SCIENTIFIC COMMITTEE
TENTH REGULAR SESSION

Majuro, Republic of the Marshall Islands
6-14 August 2014

Purse seine CPUE for skipjack and yellowfin in the Papua New Guinea purse seine fishery

WCPFC-SC10-2014/SA-WP-03

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Abstract

The decline in skipjack pole and line activity in recent years means that the continuity of this key catch per unit effort (CPUE) time series for the skipjack stock assessment is becoming uncertain. The designation of a new 'Bismarck Sea' region in both the skipjack (S5) and yellowfin (Y8) stock assessments also highlights the need for a standardised CPUE time series in that region. Domestic purse seine vessels have operated within Papua New Guinea archipelagic waters for many years, focusing on skipjack and yellowfin tuna. The fishing pattern of those vessels has remained relatively consistent over time, concentrating on sets associated with anchored Fish Aggregation Devices (FADs) and other floating objects. It was therefore felt feasible to develop a standardised CPUE series for the two species in this region, using a delta-lognormal approach. Standardised CPUE time series for skipjack and yellowfin tuna were developed for the period 1997-2012.

Introduction

The pole and line fishery for skipjack has been the basis for a standardised catch per unit effort (CPUE) time series for input into skipjack stock assessments. However, the reduction in pole and line fishing activity within the Western and Central Pacific region over time (Williams and Terawasi, 2013) has meant that the continuity of this key CPUE time series is becoming uncertain. Furthermore, during the development of the new stock assessments for skipjack and yellowfin tuna, a specific spatial model region was designated consistent with the Bismarck Sea area (region S5 in the skipjack assessment, region Y8 in the yellowfin assessment; see Rice et al., 2014 and Davies et al., 2014, respectively). Identification of an alternative fishery from which standardised CPUE time series could be developed for the region would therefore be useful.

Purse seine vessels flagged to Papua New Guinea (PNG) have operated within PNG archipelagic waters for many years, focusing on catching skipjack and yellowfin tuna (Kumoru, 2007; Usu et al., 2013). Their operations are similar to Philippine vessels, focussing their setting on anchored Fish Aggregation Devices (FADs), and the support of ranger boats (Sokimi, 2009). This approach involves direct monitoring of the catch potential under a number of FADs within an area by ranger boats, and mooring of the purse seiner at the FAD with the greatest catch potential overnight, and setting in the early morning. This process has remained relatively consistent over time (Nicol et al., 2009). Given this consistent nature, within one specific geographic region, it was felt feasible to use this fishery to develop a standardised CPUE series for the two tuna species in this region, using the delta-lognormal approach.

In the PNG EEZ, anchored FADs are licensed by individual fishing companies and the position of each anchored FAD is registered. Most are located in the archipelagic waters of the Bismarck Sea, where the majority of fishing has occurred (Figure 1) and a small number are deployed in the Solomon Sea immediately south of New Britain. Most purse seine sets on anchored FADs have been reported from the central regions of the Bismarck Sea.

The number of anchored FADs within the archipelagic waters of Papua New Guinea has fluctuated over time. Reports of the number of anchored FADs in the water from the two key locally-based fishing companies (Frabelle PNG Ltd and RD Fishing PNG Ltd, who together comprise over 88% of the reported FADs in each quarter) were available over the period 1998 (from the second quarter) to 2012. Reported FAD numbers fluctuated over time (Figure 2). Numbers varied around 450 up to 2006, with a peak of over 600 in the period from late 1999 to early 2002. Deployed FAD numbers then increased again from mid 2006 to mid 2011, stabilising around 850 FADs.

Materials and methods

The time series of operational (set-by-set) data available from PNG domestic purse seine vessels within PNG archipelagic waters was examined. Data, including the set type (e.g. unassociated, associated) and catch, were available from 74 vessels of varying time series lengths (see Figure 3). Data from some vessels represented an intermittent time series, or one of relatively short duration.

A 'core' group of 13 vessels was selected that provided a reasonable time series of information for modelling (Figure 4). This subset was also selected to exhibit a relatively consistent set type usage over time. Sets *without* information on the set type were dropped from the data set, as initial regression tree analyses (not presented) suggested these data were very influential on model estimates.

Many of the '*Dolores*' vessels fished on free-school sets in 2001, and a general trend to increased fishing on free school sets in recent years was seen. Corresponding species catch proportions are shown in Figure 5.

Examination of the average number of sets per day by vessel suggested that there had been an increase over time, with some vessels undertaking two sets per day in more recent years. This increased the average number of sets per day slightly (Figure 6). Examining the pattern of set type where two sets were made during a day, in 99% of events an unassociated set was made, combined with either a set on an anchored FAD (~75% of days) or other associated set (drifting log/debris, association with a marine mammal/whale shark).

