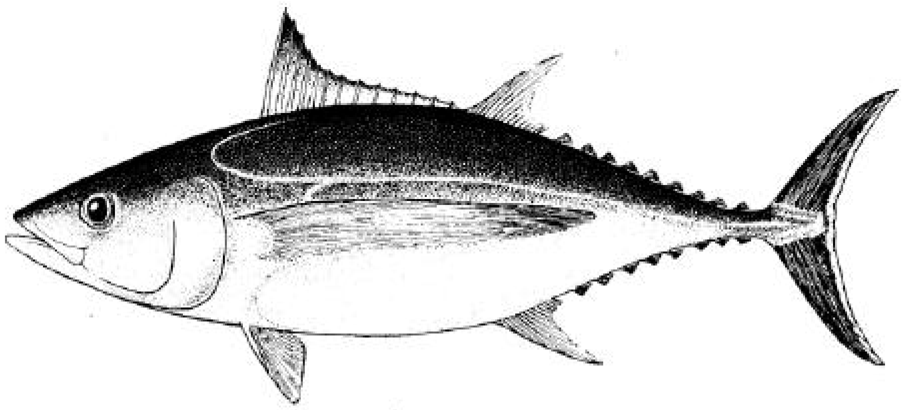
SCTB16 Working Paper

ALB–4

Standardised analysis of albacore CPUE data from the Taiwanese longline fleet, 1967 to 2000



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1 Introduction

The albacore longline fishery in the south Pacific Ocean was developed in the 1950s by the Japanese and Korean fleets (Murray 1994). The Taiwanese fleet entered the fishery in the late 1960s and has continued to operate in the fishery. Historical trends in the albacore longline fishery are summarised in Murray 1994.

Catch and effort data from the Taiwanese longline fleet has been a key input in the recent stock assessments of albacore tuna in the south Pacific Ocean (Fournier et al. 1998, Hampton 2002). The assessments have been undertaken using MULTIFAN-CL (MFCL) software and stratified the fishery into three broad latitudinal zones (see Appendix 1). The assessments have incorporated albacore catch and unstandardised effort data from the fishery aggregated by each of the spatial strata.

Catch and effort data from the Taiwanese longline fishery are considered to provide a more reliable index of albacore stock abundance than CPUE data from the other main longline fisheries. The Taiwanese fleet maintained a relatively high level of catch and effort from 1967 to 2000 and targeting practices remained relatively consistent compared to both the Japanese and Korean fleets. The fishery also maintained a broad spatial distribution throughout the area encompassed by the current assessment.

Nevertheless, trends in the spatial and temporal distribution of the Taiwanese longline fishery are likely to have occurred during the history of the fishery. These changes may have influenced the catchability of the fishery throughout the study period. While MFCL has the facility to estimate systematic changes in catchability, the recent stock assessments for albacore have assumed that catchability of the Taiwanese longline fleet remained constant (Hampton 2002).

The purpose of this paper is to apply a generalised linear modelling approach to standardise catch and effort data from the longline fishery and, thereby, derive a more reliable index for monitoring trends in the recruited biomass of albacore.

2 Data set

The data set included catch and effort data from the Taiwanese longline fleet from 1967 to 2000. The data were available in summary format aggregated by month and 5 degrees of latitude and longitude. Details of the source of the data and the methodology for calculating the aggregated data are documented in Lawson 1997. Data from 2001 and 2002 were not available for inclusion in the analysis.

The variables in the data set included year, month, latitude bin, longitude bin, total number of hooks set, and the catch of albacore tuna (in number of fish). In addition, catch data were available for the main bycatch species (YFT, BET, BFT, SBF, SKJ, BLM, BLZ, MLS, SFA, SWO, SHK, and "other" species).

The data set was subdivided into the three areas included in the South Pacific MFCL assessment (Appendix 1). In this report the North, Central, and South MFCL areas are denoted MFCL areas 1, 2, and 3, respectively.

A small number of records with extreme outliers for nominal CPUE (number of fish/number of hooks) were excluded from the data set.

3 Data summary

During 1967 to 2000, most of the Taiwanese longline activity occurred within MFCL area 2 and this area yielded the highest catch of albacore (Table 1, Figure 1, and Figure 2). Fishing effort was lower in both MFCL area 1 and 3, although overall catch rates were highest in the latter area. The lowest catch rates of albacore occurred in MFCL area 1 and this area also had the highest proportion of null catch records for albacore (Table 1 and Figure 2).

For MFCL area 2, there was a decline in the number of records included in the CPUE data set during the 1980s, while fishing effort (number of hooks) remained constant through the time period (Figure 1). This is attributable to a contraction of the area fished in MFCL area 2 and an increase in the concentration of fishing effort in certain areas (Figure 4). This is likely to be partly attributable to the declaration of EEZs by Pacific Island nations and changes in access arrangements for the Taiwanese fleet.

Overall, since the mid 1980s there has been a concentration of fishing effort in the western (Vanuatu, Fiji) and northeastern (Pitcairn) areas of MFCL area 2 (Figure 4). There was also greater inter-annual variability in total fishing effort compared to the earlier period (Figure 1).

Total fishing effort was relatively low in MFCL area 1, particularly since the mid 1980s. The range of the fishery contracted during the latter period and effort was increasingly concentrated in the southern area of the region (Figure 3). In recent years, the proportion of records with zero albacore catch has steadily increased (Figure 2).

Annual fishing effort in MFCL area 3 fluctuated between years and was particularly high in the early 1990s (Figure 1). The distribution of fishing effort remained relatively constant over the study period, with effort focussed in the Tasman Sea and east of New Zealand (Figure 5).

No strong changes in the seasonal distribution of fishing effort are apparent for the three MFCL areas (Appendix 2).

No information is available concerning the configuration of the longline gear and/or setting procedure, for example the introduction of line-shooters to the fleet.

Table 1: Summary statistics for the Taiwanwese longline CPUE data sets.

		MFCL area		
		1	2	3
Total number of records		2,108	6,887	1,427
Albacore	Catch (fish *1000)	2,210	21,595	9,067
	Zero records (%)	18.6	0.7	0.1
	Fish/100 hooks	1.62	2.67	4.03

