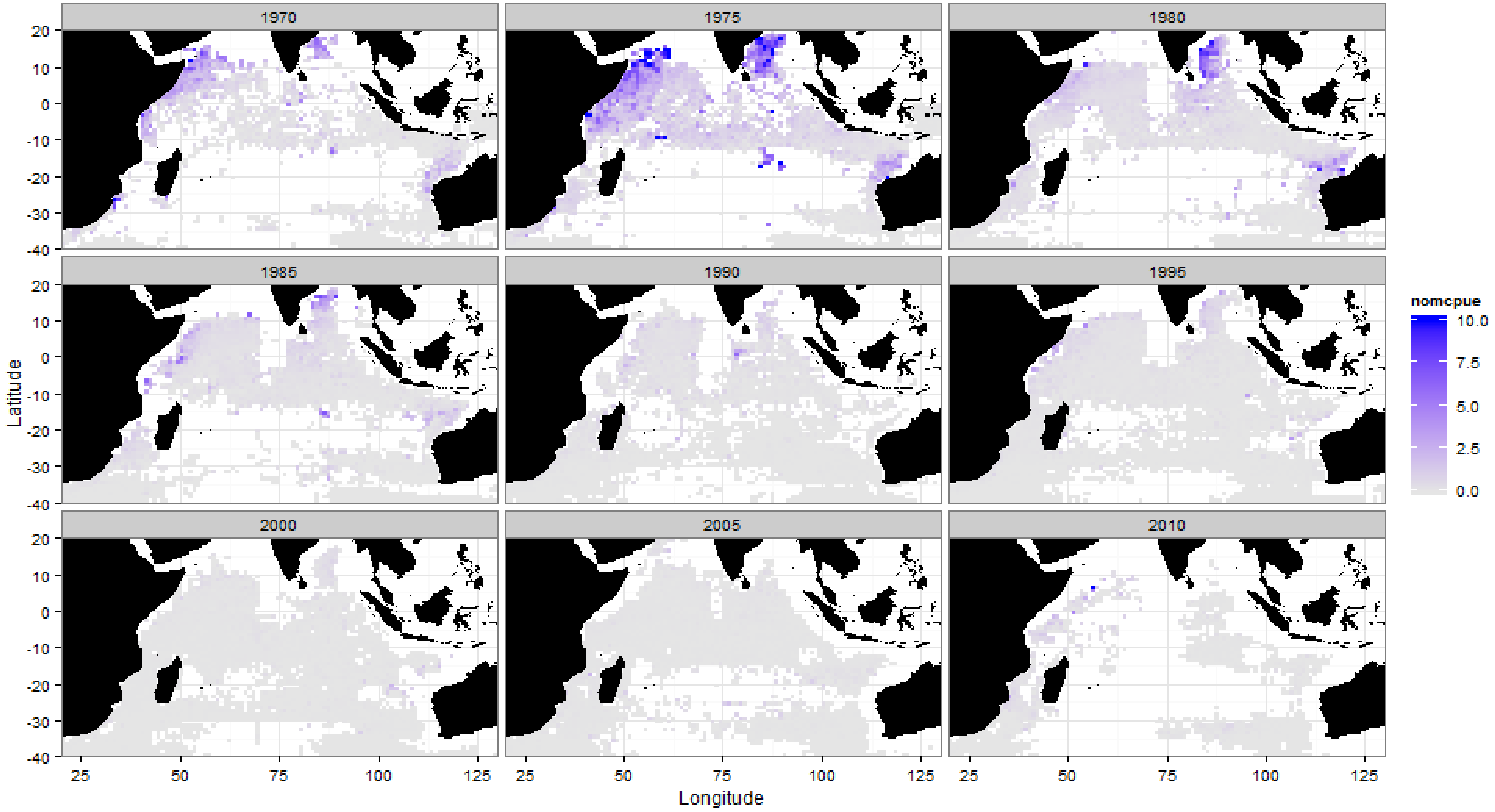

Fig. 4 Time spatial distribution of CPUE for striped marlin by 5 years.