CPUE standardisation

The skipjack or yellowfin CPUE time series (mt/set, to take into account changes in the number of sets made per day) from the subset of vessels were separately standardised using a delta-lognormal approach on the data from the (subset) 13 vessels. A constant was added to positive (successful) CPUEs using the Box-Cox approach to improve normality of the positive CPUE component. Delta-lognormal GLM models (Lo et al., 1992; Stefánsson, 1996) were built on the basis of goodness of fit (McCullagh and Nelder, 1989) and parsimony. Initial models were generally the most complex model including interactions, and complexity was then reduced as subsequent models were examined. Resulting benefits in terms of gains in degrees of freedom and relative loss in terms of residual deviance was assessed.

Given that the data were from the archipelagic waters of PNG, no location (lat/long) variable was included within the model. CPUE was modelled as tuna (skipjack or yellowfin, mt) catch per set, allowing information on set type to be incorporated. Initial models included both unassociated and associated sets within the 'settype' model factor. However, the trend towards unassociated set types for particular vessels, and the uncertainty on whether those indications were correct, led to the exclusion of unassociated set events from the analysed data.

Variables/factors examined in the binomial and positive catch model components included:

- A Year-quarter factor (inclusion of a Year*Quarter interaction did not improve model fits significantly);
- Vessel name;
- Set type (where set type was anchored FAD (AFAD), drifting FAD (DFAD), and ASS_other (other associated sets, including drifting logs));
- the catch weight of the other main tuna species (yellowfin or skipjack) in the set (mt).

While data on bigeye catches were available, there was concern that this estimate was biased due to the potential to mis-identify small bigeye. It was noted that this may also affect the estimates of yellowfin catches. However, standardisation models that included the amount of other tuna (skipjack or yellowfin) species caught in a set gave significantly improved fits to the data.

Results

Results for skipjack and yellowfin are presented separately.

Skipjack standardisation

The nominal skipjack CPUE (mt per set) was examined by year/quarter and set type (Figure 7). Clear outlier CPUEs (>400 mt/set) were removed from the data. While the periodic use of drifting FADs is noted, the model appeared to fit reasonably well to the resulting CPUE values.

The parameters included within the skipjack CPUE standardisation model and their significance (through ANOVA) are shown in Table 1. The resulting standardised CPUE time series and diagnostics are shown in Figure 8, and the components of the model presented in Figure 9. The effect on the standardised CPUE time series of sequentially adding covariates to the GLM is shown in Figure 10.

The best fitting model implies that the probability of achieving a successful set has declined over time, while the size of the skipjack catch achieved within a successful set has only declined slightly over time, perhaps at a faster rate over the last 10 years (Figure 9). This decline appears to have occurred despite the use of anchored FADs.

Yellowfin standardisation

The nominal yellowfin CPUE (mt per set) was examined by year/quarter and set type (Figure 11).

Parameters included within the yellowfin CPUE standardisation model and their significance (through ANOVA) are shown in Table 2. The resulting standardised CPUE time series and diagnostics are shown in Figure 12, and the components of the model presented in Figure 13. The effect on the standardised CPUE time series of sequentially adding covariates to the GLM is shown in Figure 14.

The two components of the delta-lognormal model indicates a slight decline in the probability of a successful catch of yellowfin, and this decline has increased slightly in the last 10 years. The size of successful catches were higher in the early 2000s, and has remained relatively constant, if variable, in other years.

Discussion

This paper presents standardised associated set CPUE time series (mt/set) for the Papua New Guinea domestic purse seine fishery operating within the 'Bismarck Sea' region. For both skipjack and yellowfin CPUE series, the key factor explaining the likelihood of both a successful set and the corresponding size of the catch of each species was the year/quarter effect. Vessel and (associated) set type were the next two most important covariates. Resulting standardised time series for the two species showed some similarities; skipjack standardised CPUE shows a downward trend from the early 2000s, driven largely by reductions in the likelihood of a successful set; yellowfin standardised CPUE also shows some decline from the early 2000s, but with greater inter-annual variability.

We note that while the fishing method and region were consistent over time, some changes in the fishery have occurred. For example, the number of anchored FADs within the archipelagic waters of PNG has fluctuated over time, with notable increases in the more recent periods. The resulting effect on the behaviour of skipjack and yellowfin and their catchability is difficult to identify. There is the potential for increased FAD numbers to reduce any downward trends in CPUE, by for example increasing the probability of a fish encountering a FAD and potentially its probability of capture. Declines in the modelled probability of a successful set occurred prior to more recent increases in deployed anchored FAD numbers, while there also appears to be no trends in model outputs consistent with the fluctuations seen in numbers of reported anchored FADs over time. With regards the increased number of sets made per day seen in recent years, we have attempted to take this into account by assessing only those sets on FADs, which has tended to maintain a one set-per-day frequency over time.