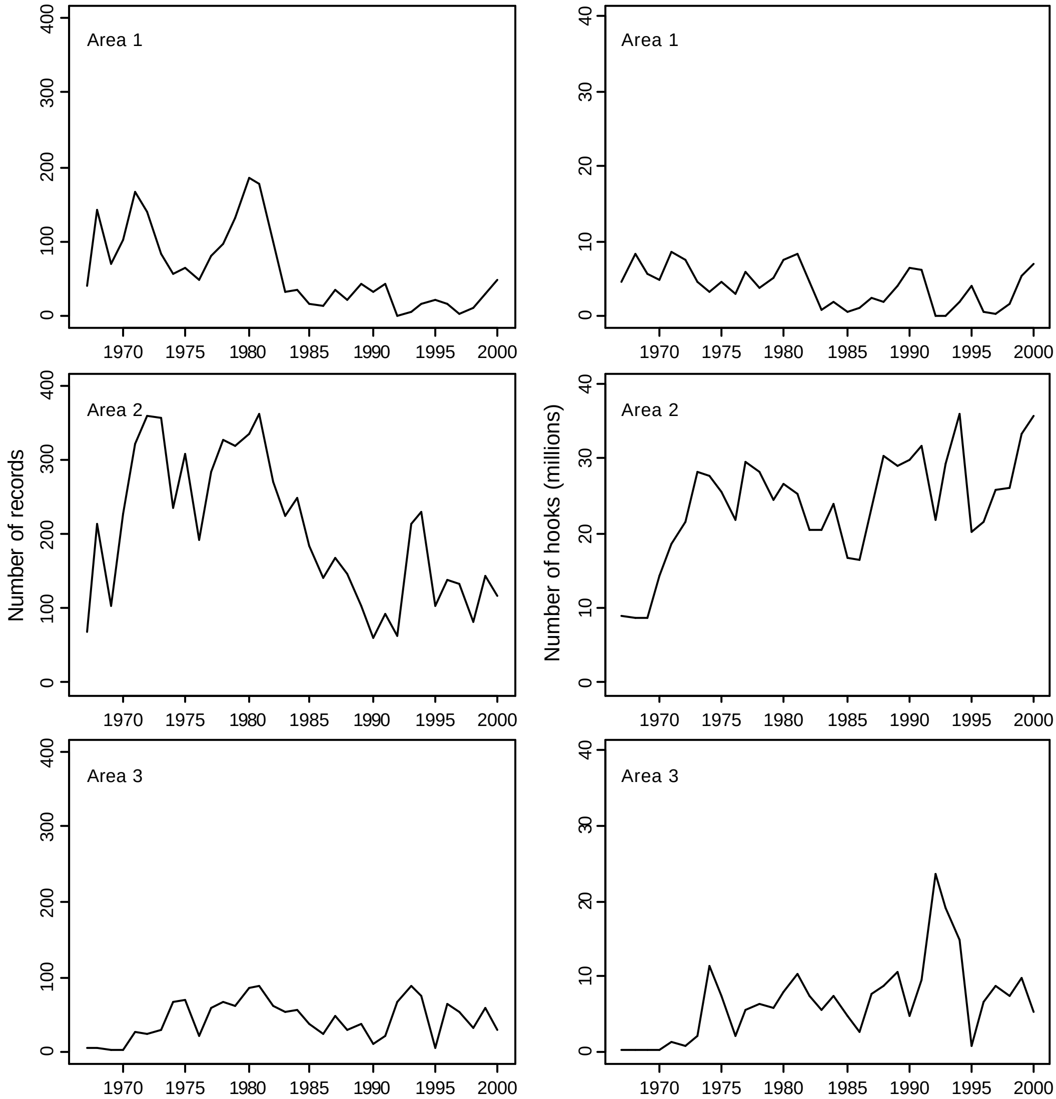

Figure 1: Annual number of CPUE records and total number of hooks set by MFCL area from 1967 to 2000.

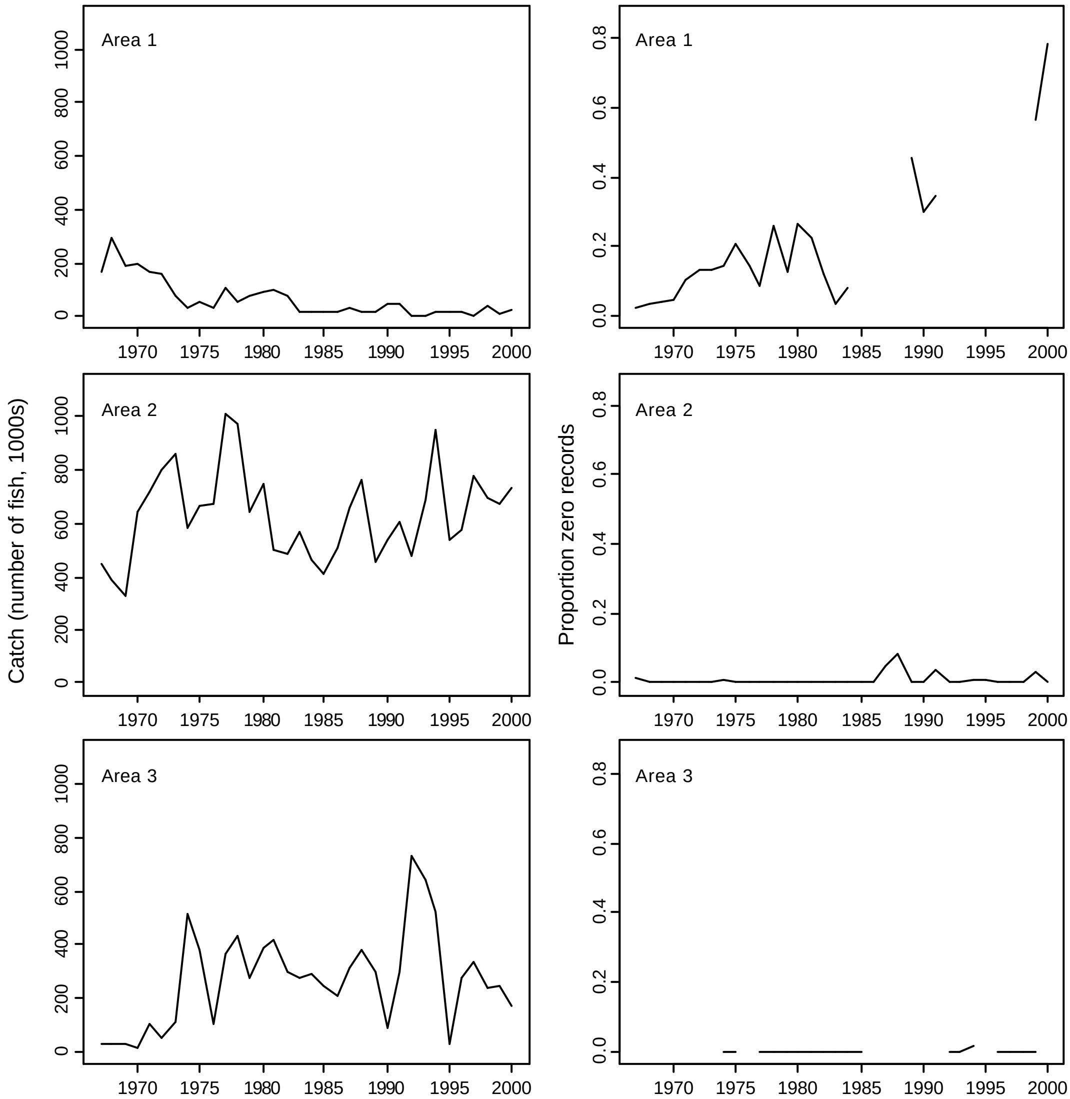

Figure 2: Annual trends in the catch (number of fish) of albacore (left) and the proportion of records with no catch of each species for the three MFCL areas. The proportion of zero records is only calculated for years with at least 30 records.