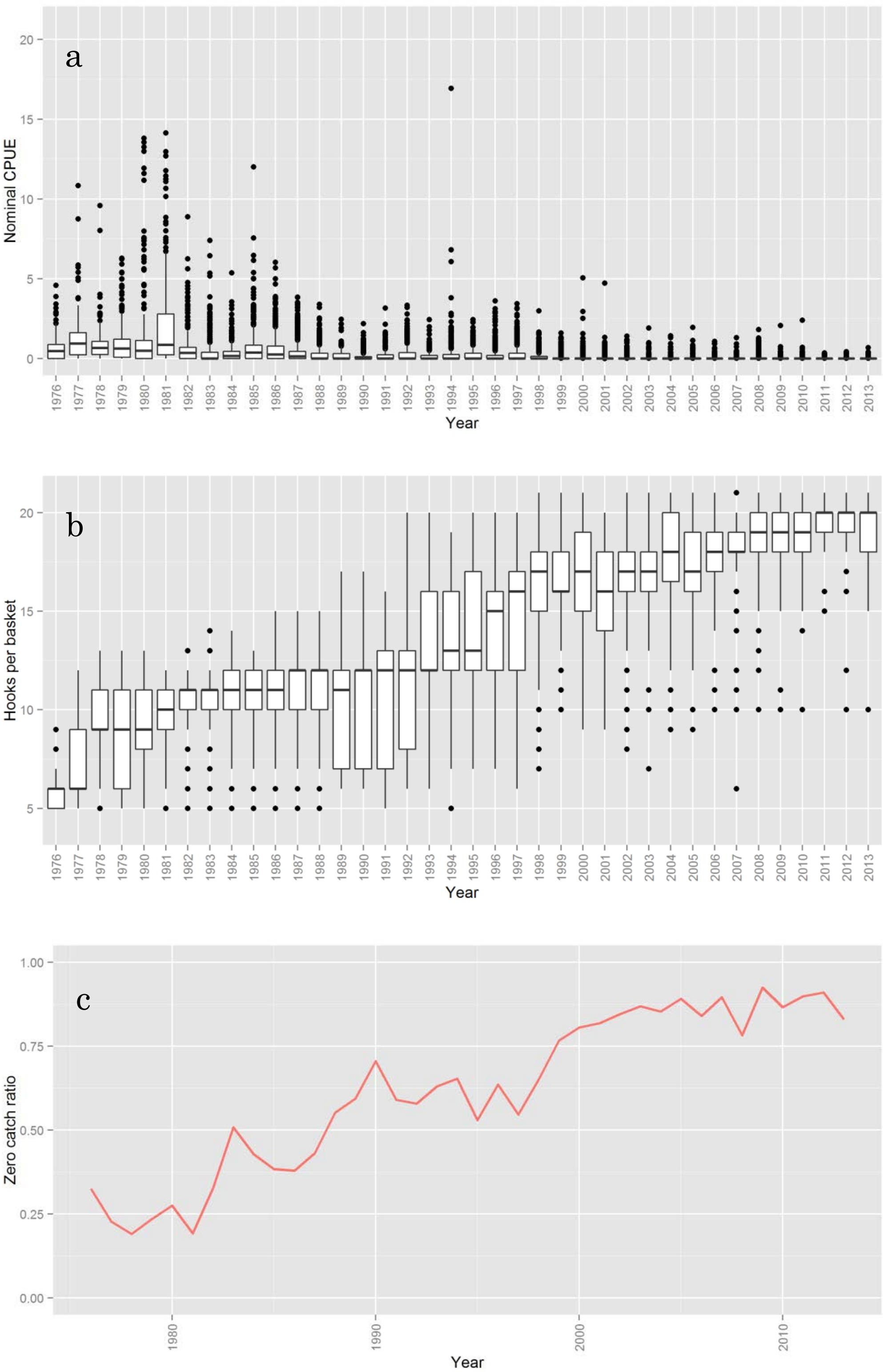

Fig. 5 Japanese longline fishery data using CPUE standardization in North East area. a: annual nominal CPUE. b: historical change of hooks per basket. c: annual zero catch ratio.

