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Reconstruction of Maldives Historic Fleet Size Composition from Partial Register Data 1970-2004

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Abstract

Maldives pole and line fleet's vessel length composition was reconstructed for 1970-2007 in order to standardize non-vessel-specific CPUE from this period. The Indian Ocean skipjack stock assessment has been using Maldivian pole and line CPUE data to derive a skipjack abundance index, with vessel length used as an important covariate in the standardization. Unfortunately information on fleet size composition is missing before 2004. To develop an abundance index covering the period 1970-2003 will require an estimate of the size composition of the vessels during this period. “Survival” of vessels was estimated from the 2004-2015 effort data using a simple survival analysis regression based on the Weibull probability density. The model was fitted to vessel-specific data 2004-2015 to estimate how long vessels remained active as they age. Two models were explored with survival dependent or not dependent on vessel length. The survival model was used with year of registration to estimate fleet length composition at each quarter 1970-2007.

Introduction

Vessel size is a strong determinant of catching power of Maldives tuna pole and line vessels (Sharma *et al.* 2014), and analyses to standardise CPUE have relied on information on vessel size (Medley *et al.* 2017), which are missing from historical data (earlier than 2004). In order to standardise and use historical CPUE as abundance indices, fleet size composition will need to be estimated. Until 2004, neither vessel length nor catch and effort by vessel was recorded for the fleet, but catch and effort data were aggregated by month, administrative atoll and vessel type (mechanized or non-mechanized pole-and-line vessels).

The Indian Ocean skipjack tuna (*Katsuwonus pelamis*) fishery is one of the largest tuna fisheries in the world, with total catches of 400-600 thousand tonnes over the past decade. Of the three model-based stock assessments of Indian Ocean skipjack, the Maldives PL standardized CPUE data was used. The data set is one of the only reliable sources of information for abundance of skipjack and hence further analyses of the data that contribute to this index is being conducted with the aim of reconstructing a longer historic series. The IOTC Working Party on Tropical Tunas (WPTT19, 2012) recognized that it was worth further

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effort to extend the CPUE series of the Maldivian Pole and Line (PL) fishery, and this document describes one of the activities contributing to this.

A reconstruction of an abundance index based on CPUE to 1970 would depend on accounting for any changes in fishing power. When nominal effort is defined as a boat day (all fishing vessels assumed to be equally efficient), there appears to be a generally increasing trend in the PL CPUE since the 1970s, with a possible decline in the most recent years. How much of the change in CPUE can be attributed to change in fishing power is not clear, but at least some of the change in catch rates could be linked to changes in vessel length.

Sharma *et al.* (2014) made a first attempt by estimating how vessel size might have changed over time based on extrapolating the trend in average vessel size 2004-2012 back to 1985. This assumed the rate of change began in 1985 and remained constant to 2012. However, because it was based on extrapolation and was untestable, this was not felt to be a reliable estimate and an alternative approach was considered necessary that made better use of the available data.

Methods

Data

Indirect information on fleet composition is recorded in the vessel registry which indicates the year of first registration for vessels. The Ministry of Transport and Communication maintains the national registry of vessels, including registered fishing vessels, that records key features of vessels relevant to measuring their fishing power including date of registration, length, breadth, depth, gross tonnage and horsepower of newly registered vessels in each year. The register does not include a scrapping date or maintain a time series of information, so whether vessels are still operational is not apparent from the register data alone. Fishing vessels in the register are recorded for the period 1958-2010, and generally includes most of the vessels in the catch-and-effort database. The register was likely created after 1958.

Registration information is not necessarily kept up-to-date, and there is no time series of vessel characteristics. However, it is very unlikely that vessel length will have changed since first registration, although in very rare cases during major refurbishments keels have been extended to increase the vessel size while carrying the same registration number.

From January 2004, individual vessel trip landings are recorded, so vessels in the register can be linked to catch-effort records after this date. Any vessel registered before 2004, but with a catch-effort record since 2004, could be considered as surviving and being active during the interim period. A fishing vessel registered before 2004, but with no catch-effort record would have retired from the fishery at some point in the interim period.