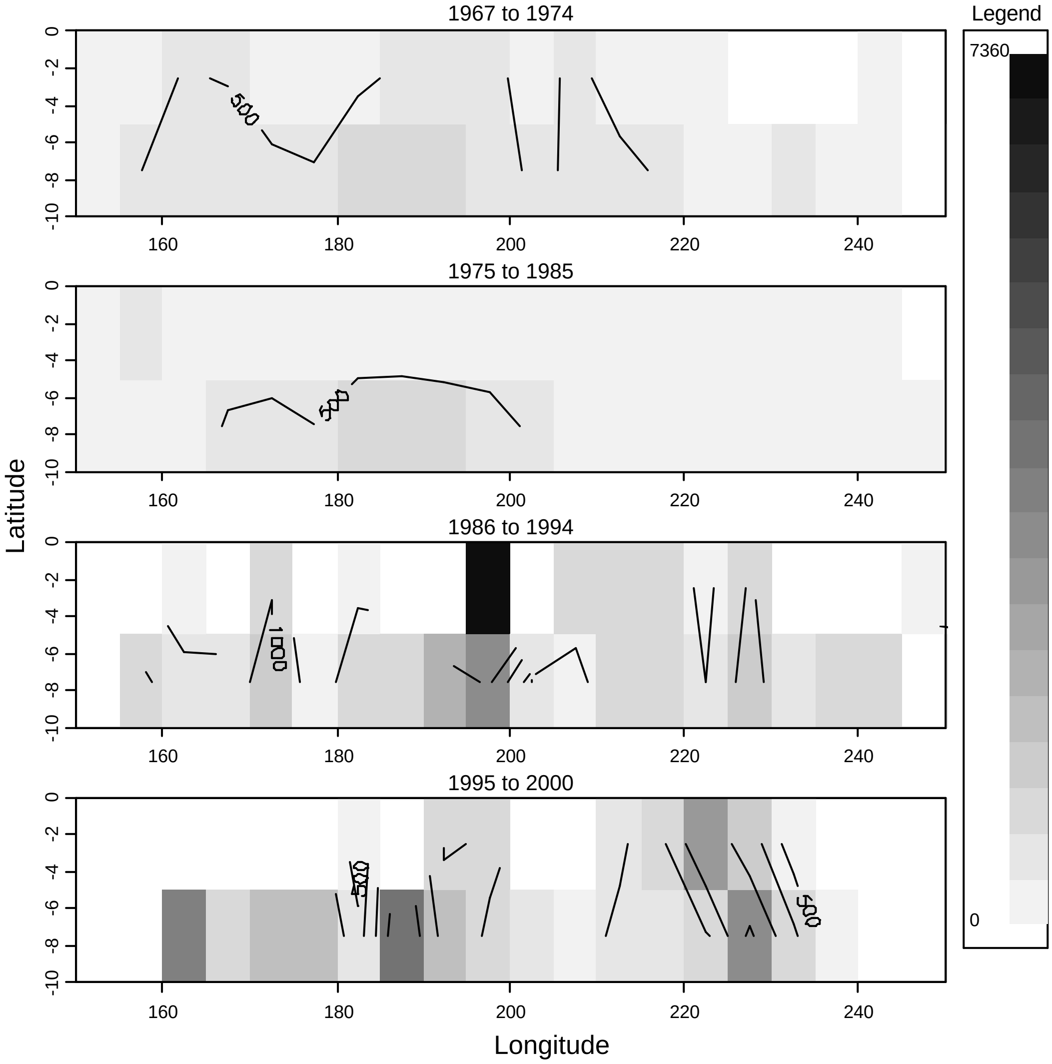

Figure 3: Decadal distribution of fishing effort (mean number of hooks (100s) per record) by the Taiwanese fleet by latitude and longitude bin for MFCL area 1. The contour lines represent 500, 1000, 2000, 3000 hooks (x100).

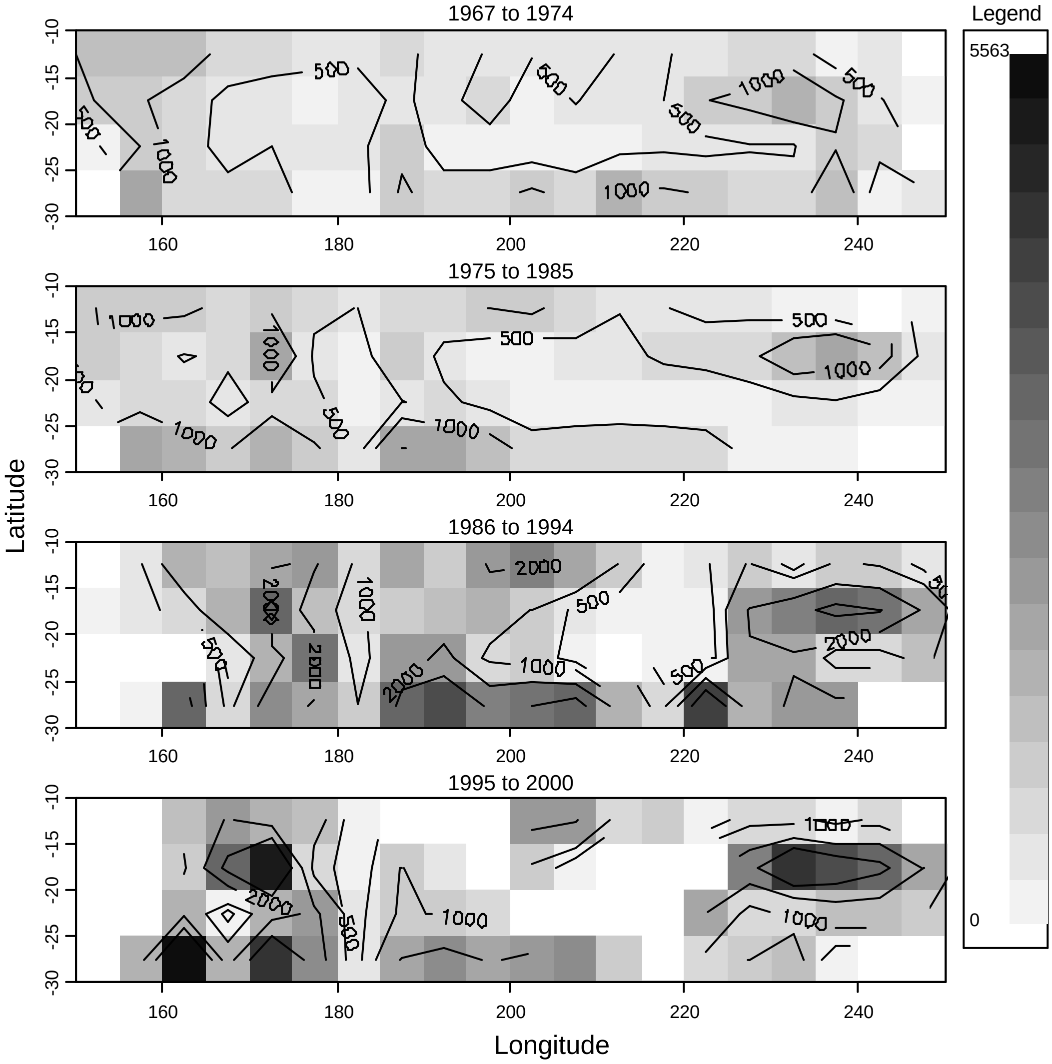

Figure 4: Decadal distribution of fishing effort (mean number of hooks (100s) per record) by the Taiwanese fleet by latitude and longitude bin for MFCL area 2. The contour lines represent 500, 1000, 2000, 3000 hooks (x100).