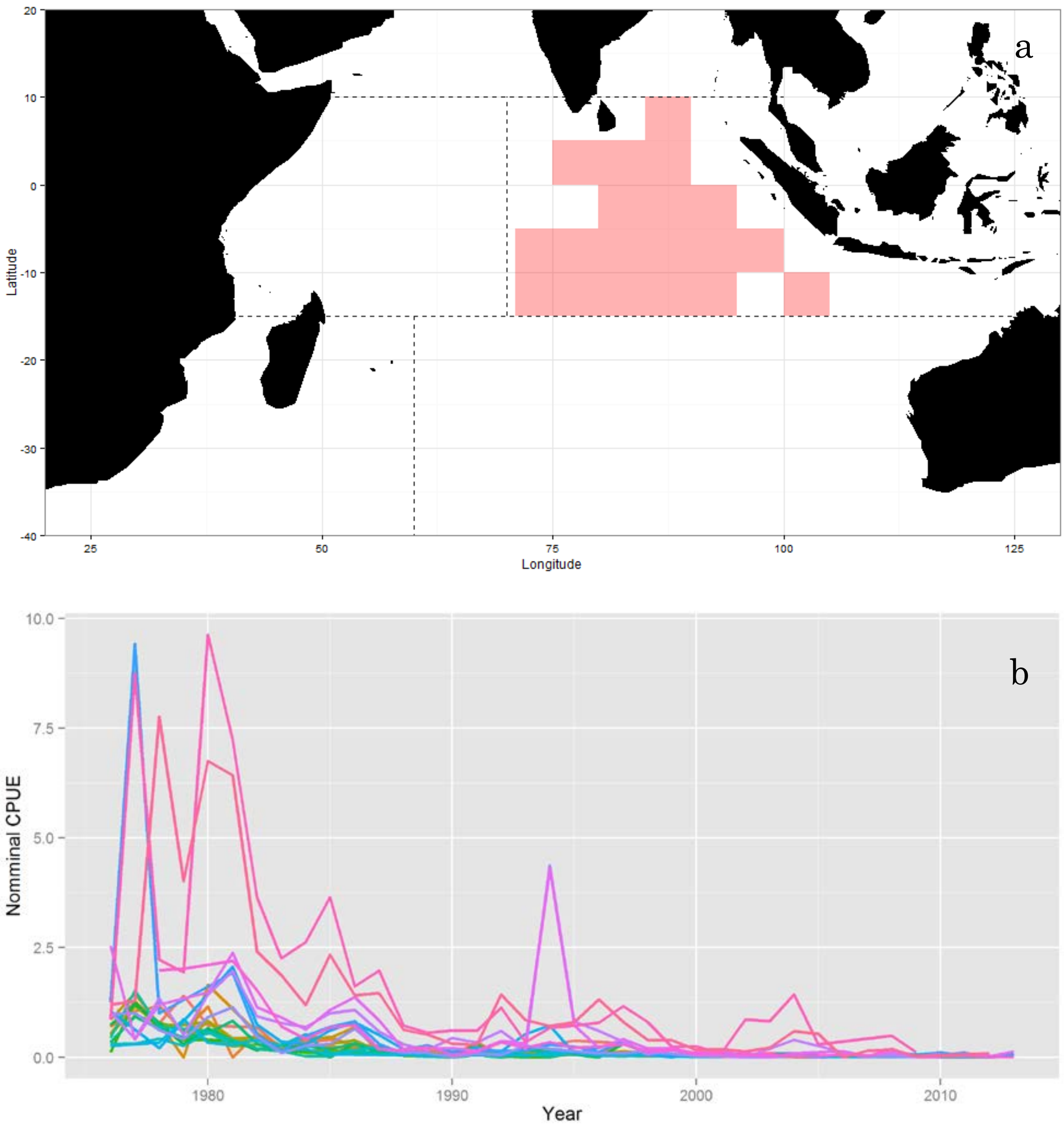

Fig. 6 Analysis 5 x 5 area in North West area. a: analysis area by 5 x 5 degree. b: nominal CPUE by 5 x 5 area.