Plotting the estimated density of vessel length for vessels registered in 5-12 year periods reveals a significant change in length compositions for new vessels entering the fleet (Figure 1), with a shift to larger vessels over time, lengths becoming increasingly skewed as larger vessels enter the fishery. This pattern might be expected if vessels retire within 5 years of registration. However, in the past the retirement age of vessel would have been much longer (perhaps more than 10 years[3]). At the other extreme, if vessels never retired but accumulated, the resulting size composition would be more evenly spread (Figure 2). Reality should lie somewhere between these two extremes, and it would seem reasonable to allow for a scrapping rate that takes account of the likely survival of vessels over time.

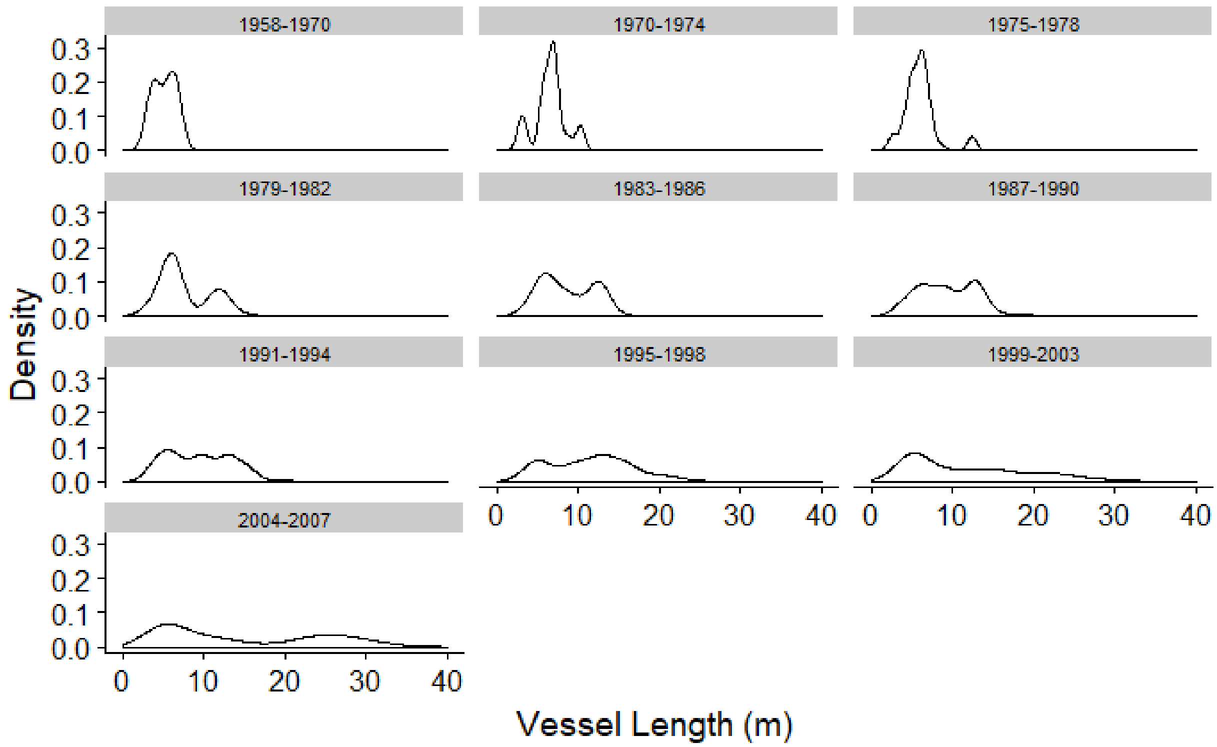

Figure 1 Vessel size composition for their period of registration as a smoothed density.

[3] Vessels prior to around 2000 were built from wood and vessel from 1980 were all from coconut timber which is quite durable lasting around 10-15 years.