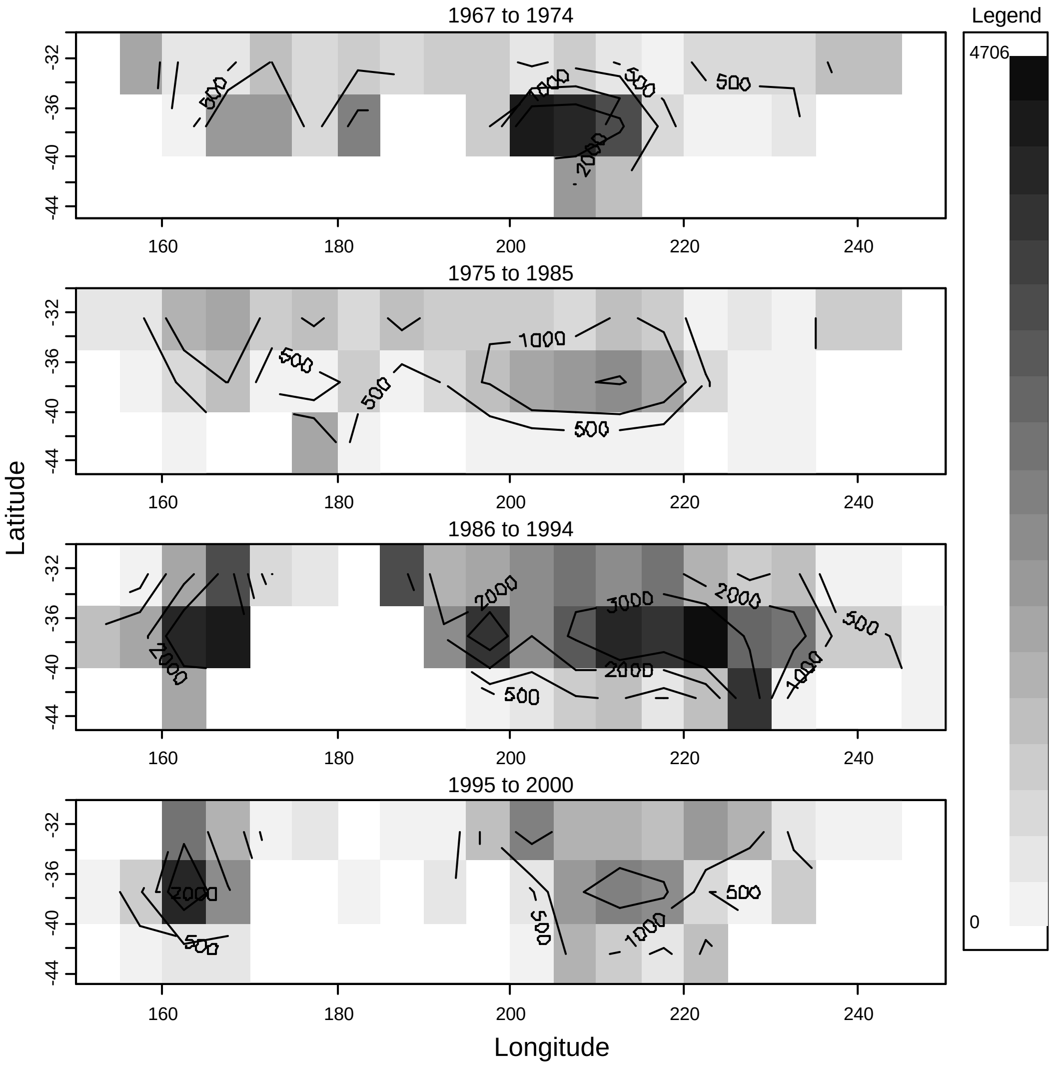

Figure 5: Decadal distribution of fishing effort (mean number of hooks (100s) per record) by the Taiwanese fleet by latitude and longitude bin for MFCL area 3. The contour lines represent 500, 1000, 2000, 3000 hooks (x100).

4 Standardised CPUE analysis

4.1 Methods

Separate standardised CPUE analyses were conducted for each of the three MFCL areas using a generalised linear modelling approach. Modelling the CPUE data separately enables a different parameterisation for each of the significant explanatory variables included in the respective CPUE model.

For each model, the dependent variable was the natural logarithm of the non-zero catch, expressed as the total number of fish caught in the year/month/lat/long cell. Zero catch records were excluded from the analysis. These generally comprised a small proportion of the total records in each MFCL area, with the exception of the recent years in the MFCL area 1 data set.

The potential explanatory variables included the categorical variables year and month. Latitude and longitude and the catch of the individual associated species were included as third order polynomial functions. The effort variable (number of hooks) was initially included as a third order polynomial function. However, the parameterisation resulted in an unrealistic relationship between catch and effort and a poor fit to the low catch values. In the final model, the effort variable was incorporated as a linear function of the natural logarithm of the number of hooks. This imposed a linear relationship between the catch and the number of hooks set.

Initial exploratory analysis revealed an apparent interaction between the latitude and longitude and this interaction term was included as potential explanatory variable in the stepwise fitting procedure.

The monthly Southern Oscillation Index (SOI) was included as a potential explanatory variable in all CPUE models (source: http://www.cpc.ncep.noaa.gov/data/indices/index.html). The SOI index was included for the corresponding month of fishing, lagged by three months, and the running mean of the preceding three months.

Sea surface temperature (SST) was included as a potential explanatory variable in the CPUE models. The variable was expressed as the deviation from the monthly mean SST of the individual 5 degree latitude/longitude bin from the 1967–2000 period and parameterised as a third order polynomial function.

A stepwise fitting procedure was applied to each of the three MFCL area data subsets, with each record weighted by the level of effort (number of hooks) in the cell. This process identified the main explanatory variables. These were common between each of the three CPUE models although the parameterisation of these variables differed considerably between models. In addition, each model included a number of additional variables. These additional variables explained a very small proportion of the total variation and had minimal effect on the annual indices from the respective model (Table 2).

For simplicity, a generic model structure was applied to each the three MFCL area data sets, accounting for the main explanatory variables only. The final model included the year, month, number of hooks, latitude and longitude. The effort variable was a linear function of the natural logarithm of the number of hooks. The year and month variables were included as categorical variables. The latitude and longitude were included as an interaction term.

The generic CPUE model for albacore has the formulation:

Log(catch) ~ log(Num_hooks) + as.factor(Year) + interaction(lat, long) + as.factor(month)

To determine the relative catch rates between the three MFCL areas, the annual CPUE indices (model coefficients) were exponentiated and then scaled to the global mean catch rate for the specific MFCL area.

4.2 Results

The generic CPUE models for the three MFCL areas explained a high proportion of the observed variation in the natural logarithm of the catch of albacore (number of fish). The MFCL area 2 and 3 models explained about 90% of the variation, while 82% of the variation was explained by the MFCL area 1 model (Table 3).

The individual CPUE models represented a good fit to data, except for records with a very small catch (less than 20 fish) (Figure 7). The higher proportion of small catches in the MFCL area 1 CPUE data set explains the lower explanatory power of the respective CPUE model (Figure 6).

The predicted relationships between the number of hooks set and albacore catch are given in Figure 8.

For the three MFCL areas, the models predict a strong seasonal trend in catch rates with catch rates peaking during winter (May–September) and lowest catch rates in summer (Figure 8). The seasonal effect is most pronounced within MFCL area 1.

The three CPUE models predict strong spatial trends in the relative catch rate of albacore (Figure 9). For each of the three areas, there is an increase in catch rates with increasing latitude, although the magnitude of this effect is strongest in the two northern areas (MFCL areas 1 and 2). Catch rates are also predicted to be relatively high in the area of MFCL area 1 and 2 within the Tasman Sea (Figure 9).

The year effects from the albacore CPUE models were comparable to the annual trends in unstandardised catch rates from the fishery (Figure 10). For MFCL area 2, the decline in CPUE indices was slightly higher than for the unstandardised data. For MFCL area 3, there was an apparent large decline in catch rates during the initial development of the fishery. However, the CPUE indices for this period are highly uncertain (Figure 8).

Table 2: Summary of step-wise fits to each of the MFCL area albacore CPUE data sets. The r-squared value (%) is given for each iteration.

Iteration	MFCL area 1		MFCL area 2		MFCL area 3	
	Variable	R^2	Variable	R^2	Variable	R^2
1	Num_hooks	43.2	Num_hooks	79.0	Num_hooks	79.1
2	Lat*long	68.6	Year	84.7	Year	87.7
3	Year	79.5	Lat*long	89.4	Lat*long	89.2
4	Month	80.7	Month	90.0	Month	90.1
5	YFT	81.3	BET	90.0	BLZ	90.2
6	SWO	81.5	SOIrun3	90.1	SOI_lag3	90.4
7	SOI_lag3	81.7	SST_dev	90.1	MLS	90.4
8	BET	81.8	MLS	90.2	BET	90.4
9	BLM	82.0	SWO	90.2	SWO	90.5
10	SST_dev	82.1	YFT	90.2		
11	BLZ	82.2	BLM	90.2		

Table 3: Proportion of the observed variation in the natural logarithm of albacore catch explained by each of the three generic MFCL area CPUE models.