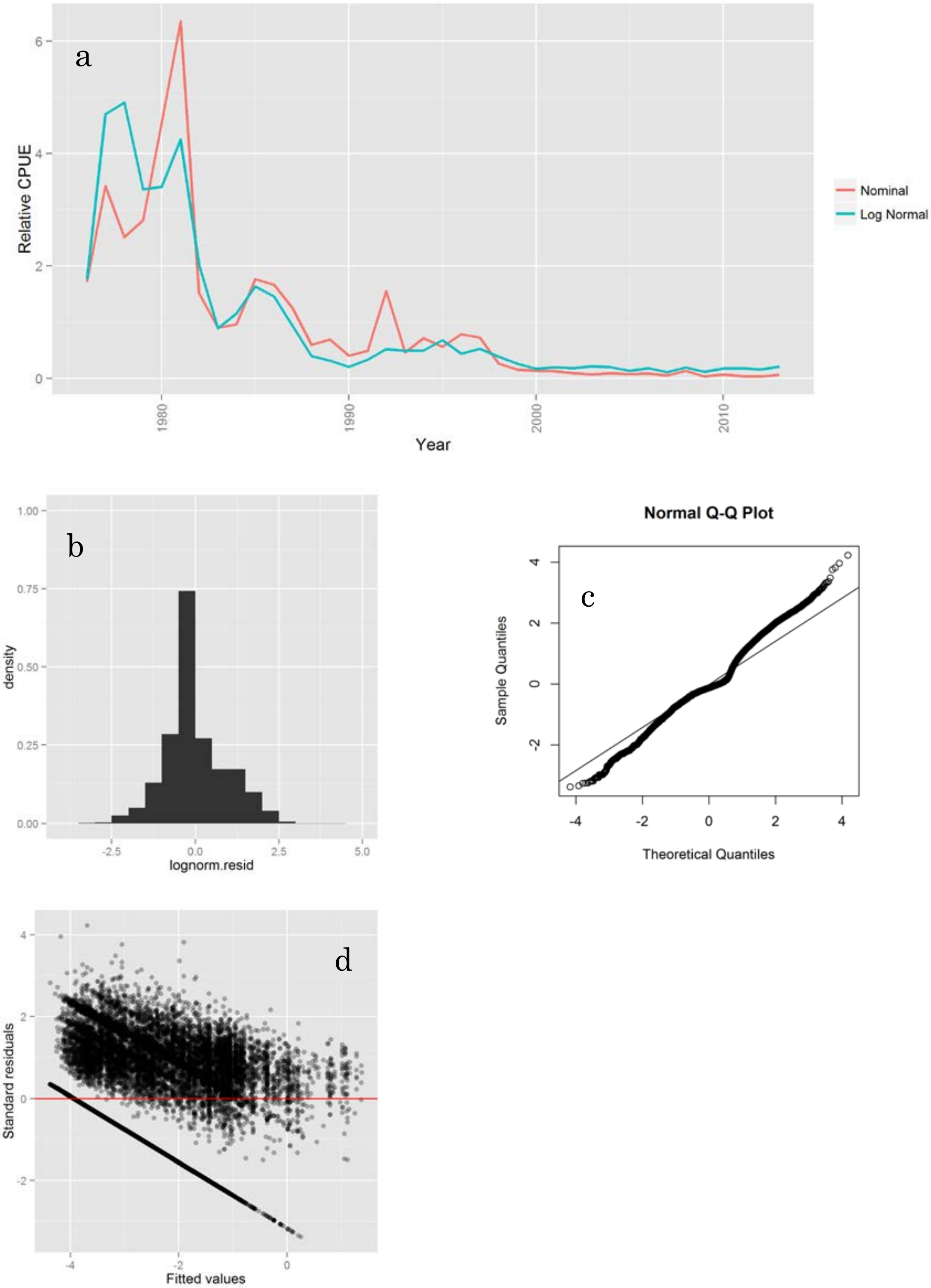

Fig. 7 Result of CPUE standardization in North West area. a: Comparison of standardized CPUE and nominal CPUE (relative scaled). b: Residual distribution. c: Q-Q plot. d: Residual plots.

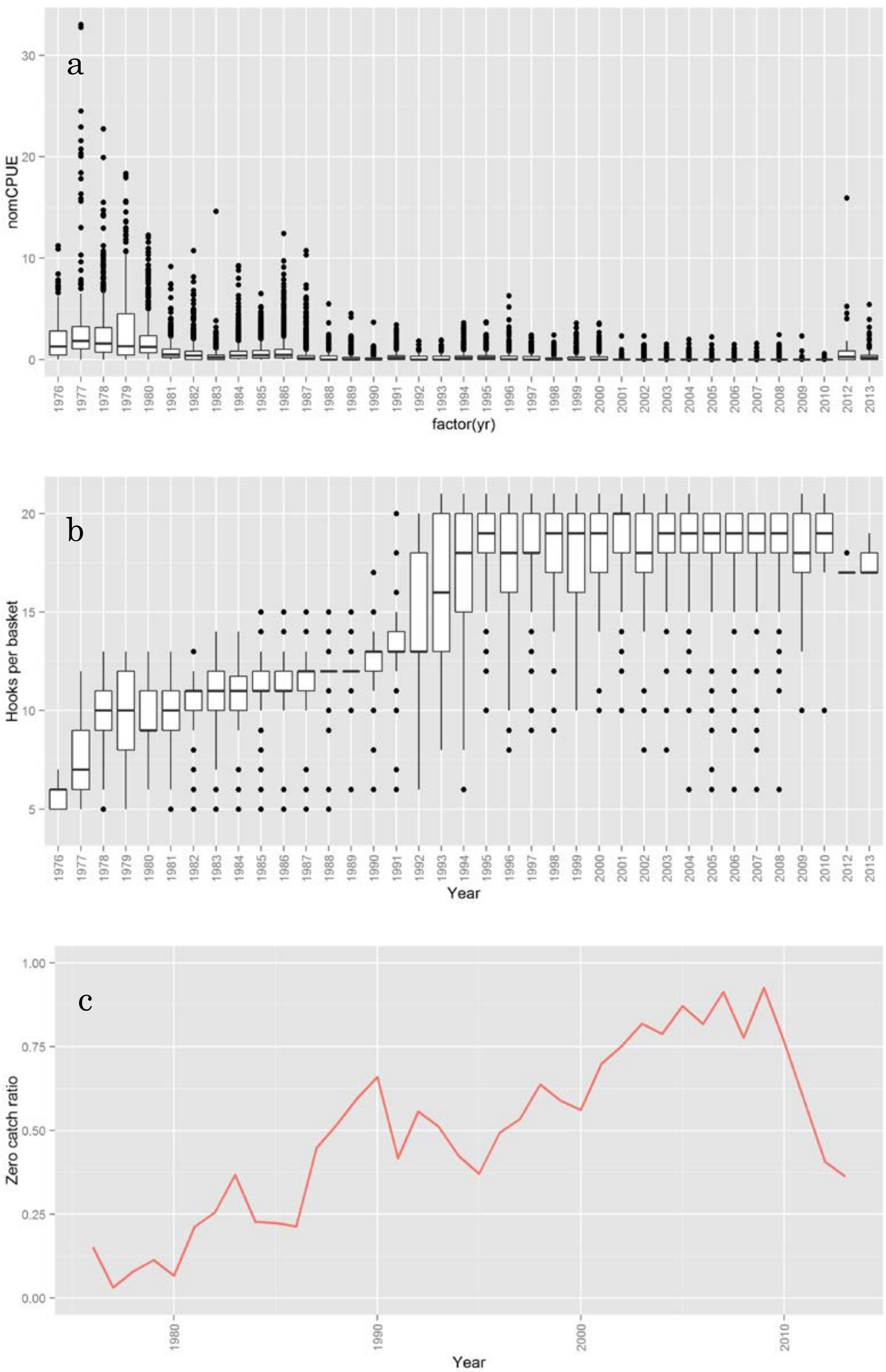

Fig. 8 Japanese longline fishery data using CPUE standardization in North West area. a: annual nominal CPUE. b: historical change of hooks per basket. c: annual zero catch ratio.