However, the relationship between purse seine CPUE and stock abundance remains uncertain (e.g. Labelle et al., 1997), a result of the fact the potential for the densities of schooling pelagic fish such as tuna to remain constant in geographic areas when stock size is actually decreasing. That issue remains relevant to the current analysis.

Acknowledgements

We would like to acknowledge funding for this work from the WCPFC and from the Australian Aid (AusAID) Fisheries for Food Security programme. We would also like to thank NFA for the funding of the placement of TU and BK at SPC, which facilitated this work.

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Tables

Table 1. ANOVA of the final standardisation model for skipjack tuna (CPUE = skipjack mt/set)

Binomial model

	Df	Resid.Df	Resid.Dev	P
NULL		19367	15081	
as.factor(Yr_Qtr)	63	19304	14040	***
as.factor(vessel name)	12	19288	13827	***
as.factor(settype)	2	19286	13808	***
Yft_mt	1	19285	13783	***
as.factor(vessel name) * as.factor(settype)	30	19255	13731	**

Positive cpue (skipjack mt/set) model

	Df	Resid.Df	Resid.Dev	P
NULL		16819	21951	
as.factor(Yr_Qtr)	63	16756	20515	***
as.factor(settype)	2	16754	20476	***
as.factor(vessel name)	16	16738	19711	***
Yft_mt	1	16737	19188	***
as.factor(Yr_Qtr) * as.factor(settype)	101	16636	19017	**
yft_mt * as.factor(settype)	2	16634	19000	***

Table 2. ANOVA of the final standardisation model for yellowfin tuna (CPUE = yellowfin mt/set)

Binomial model

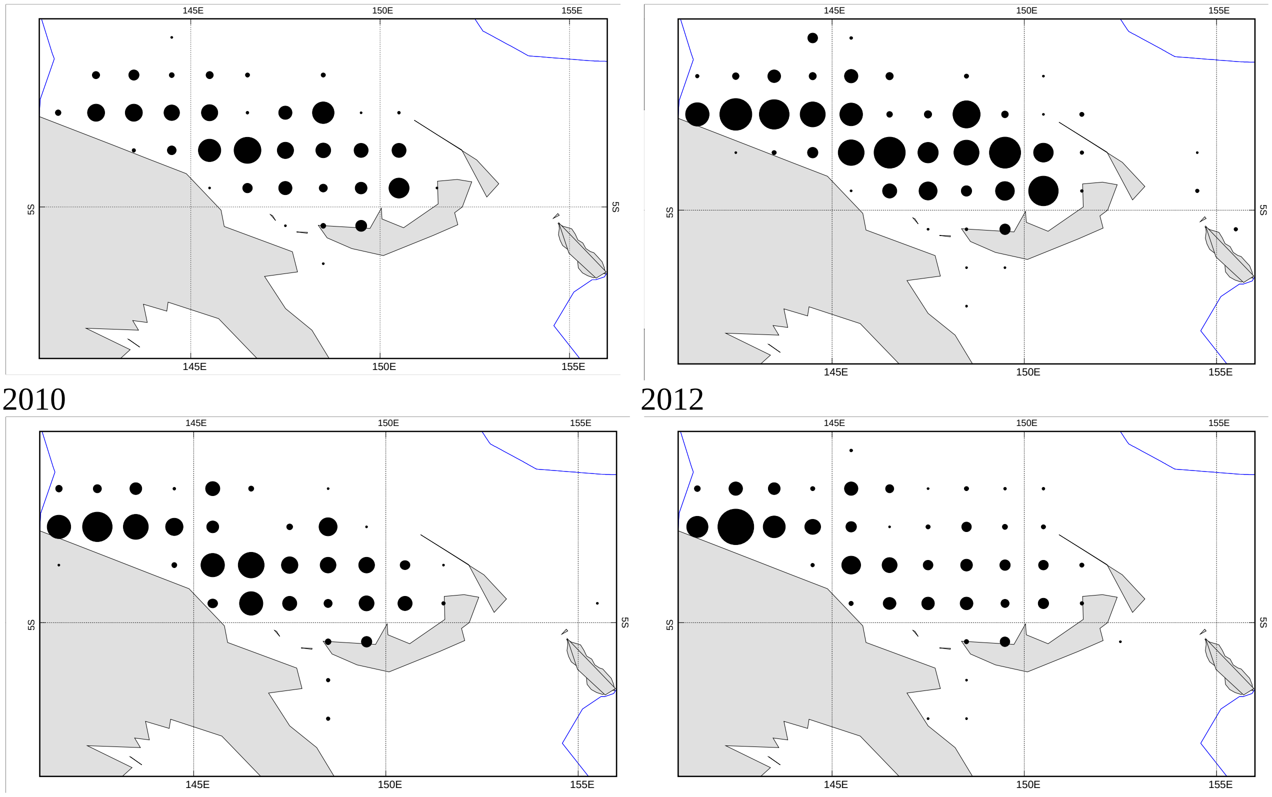
	Df	Resid.Df	Resid.Dev	P
NULL		17469	12242	
as.factor(Yr_Qtr)	63	17406	11159	***
as.factor(vessel name)	12	17394	10970	***
as.factor(settype)	2	17392	10958	***
Skj_mt	1	17391	10908	***
as.factor(vessel name) * as.factor(settype)	22	17369	10870	*