MFCL region	Percent R^2
1	82.31
2	91.13
3	90.33

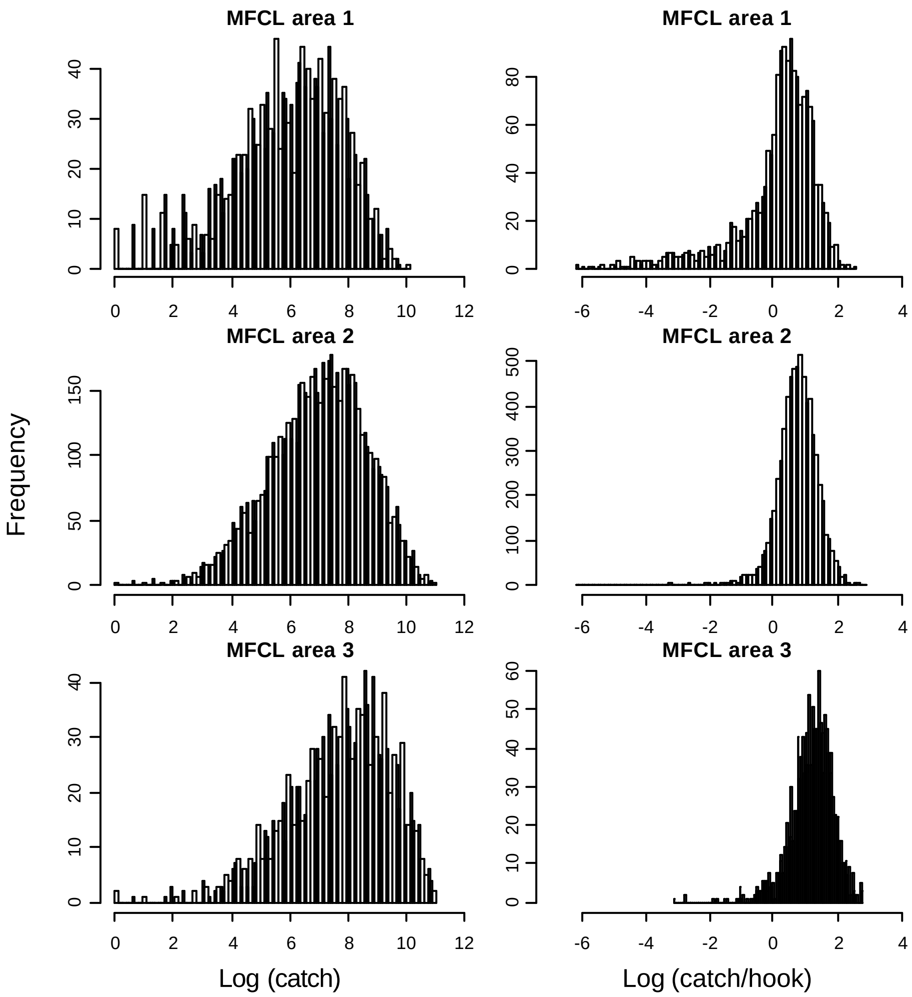

Figure 6: Histograms of the distribution of logarithm of albacore catch (number of fish) and catch rate (number of fish per 100 hooks) for each of the three MFCL area data sets.

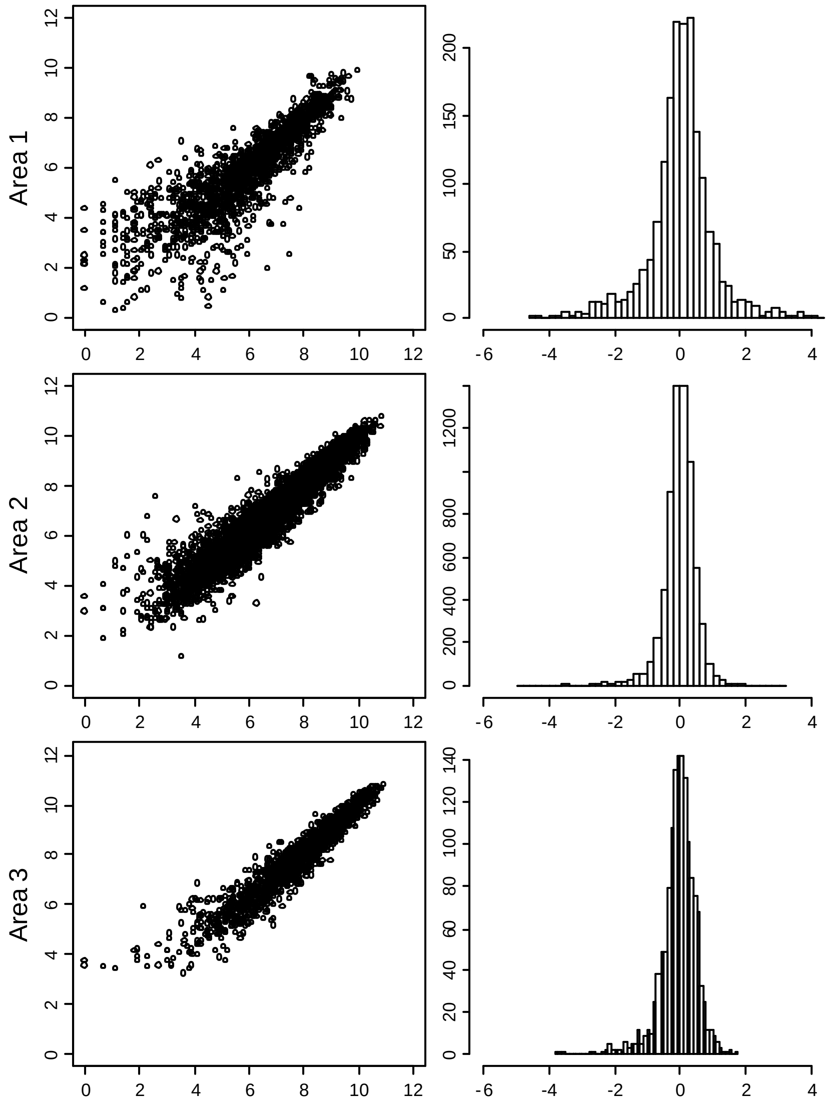

Figure 7: A comparison of the observed (x-axis) and predicted (y-axis) values from each of the three MFCL area CPUE analyses (left) and the distribution of the residuals for each model.