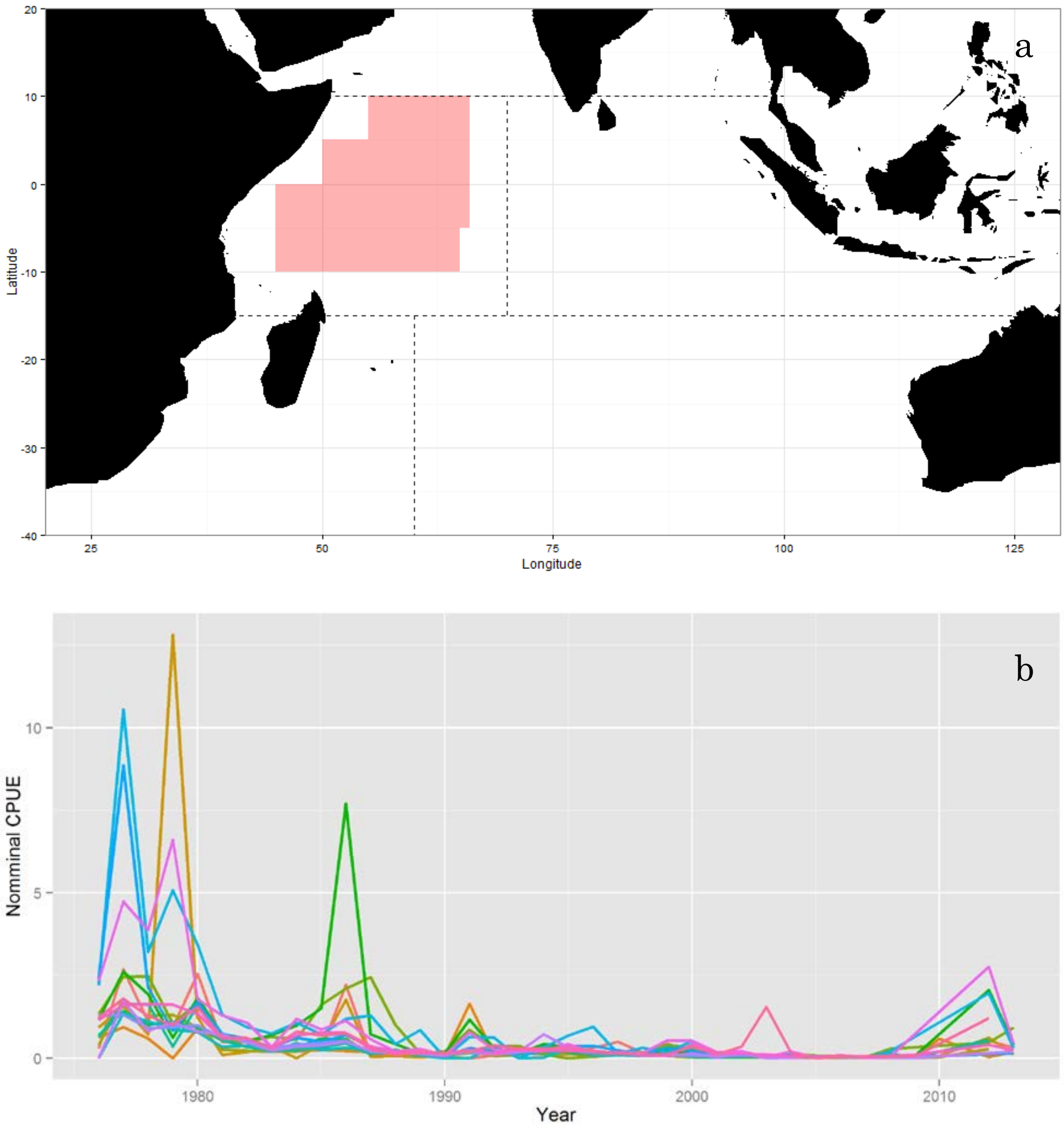

Fig. 9 Analysis 5 x 5 area in North East area. a: analysis area by 5 x 5 degree. b: nominal CPUE by 5 x 5 area.

