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STANDARDIZATION OF THE CATCH PER UNIT EFFORT FOR ALBACORE (*THUNNUS ALALUNGA*) FOR THE SOUTH AFRICAN TUNA-POLE (BAITBOAT) FLEET FOR THE TIME SERIES 1999-2011

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SUMMARY

Albacore, Thunnus alalunga*, is the main target of the South African tuna pole (baitboat) fleet operating along the west and south west coast of South Africa and the South African catch is the second largest in the region with annual landings of around 5,000 t. A standardization of the CPUE of the South African baitboat fleet for the time series 1999-2011 was conducted using a lognormal GLM on a dataset that included all baitboat vessels in the fleet. The explanatory variables included year, month, area, distance offshore and target. Total deviance explained by the model was 45.1%. The inclusion of the effect of targeting other species of tuna, yellowfin in particular, caused the greatest improvement in explanatory power. The standardized CPUE is similar to the nominal CPUE with no overall significant upward or downward trends. The analyses indicate that the CPUE for the South African baitboat fishery for albacore has been stable over the last decade.*

RÉSUMÉ

*Le germon (*Thunnus alalunga*) est la principale cible de la flottille de canneurs sud-africains qui opère à l'Ouest et au Sud-Ouest du littoral de l'Afrique du Sud, les captures sud-africaines se trouvant au deuxième rang dans la région, avec des débarquements annuels se chiffrant à environ 5.000 t. Une standardisation de la CPUE de la flottille de canneurs sud-africains a été réalisée pour la série temporelle 1999-2011 à l'aide d'un GLM lognormal sur des jeux de données qui incluaient tous les canneurs de la flottille. Les variables explicatives incluaient année, mois, zone, distance du rivage et cible. La déviance totale expliquée par le modèle s'élevait à 45,1%. L'inclusion de l'effet du ciblage d'autres espèces de thonidés, notamment l'albacore, a entraîné la plus grande amélioration de la puissance explicative. La CPUE standardisée est similaire à la CPUE nominale sans aucune tendance générale significative à la hausse ou à la baisse. Les analyses indiquent que la CPUE pour la pêcherie de canneurs sud-africains ciblant le germon s'est maintenue stable au cours de la dernière décennie.*

RESUMEN

El Programa de investigación de atún rojo para todo el Atlántico, denominado GBYP, entre otros objetivos, tiene la tarea de mejorar los conocimientos de la biología, la ecología y la etología del atún rojo, prestando especial atención a la identificación de las subpoblaciones. Se presentan los resultados de los tres primeros años de actividades de recuperación y minería de datos. El GBYP pudo recuperar una cantidad considerable de conjuntos de datos históricos y recientes, que afectan a la mayoría de los artes y a muchos caladeros. Los datos relacionados con los artes pesqueros utilizados por los buques cubren los años desde 1903 a 2010, mientras que los datos relacionados con las almadrabas constituyen una serie histórica muy larga, desde el año 1512 hasta 2009, lo que constituye la serie temporal más larga de todas las OROP. También se recuperaron datos de peces engordados. La mayoría de los datos se refieren a la Tarea II (talla, peso, esfuerzo) pero también hay una gran cantidad de datos de captura. En varios conjuntos de datos hay incluidos datos sobre otras especies de captura fortuita. Los datos fueron verificados con la base de datos de atún rojo de ICCAT y posteriormente se comprobó su calidad individualmente. Este informe incluye una perspectiva general de los diversos conjuntos de datos.

KEYWORDS

Albacore, Thunnus alalunga*, Standardized CPUE, Baitboat, Tuna pole, Catch, Effort, GLM*

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1. Introduction

Traditionally, albacore, *Thunnus alalunga,* is the main target of the South African tuna pole (baitboat) fleet which operates in waters up to 1000 km off the South and West coast of South Africa and off Namibia. The South African catch is the second largest in the region with annual landings of around 5000 t. A large part of the catch is comprised of juvenile and sub adult fish below 900 mm FL which are abundant along the Southern African Atlantic coasts from November to May. The fishery started in the late 1970s and originally targeted yellowfin tuna, *T. albacares,* but switched to albacore when yellowfin moved off the Cape waters in 1980, a pattern that repeated itself in the middle of the first decade of the 21st century, when the yellowfin became abundant again around the Cape. Although tuna occur in mixed shoals, catches of bigeye tuna *T. obesus* and skipjack *Katsuwanus pelamis* are caught in low numbers in comparison to albacore.

The tuna pole fishery was originally managed as part of the linefishery, but it became a separate sector after an environmental emergency was declared in 2000 due to the collapse of most of the targeted sparid and sciaenid stocks. Since the medium term rights allocation in 2002 the tuna pole fishery sector consists of 191vessels of more than 10 m length, of which 136 are active. Reporting of monthly catch statistics has been compulsory since 1985 and includes daily catch (kg) per species per boat. The fishing area is also indicated and coded according to shore location and distance offshore.