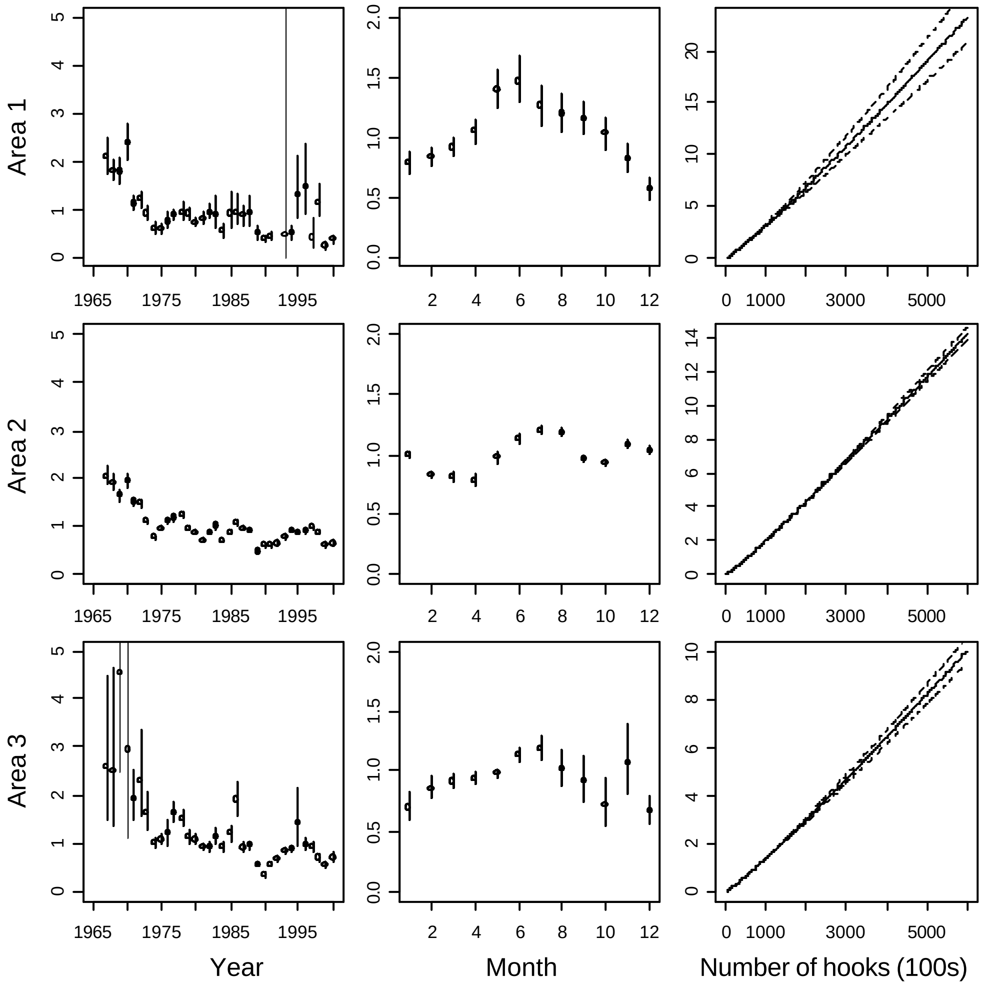

Figure 8: Predicted relationship between albacore catch and year (left), month (centre), and number of hooks set (right) for each MFCL area. The confidence intervals represent +/- two standard errors.

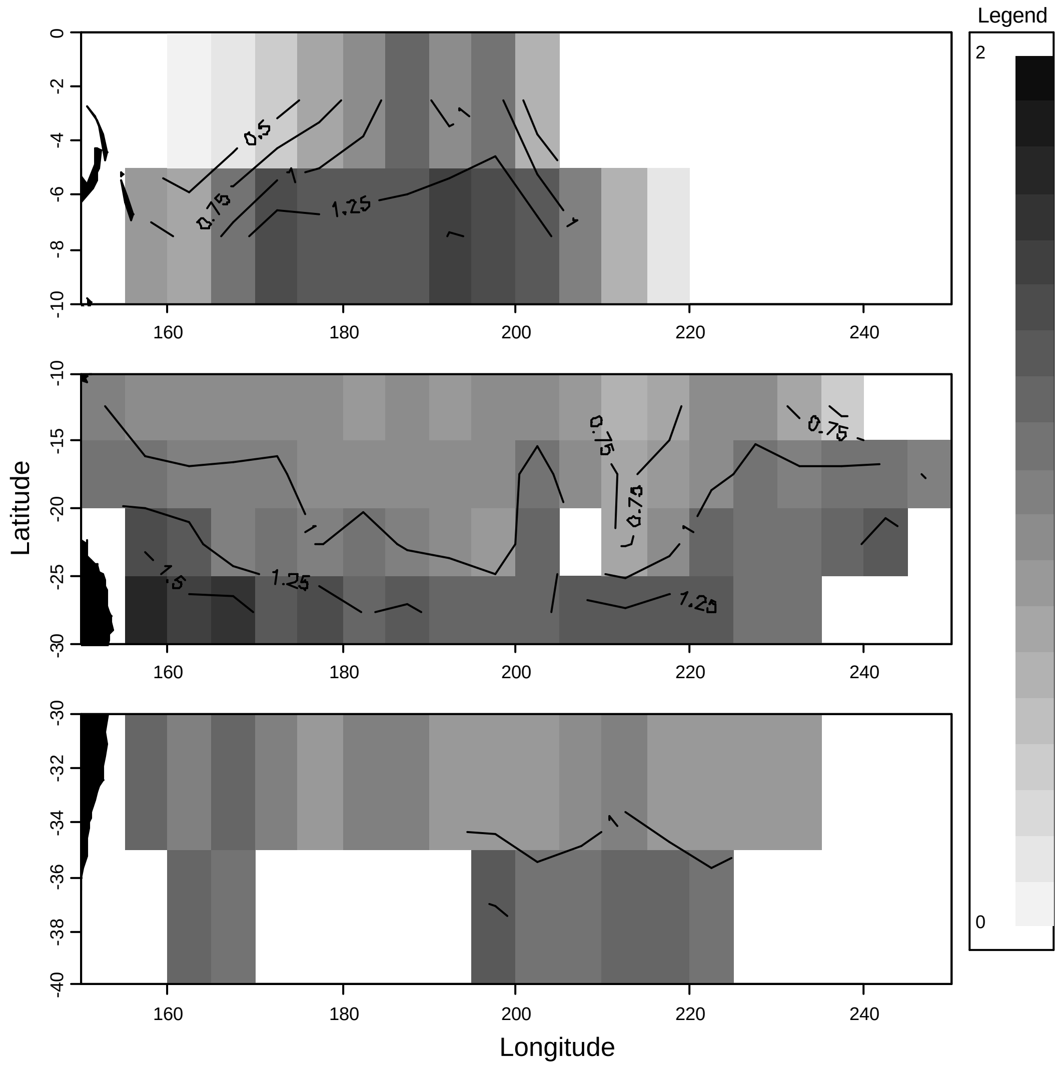

Figure 9: Relative catch rate of albacore by latitude and longitude bin for each MFCL area (1 to 3, top to bottom). The relative catch rates are not scaled to be comparable between the three models. Only lat/long cells with at least 30 records are presented.