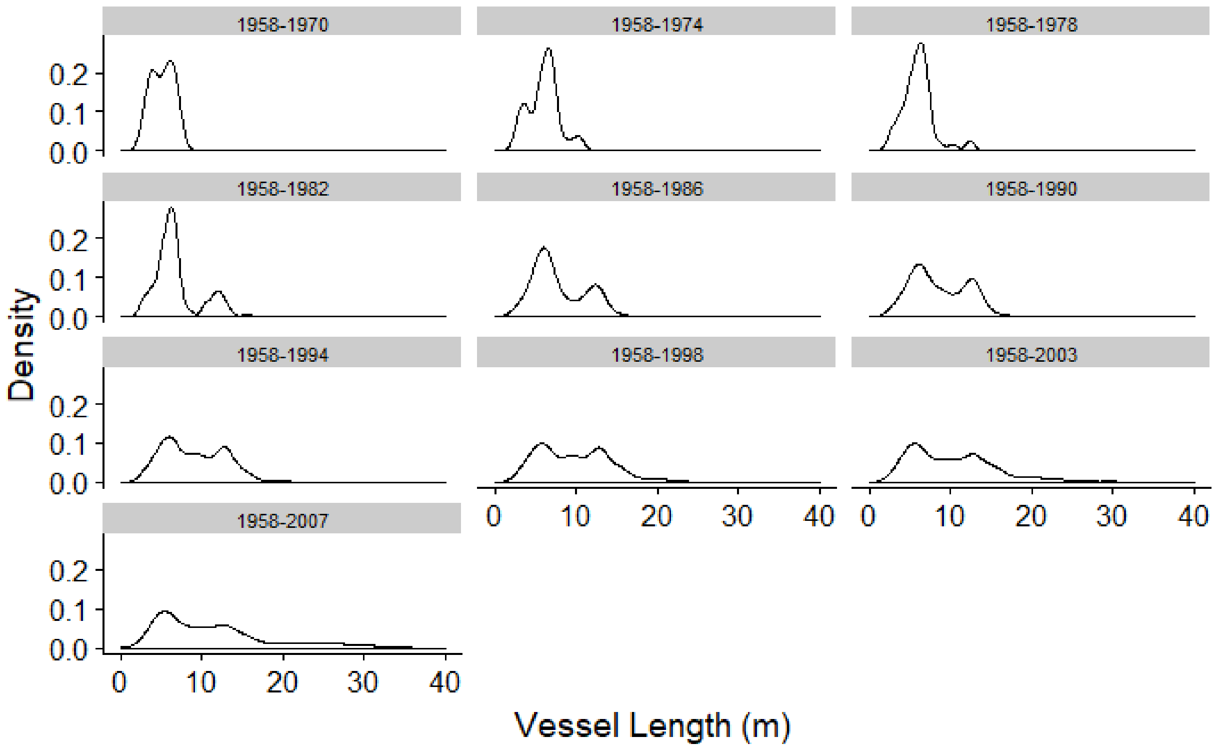

Figure 2 Cumulative vessel size composition for their period of registration as a smoothed density.

Statistical Analysis

"Survival" of vessels can be estimated using effort data 2004-2015 joined to the vessel register. Vessels in the register but not in the trip data were removed as there was no information on the point of their retirement, and the last date of activity was recorded for each remaining vessel. Vessels still active in 2015 are considered to have survived throughout this time period. There were 1467 observations on vessels that were suitable for fitting a survival regression model.

The Weibull probability density function is often used as a simple description of "time to failure". It allows the failure rate to change through time, which seems appropriate in case. In particular we might expect the failure rate to increase as vessels get older. The Weibull distribution should be able to capture this effect, at least approximately. The Weibull distribution depends upon shape (a) and scale (b) parameters:

$$f(x; a, b) = \frac{a}{b}\left(\frac{x}{b}\right)^{a-1} e^{-(x/b)^{a}}$$

The shape parameter (a) determines the failure rate, where $a = 1$ the model has a constant failure rate (exponential) and ($a > 1$) implies increasing failure rate with age, which is what we might expect for vessels.

A survival analysis regression was conducted which allows the model to use alternative explanatory variables in the shape parameter, which controls the failure rate. As well as estimating a single shape parameter, it was considered worth exploring the effect of vessel length on vessel survival as this could significantly change the fleet size composition. Vessel length was therefore fitted as a covariate in the shape parameter linear predictor. The model was fitted using the R package "survreg".

The estimated probabilistic survival rate was then used to estimate the fleet size composition for each quarter in 1970-2007 using the registration year and catch effort data in 2004. If the fishing vessel conducted a trip in 2004-2005, then the vessel must have survived since its registration and it makes a full contribution to the fleet composition in the intervening quarters. If no trip took place for the vessel after 2004, then it is assumed the vessel did not survive, but left the fishery at some point during the intervening quarters. The contribution made in each quarter is the probability the vessel is still operating which was estimated from the fitted Weibull regression model.