Positive cpue (yellowfin mt/set) model

	Df	Resid.Df	Resid.Dev	P
NULL		15515	16933	
as.factor(Yr_Qtr)	63	15452	15648	***
as.factor(settype)	2	15450	15645	
as.factor(vessel name)	12	15438	14995	***
Skj_mt	1	15437	14298	***
as.factor(Yr_Qtr) * as.factor(settype)	73	15364	14129	***
as.factor(vessel name) * as.factor(settype)	21	15343	14098	*

skj_mt * as.factor(settype)	2	15341	14079	***

Figures


2000

2005

2010

2012

Figure 1. Geographic distribution of PNG domestic purse seine vessel effort (on Associated sets only, max circle size = 300 sets) within PNG archipelagic waters, at the 1°x1° scale, over the period 2000-2012.

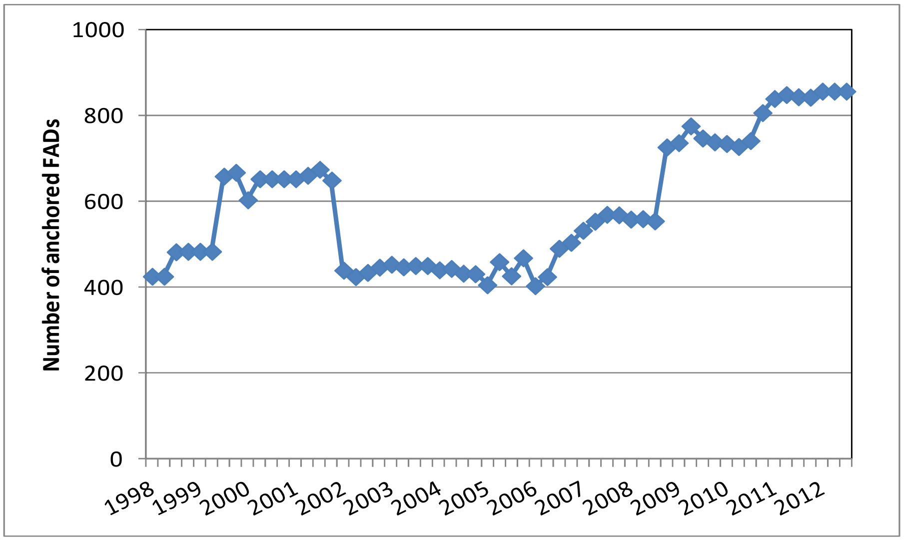


Figure 2. Quarterly number of anchored FADs reported by the two key locally-based companies (Frabelle (PNG) Ltd and RD Fishing PNG Ltd) within PNG archipelagic waters over the period 1998 to 2012.

Figure 3. Available time series of PNG-flagged purse seine vessels operating within the PNG archipelagic waters. Plot presents proportion of sets in each yr/qtr of vessel data where the set made was unassociated (UNA, blue) or associated (ASS, green; includes sets on anchored FADs, drifting FADs, logs etc.).

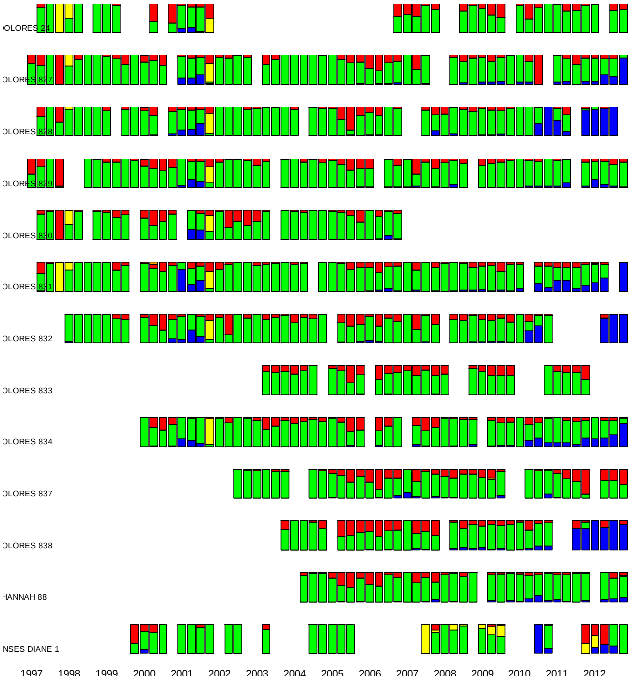


Figure 4. Time series of set type proportions over time (by Year/Quarter) for the selected sub-set of vessels where sets were unassociated (UNA, blue), anchored FAD (green), drifting FAD (yellow), and other associated (red).