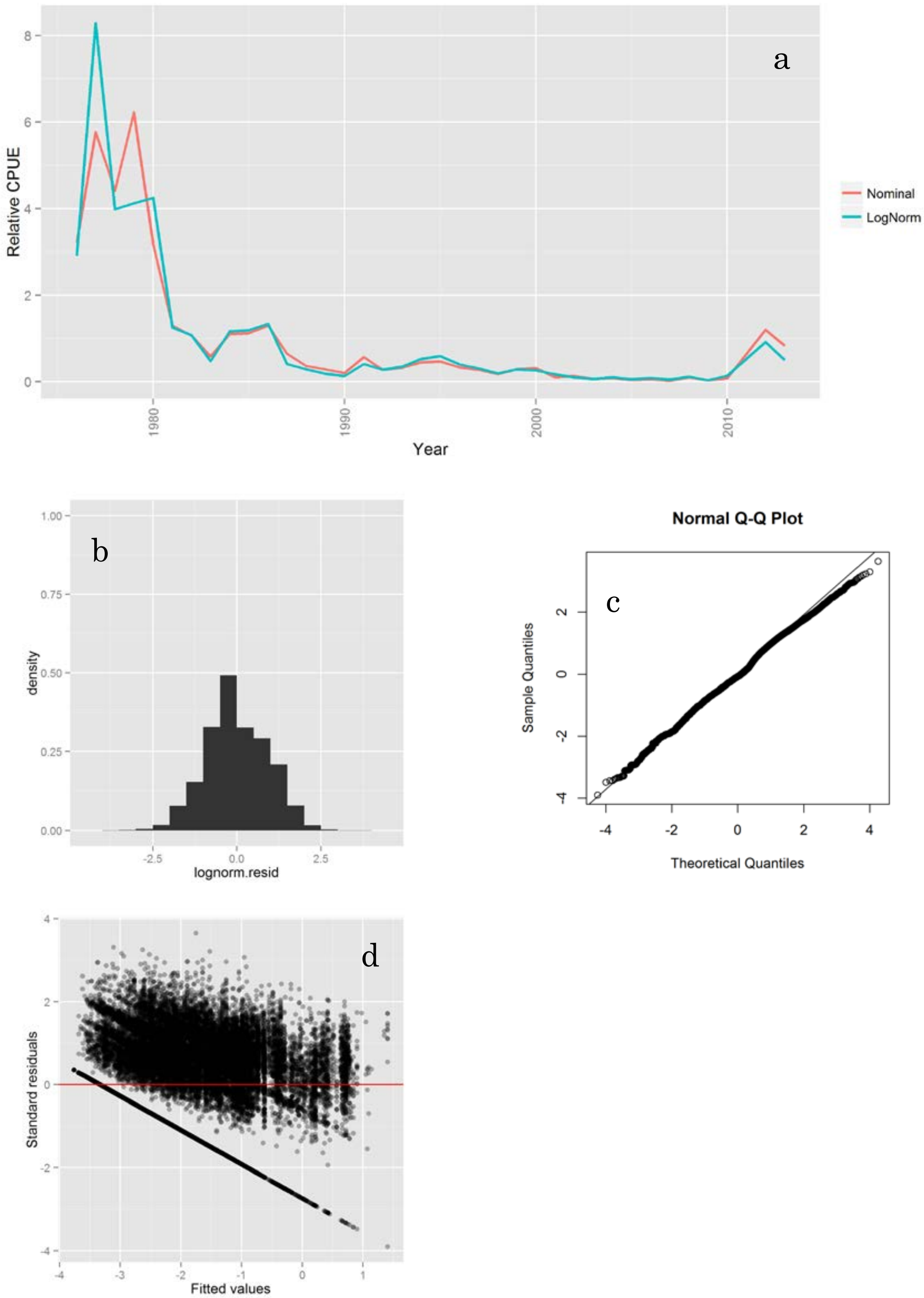

Fig.10 Result of CPUE standardization in North East area. a: Comparison of standardized CPUE and nominal CPUE (relative scaled). b: Residual distribution. c: Q-Q plot. d: Residual plots.