From 2004 onwards, individual vessels began to be reported for each month, and the monthly summaries ceased in 2007. The estimated vessel length composition information should only be used to interpret the effects of vessel length on the non-vessel-specific catch and effort data compiled by month 1970-2007. The data compiled by vessel will, of course, not need to use this information.

Results and Discussion

The survival analysis fitted the data reasonably well, albeit with some overestimation of younger vessels and underestimation of older ones (Figure 3). The model is clearly not exact and does not account for any historical factors, such as subsidies, which might affect vessel longevity.

Although including a term for vessel length is statistically significant (Table 1), the parameter is small and negative, implying larger vessels do not last as long as smaller vessels in the fishery. This may be an artefact of the data because smaller vessels are the only ones in the fishery at the start of the series and their initial survival has not been monitored (data are heavily left censored).

The overall average vessel survival is equal to the survival of the vessel with average length (Figure 4). Other factors probably do affect a vessel's active life, and length could well be a factor. But this model is clearly not capturing these effects, and additional covariates would be required to improve the survival estimates.

Table 1 Analysis of variance and parameter estimates for the Weibull survival analysis model without and with vessel length as an explanatory covariate.

Terms	**Residual Degrees of Freedom**	**Residual Deviance**	**Df**	**Deviance**
Constant	1465	9487.8		
Vessel Length	1464	9271.6	1	216.2

Model Estimates		
	Estimate	**SE**
(Intercept)	*2.542*	*0.0164*
Log(scale)	*-0.514*	*0.0213*
(Intercept)	*3.106*	*0.0392*
Vessel Length	*-0.039*	*0.0024*
Log(scale)	*-0.609*	*0.0216*