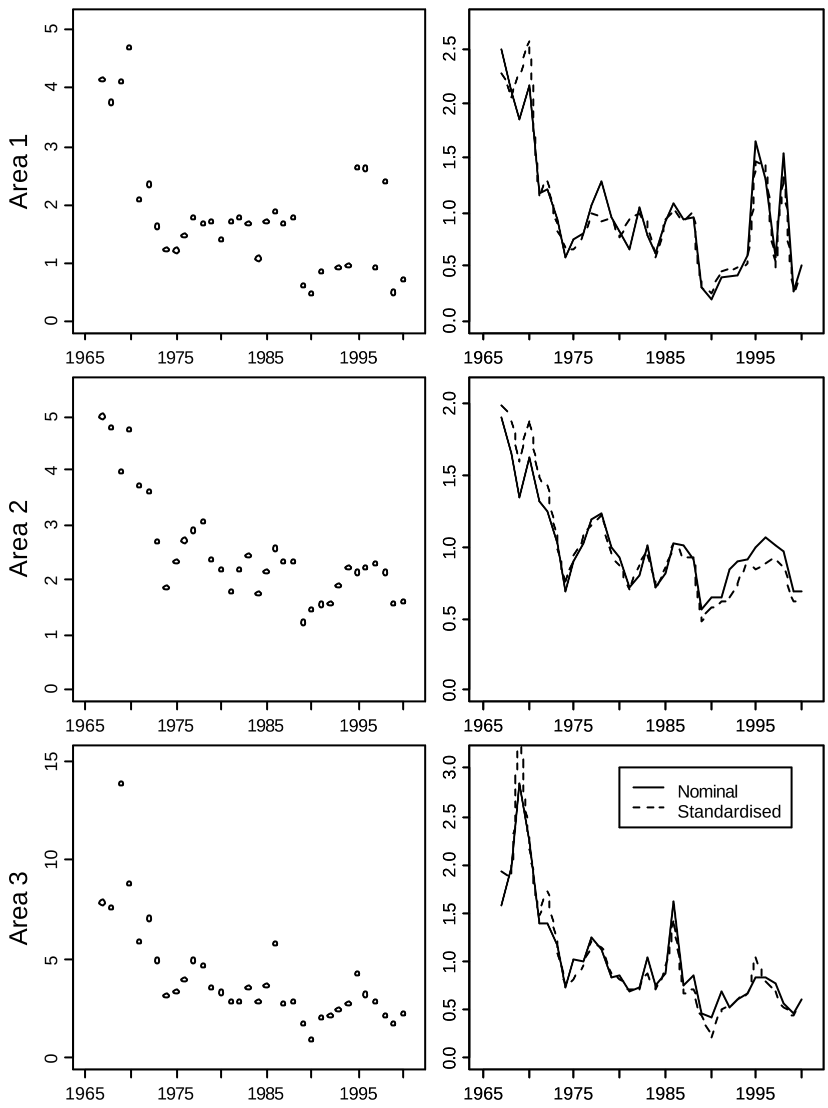

Figure 10: Annual CPUE indices by MFCL region for the South Pacific albacore stock. Standardised indices (left) scaled by global mean catch rate (number of fish/hundred hooks) and a comparison of the standardised indices and nominal CPUE (number of fish/hundred hooks) for each area (right). For comparison, the two series are scaled to the mean of the series.

5 DISCUSSION

The three generalised linear models explain a high proportion of the observed variation in the albacore catch from the Taiwanese fleet aggregated by month and spatial cell. Most of the observed variation is explained by the level of fishing effort in the cell. The year effect also contributes significantly to the explanatory power of each model and the individual annual indices have high precision, with the exception of years with very limited data.

The CPUE models do not reliably predict very small catches of albacore. These account for only a small proportion of the total number of records due to the temporal and spatial aggregation of the data. Similarly, there are very few records with no albacore catch, with the exception of the data from the more recent years in MFCL area 1.

Since the mid 1980s, fishing effort and albacore catch in MFCL area 1 by the Taiwanese fleet has been low and there has also been an increase in the proportion of the zero albacore catches in the area. During the same period, there was a decrease in the proportion of albacore in the catch and a corresponding increase in the proportion of bigeye and yellowfin in the catch (see Appendix 2). This trend has been most pronounced in the last three years of the time-series and may indicate a recent shift in the targeting behaviour of the fleet. In contrast, albacore accounted for most of the total catch from the two other MFCL areas throughout the time period.

Changes in targeting behaviour may be explained by the CPUE model only if these equate to measurable differences in the variables included in the model data set. Given the highly aggregated nature of the Taiwanese longline data, it is unlikely that changes in targeting behaviour will be described by the variables available, although it may be approximated by the inclusion of catch data from the associated target species as a predictor variable. The inclusion of the catch of yellowfin and, to a lesser extent, bigeye in the MFCL area 1 analysis marginally improved the explanatory power of the model, although there was no significant difference in the year effects between the generic model (excluding the associated catch) and the full model. This may be partly due to the removal of null albacore records from the CPUE data set.

The impact of aggregation of the data to the current spatial scale (5 degree bins) has the potential to introduce biases to the annual indices if the fleet has the potential to increasingly target finer scale areas that yield higher catch rates. This may occur through the increased availability of bathymetric and oceanographic data. The models have attempted to incorporate the readily available environmental data. These proved to be uninformative in the prediction of the catch of albacore. However, such information is likely to be more informative at a higher level of spatial resolution, especially if more detailed oceanographic information is included as predictive variables, for example information concerning the location of oceanic features such as fronts and eddies.

Future analyses should explore the potential biases introduced in the analysis by the aggregation of CPUE data at various spatial scales. However, this would be dependent on the availability of longline data at a high level of resolution, preferably at the level of the fishing event.

The trends in annual indices are broadly comparable between the three MFCL areas. There was a strong initial decline in catch rates during the late 1960s–early 1970s. The high initial declines in catch rate may be attributable to localised declines in small areas attracting a considerable proportion of the total annual fishing effort. The Tokelau and Tuvalu EEZs attracted considerable effort in 1968–69 followed by Papua New Guinea and Solomon Islands in 1970–1974. These areas straddle the boundaries between MFCL areas 1 and 2. There was no strong concentration of effort in MFCL area 3, although this area exhibited a similar strong decline in catch rates prior to 1975.

Over the subsequent years, fishing effort was more widely distributed. During this period, standardised catch rates fluctuated, approximating a 7-year cycle, with peaks in catch rate about 1978, 1986, and 1995. These variations are likely to be attributable to variations in recruitment, possibly correlated with the Southern Oscillation Index. Inter-annual variation in recruitment strength can be investigated further in the framework of the stock assessment model for albacore.

6 References

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Lawson, T.A. 1997. Review of catch estimates for Taiwanese distant-water longliners. Oceanic Fisheries Programme Internal Report No. 31. Oceanic Fisheries Programme, Secretariat of the Pacific Community, Noumea, New Caledonia.

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Appendix 1. MFCL stock assessment model areas.

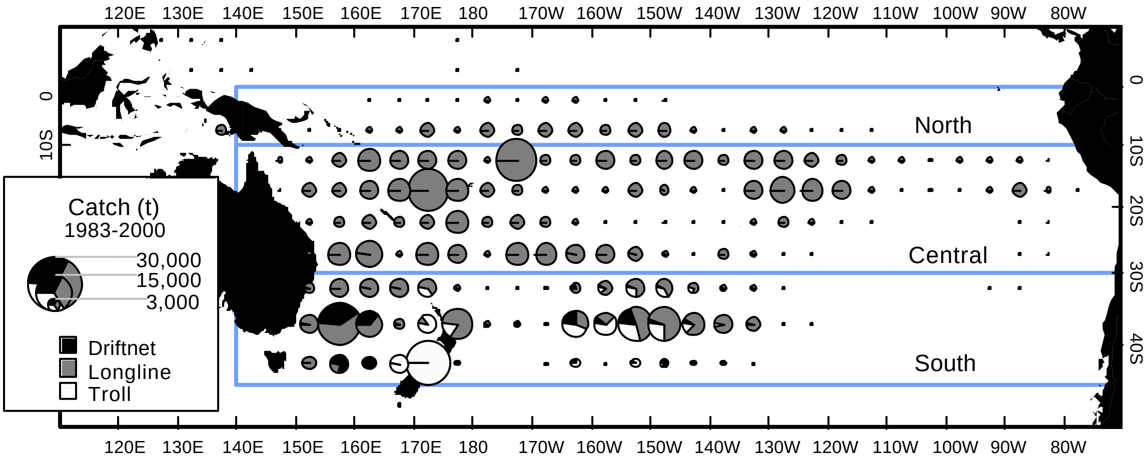

Figure A1. Albacore catch distribution (1983-2000) by fleet. The spatial stratification used in the MULTIFAN-CL model is shown (from Hampton 2002).

Appendix 2. Annual trends in the main variables included in the CPUE data set.