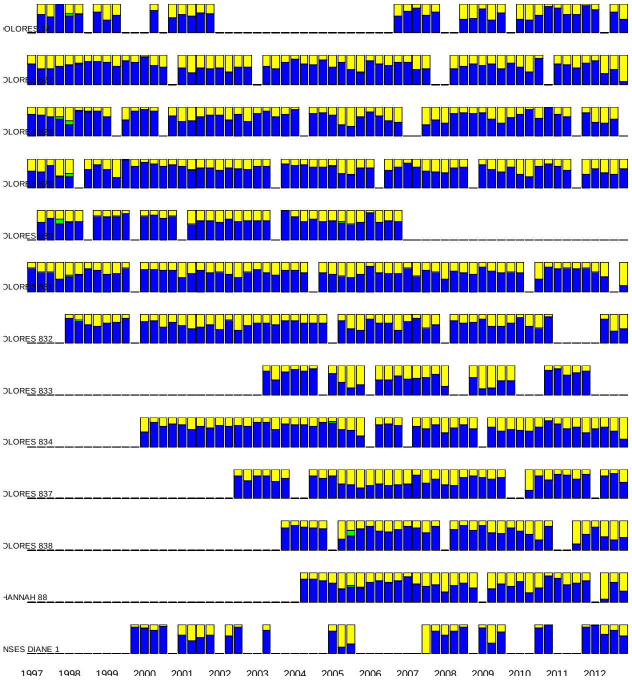


Figure 5. Subset data species catch proportions across all sets, by year and quarter and vessel, from the selected sub-set of vessels, for skipjack (blue), bigeye (green) and yellowfin (yellow).

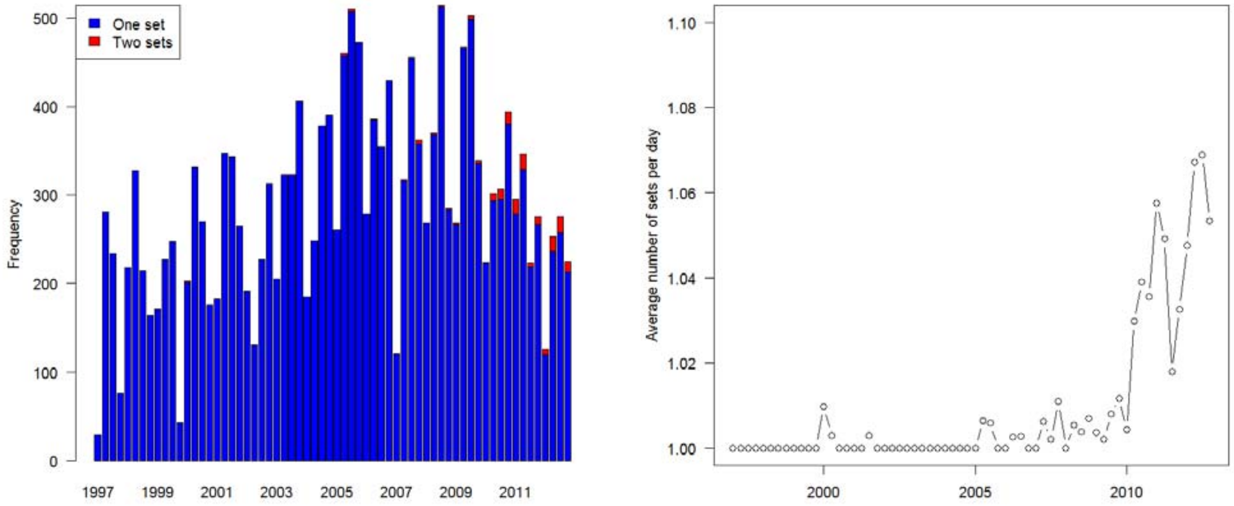


Figure 6. Frequency of days where one or two sets were made over time (left) and the average number of sets per day within the data set (right). Note the limited axis range on the right hand figure.