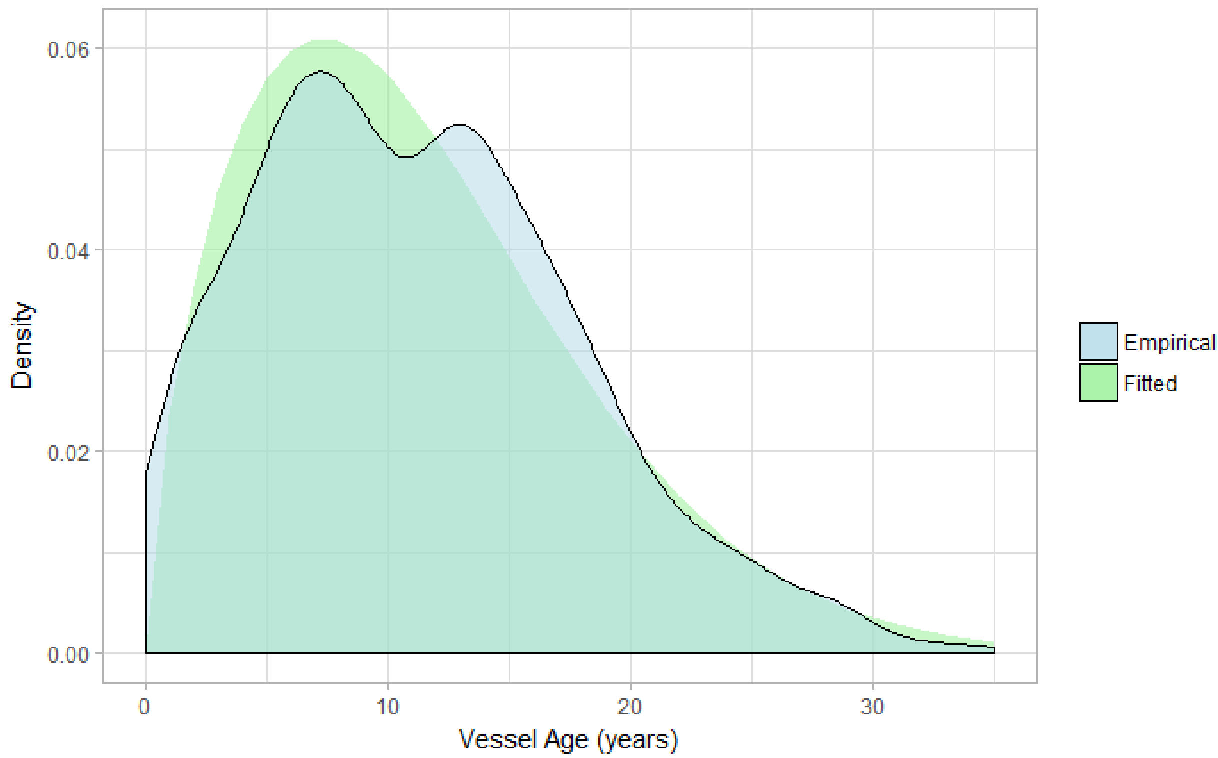

Figure 3 Probability density plot for age based on non-parametric smoothed data (Empirical) and the Weibull parametric model (Fitted).

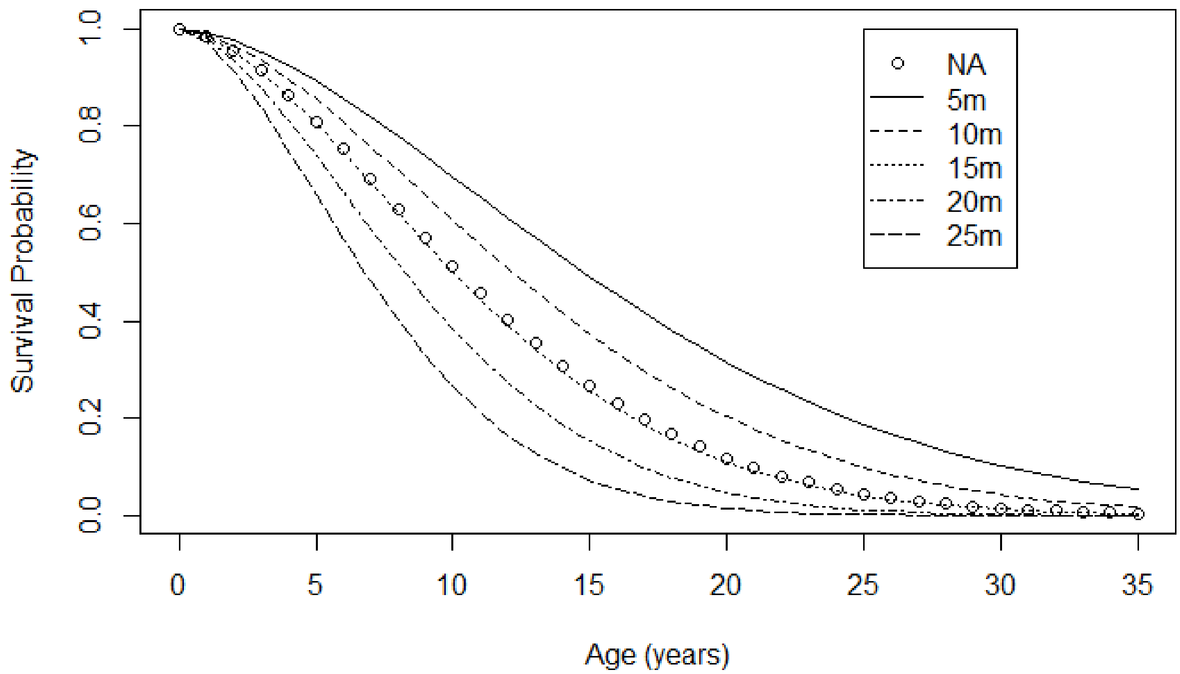

Figure 4 Cumulative survival probabilities for the model independent of vessel length, and the alternative model with 5 comparative vessel lengths.

Not accounting for genuine changes in vessel longevity based on vessel length could lead to inaccurate fleet size composition estimates. Therefore estimates for both models are generated to smooth the cumulative vessel size composition calculated from the vessel register to see how sensitive the estimates of length composition might be to the model's terms.

The model based on vessel length makes little discernible difference in the visual representation (Figure 5), with the final average length in 2007 being around 20-30cm less for the model including vessel length as a term. The model estimates of vessel size composition are only used for the period 1970-2003, so the overall effect of vessel length on longevity is small.

The probability matrix of vessel length for each quarter 1970-2007 (Figure 6) shows clear patterns as the fleet developed during this period. Vessel mean length appears to have increased linearly after mechanization in 1980 (Figure 5), but there are preferred vessel standard sizes that have changed over time. The resulting probability matrix is suitable not only for models using vessel length as a covariate, but also for using vessel length categories.