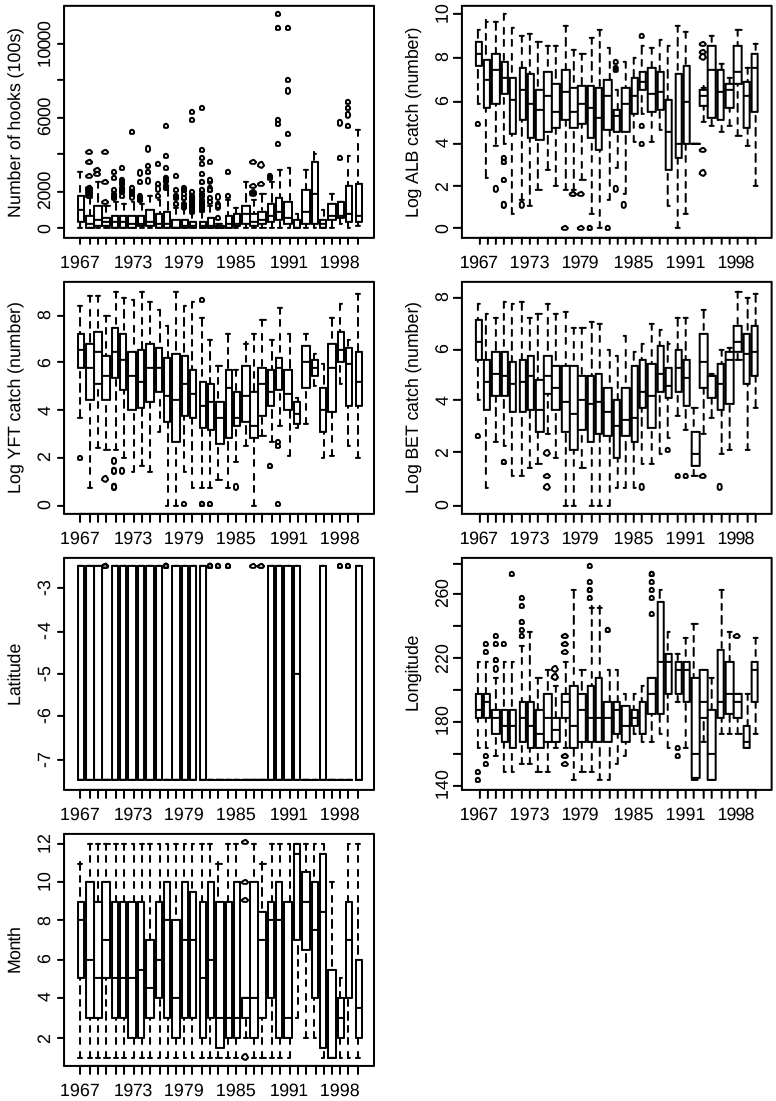

Figure B1: Boxplots of the main variables included in the MFCL area 1 data set by year.

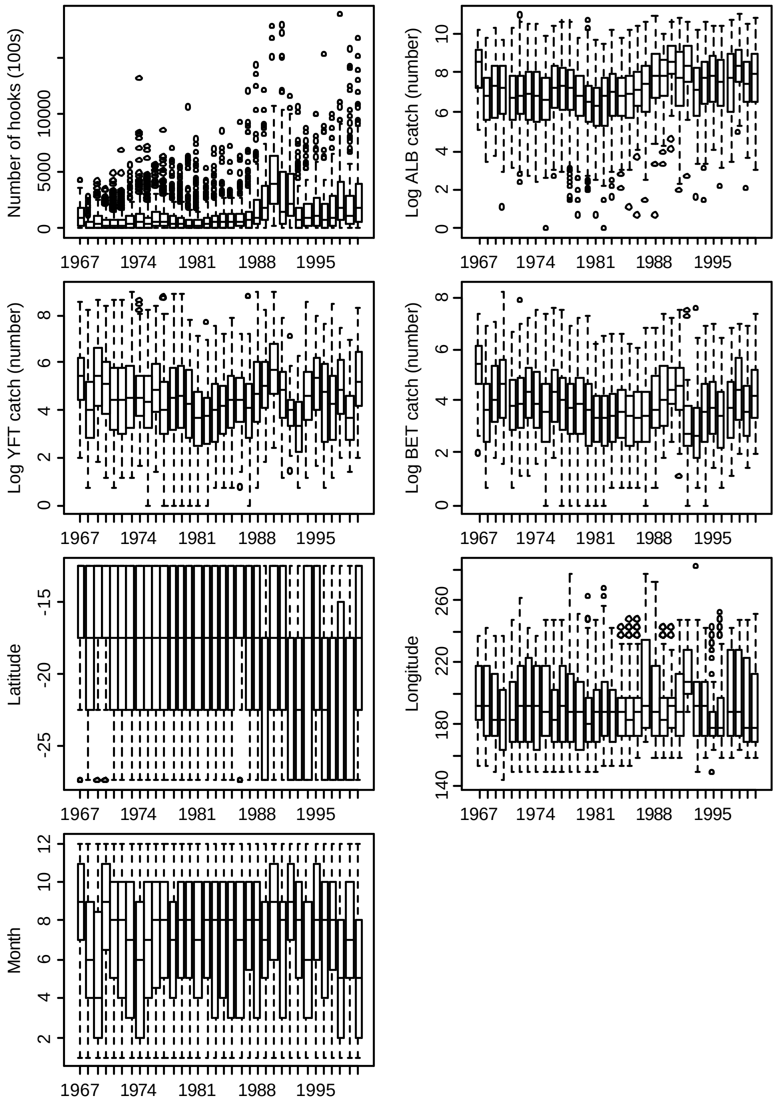

Figure B2: Boxplots of the main variables included in the MFCL area 2 data set by year.

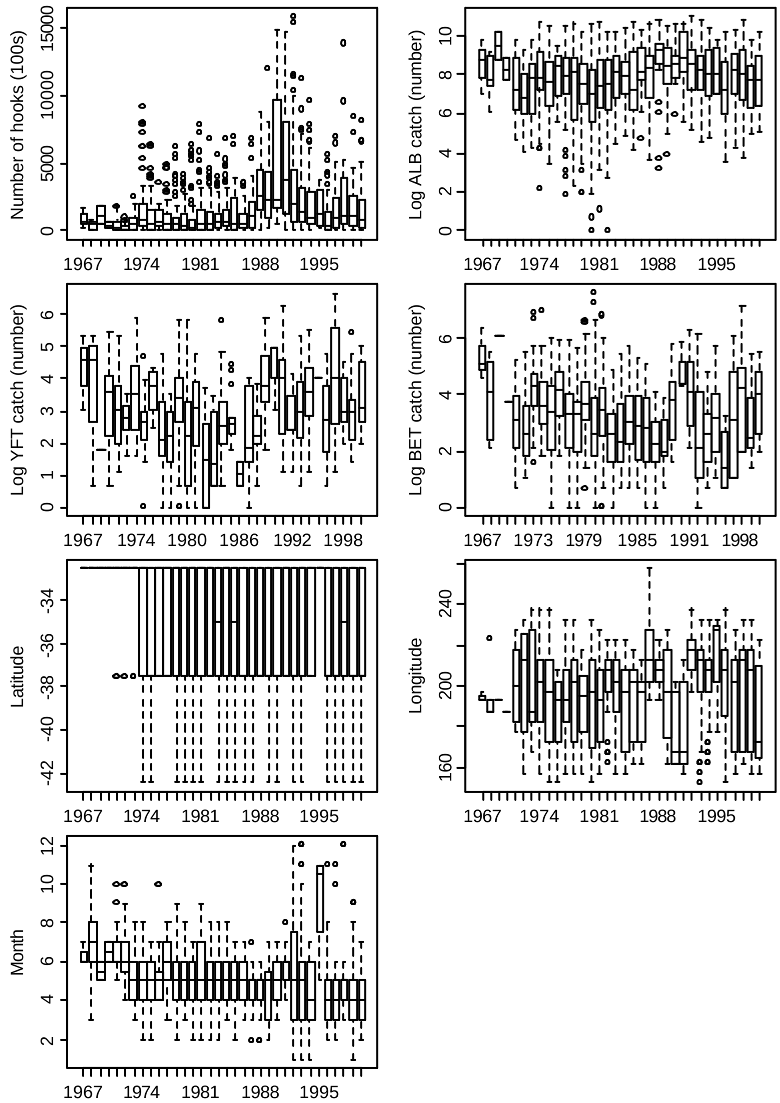

Figure B3: Boxplots of the main variables included in the MFCL area 3 data set by year.