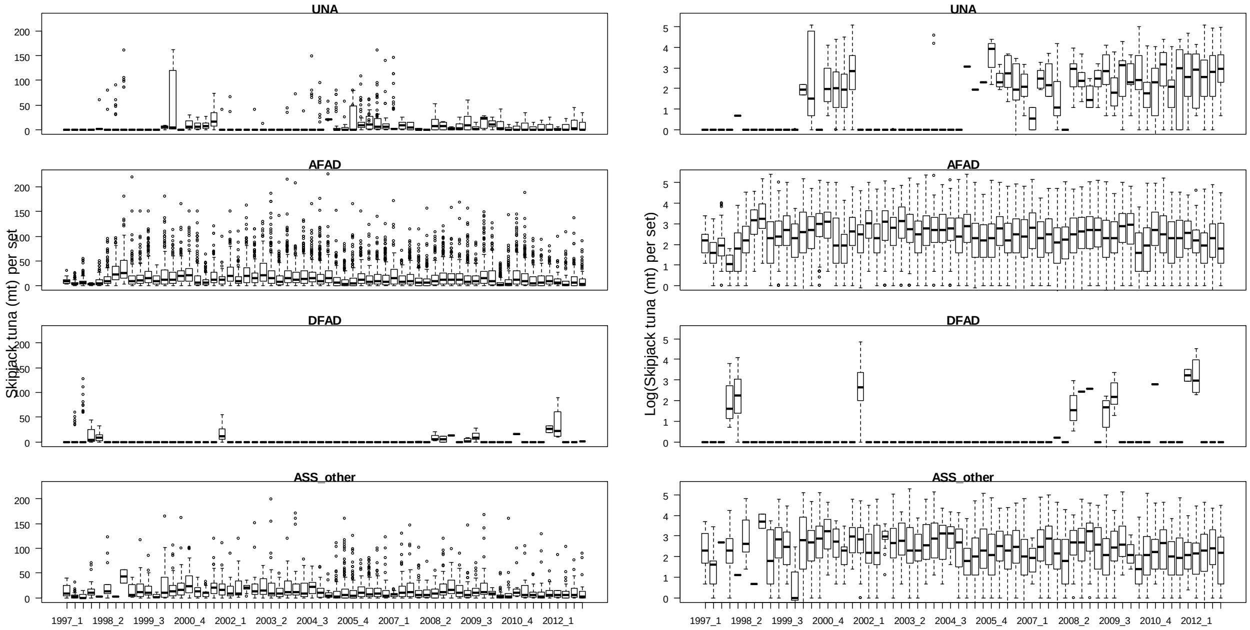


Figure 7. Nominal skipjack CPUE (mt/set) plots by set type (left) and log(+'ive CPUE) by set type (right).

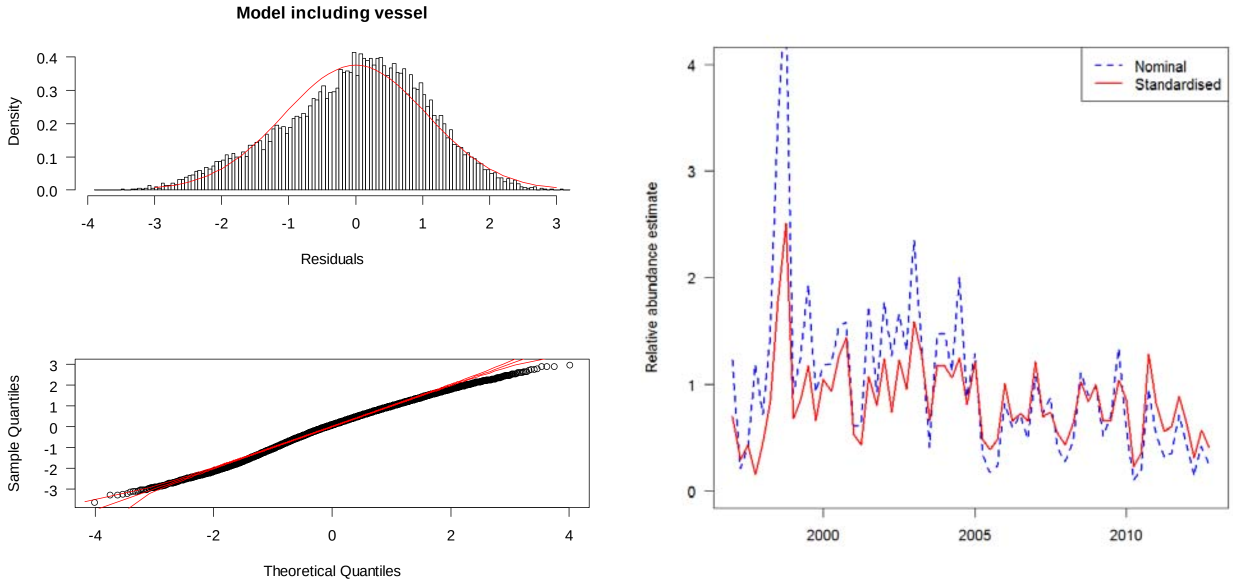


Figure 8. Residual plot of GLM on positive catch rates (left) and nominal and standardised CPUE time series (right).