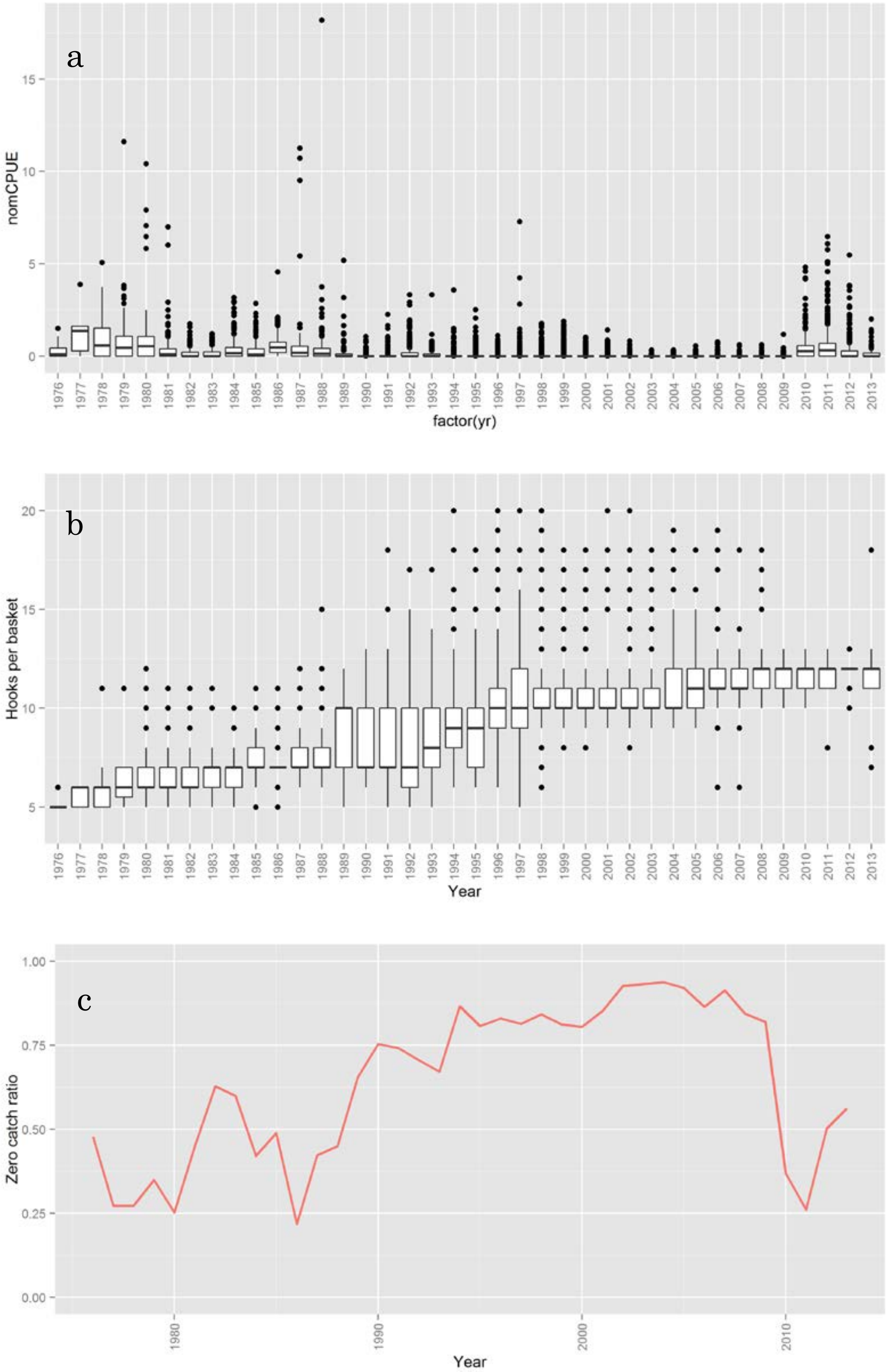

Fig. 11 Japanese longline fishery data using CPUE standardization in South East area. a: annual nominal CPUE. b: historical change of hooks per basket. c: annual zero catch ratio.