The initial years of the data period was a critical time in the Maldives tuna fishery. Some of the key developments in the fishery include mechanization of the fleet, subsidies on import of construction material, development of the vessel design, loan and instalment schemes for new vessels. Additionally, the Anchored FAD programme, initiation of fresh and canned tuna export to overseas and expansion of landing opportunities had a big influence on the fishermen's income and investments in new vessels. Further, the 2004 tsunami destroyed or damaged a significant number of vessels removing them from the fishery either temporarily or permanently. It is possible that accounting for these factors could improve reconstruction of the historical fleet's fishing power.

Figure 5 Estimate mean vessel length 1970-2007 for model with and without terms accounting for the effect of vessel on longevity.

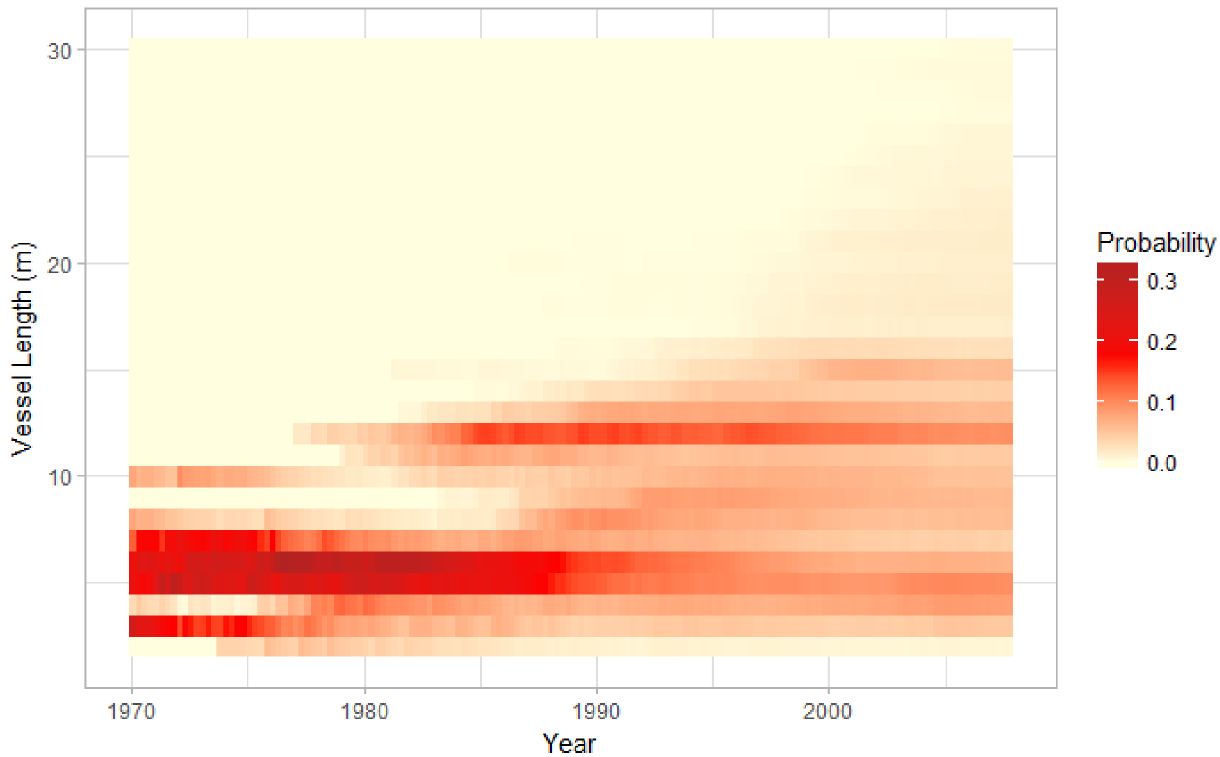

Figure 6 Probability matrix for vessel length composition for each quarter 1970-2007 corresponding to the period when non-vessel-specific data were collected.

References

Sharma, R., Geehan, J., Adam, M.S. (2014) Maldives Skipjack Pole and Line Fishery Catch Rate Standardization 2004-2012: Reconstructing Historic CPUE till 1985. IOTC, 2014 WPTT 16 42.

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