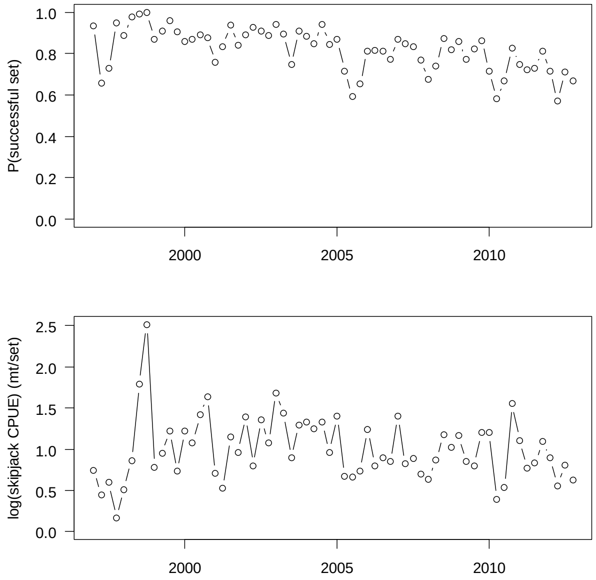


Figure 9. Estimated components of the delta-lognormal model.

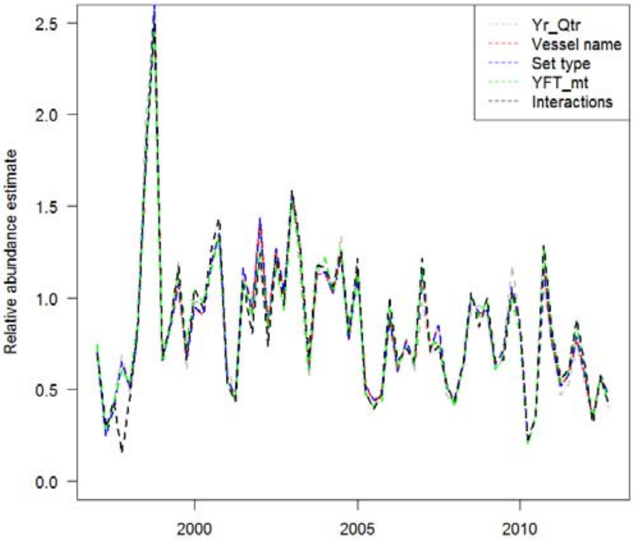


Figure 10. Step plot indicating the effect on the standardised CPUE series of the addition of factors.

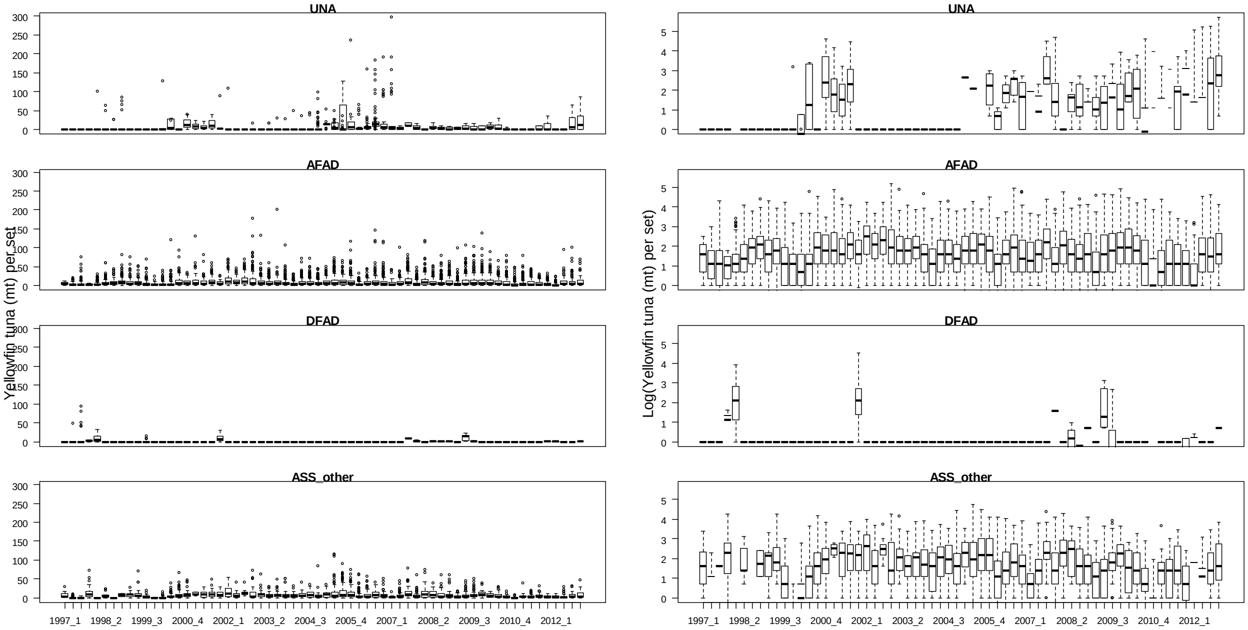


Figure 11. Nominal yellowfin CPUE (mt/set) plots by set type (left) and log(+ive CPUE) by set type (right).