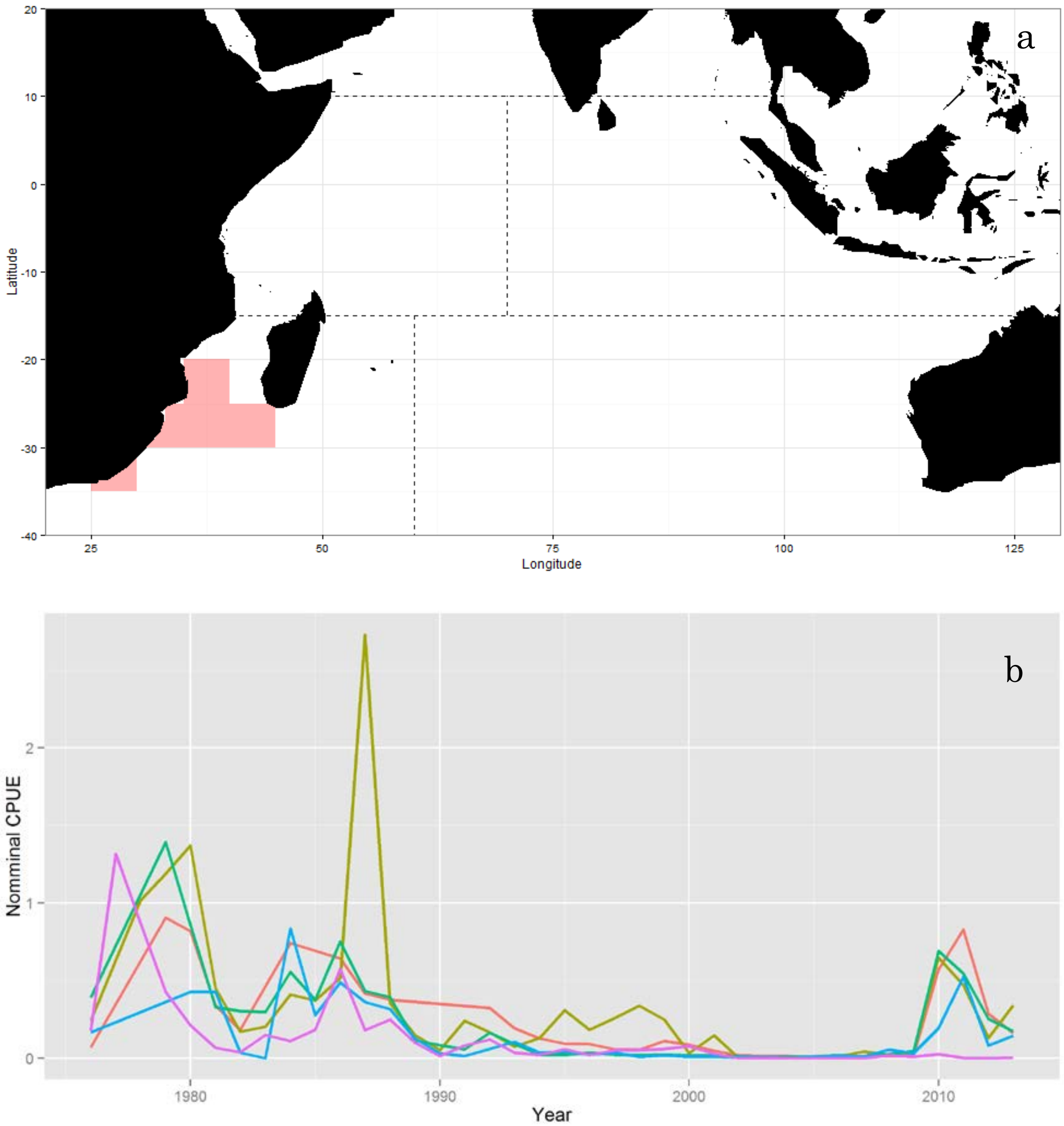

Fig. 12 Analysis 5 x 5 area in South East area. a: analysis area by 5 x 5 degree. b: nominal CPUE by 5 x 5 area.

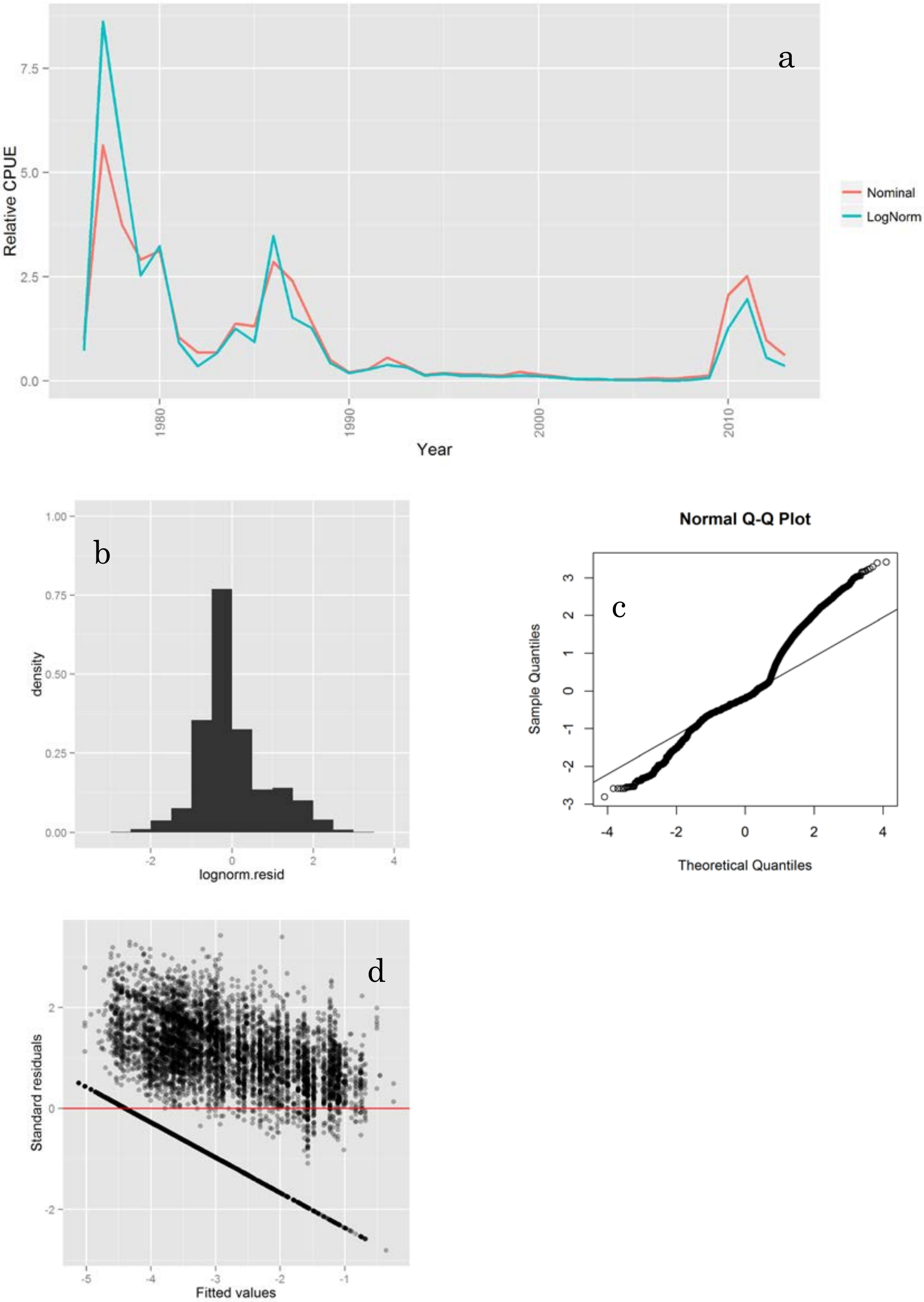

Fig. 13 Result of CPUE standardization in South East area. a: Comparison of standardized CPUE and nominal CPUE (relative scaled). b: Residual distribution. c: Q-Q plot. d: Residual plots.