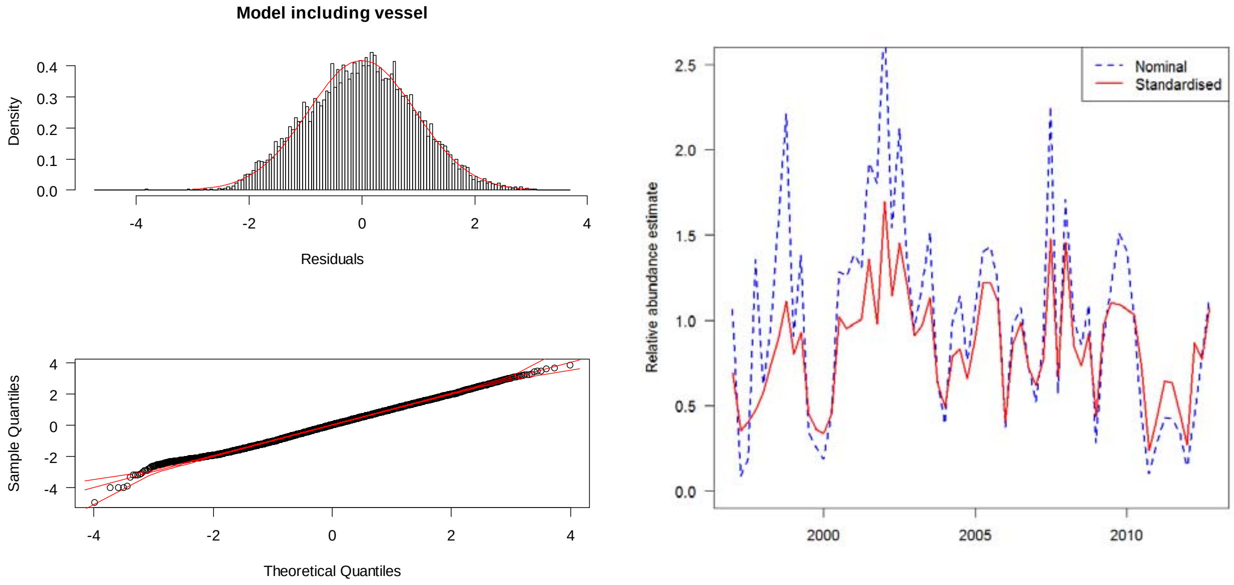


Figure 12. Residual plot of GLM on positive catch rates (left) and nominal and standardised CPUE time series (right).

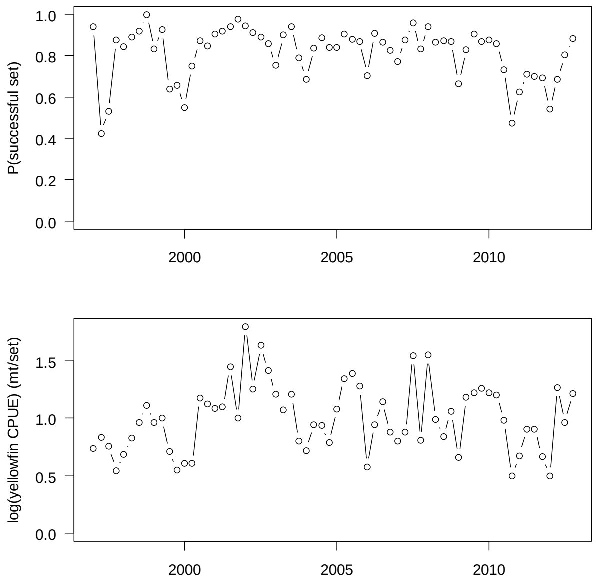


Figure 13. Estimated components of the delta-lognormal model.

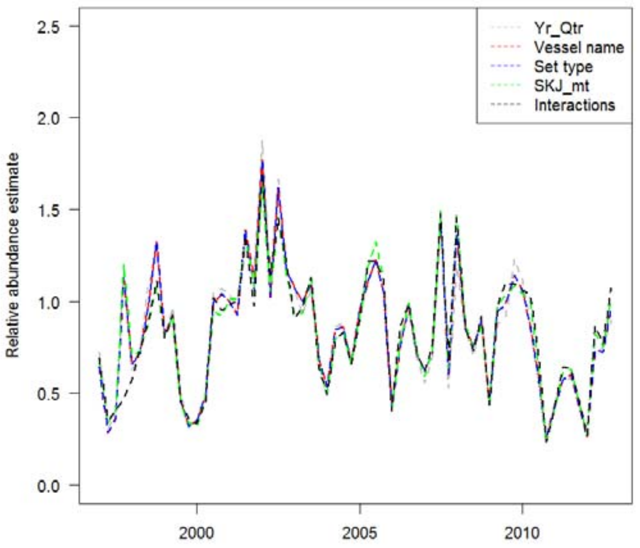


Figure 14. Step plot indicating the effect on the standardised CPUE series of the addition of factors.