Albacore *Thunnus alalunga* are caught by both surface and longline gear mainly along the west and south west coast of South Africa. In the south Atlantic, the Chinese-Taipei longline fleet has accounted for 46 to 90% of the total annual southern Atlantic albacore landed between 1970 and 2004 (ICCAT task I data). The South African baitboat fleet follows the Chinese-Taipei, landing approximately 4000t annually. Catches vary depending on the availability of albacore and yellowfin tuna in inshore waters. Other important southern Atlantic albacore fisheries are Brazil (longline) and Namibia (baitboat).

Characterisation of the South African fleet:

Traditionally the South African fleet has been characterized into three different categories (1) Skiboats, (2) Poleboats and (3) Freezer vessels (Leslie *et al*. 2004):

(1) Trailerable skiboats, gamefishing and recreational vessels of less than 25 GRT operating mainly out of harbours around Cape Town and are mostly confined to day trips within a range of 50 nm. Fishes are targeted with pole and with rod and line gear.
(2) Poleboats, which represent the bulk of the fleet, are mainly older displacement type vessels converted from other fisheries. These vessels can undertake multiday trips of limited duration and range, as the catch is kept on ice.
(3) Freezer vessels are mainly vessels up to 30m and 230GRT. Due to their large size and freezing facilities, these vessels can stay out at sea for long periods and reach the farthest fishing grounds.

There is considerable overlap between these categories as many of the modern pole vessels also have freezing capacity. Moreover, there are other factors that influence vessel performance significantly, such as navigational gear, the use of live bait, and more recently sonar.

A standardization of the CPUE of the South African baitboat fleet was first undertaken by Punt *et al*. (1996), who used Generalised Linear Models (GLMs), assuming a log-normal error distribution. The model was updated and refined by Leslie in (2000) and Leslie *et al.* (2004), who tested different error structures within a GLM and GLMM framework, using an offset to accommodate zero catches. Smith and Glazer (2007) applied a lognormal GLM to standardize the time series 1999-2005.

In the previous contribution a second dataset containing 40 indicator vessels, chosen based on the number of years fishing, was used. By using indicator vessels that fished over the entire time series we aimed to minimize variation in the data caused by vessels that have fished intermittently over short periods, which might be less consistent in targeting and catch reporting. Moreover, confining the analyses to indicator vessels allowed us to verify their vessel specifications i.e. GRT, length and boat category. However, using indicator vessels did not improve the analysis. The inclusion of *vessel* did not add to the explanatory power of the model, possibly because the categories (skiboat, pole and freezer) were somewhat artificial. Skipper and crew skills, electronic aids and the use of live bait are likely to influence catch rates and search times more than vessel size. Vessel type was not included in this study. In this contribution we build on the experience of the previous work and provide a standardized CPUE for the time series 1999-2011.

2. Materials and Methods

2.1. Catch and effort data preparation

Since 1985, catch statistics have been captured into the National Marine Linefish System (NMLS), a database system developed to capture and analyze recreational and commercial linefishing data (Penney 1993). From 1995 the data capturing procedure began to distinguish tuna pole vessels from linefish vessels. This is despite the tuna pole medium term rights allocation process only being conducted in 2002. Since there are tuna pole classifications prior to 2002, no assumption was made that linefish vessels capturing tuna prior to 2002 were tuna pole vessels and these catches were not included in the analyses. The dataset included all tuna pole vessels with tuna catches from 1999 to 2011. .

2.2. Targeting

Prior to 2002 the tuna pole sector fell within the multi-species linefishery. To analyse albacore-directed trips only, all trips with catches of albacore, yellowfin, big-eye, skipjack, bluefin and unspecified tuna were extracted. This method may include vessels targeting other catch but caught tuna and it will exclude vessels that targeted tuna but had zero catches. In the data from 1999 onwards however, the number of zero-catches has decreased sharply. The tuna directed fishery (i.e. vessels that undertake pole fishing) can be distinguished in the database based on the rights register and from 1999 onwards zero catches represented only a negligible number of data points (27 records), which were removed from the analyses.

2.3 Unspecified tuna

In previous analyses conducted by Leslie *et al*. (2004) and Smith (2005) various rules were applied to the data, depending on the presence of albacore and other tuna species, to decide on whether unspecified tuna was albacore. Based on the methods used by Leslie *et al*. (2004), the following rules have been adopted for unspecified tuna:

1a albacore catch was reported ....unspecified tuna were removed from the dataset
1b albacore catch was not reported 2
2a big-eye, bluefin and/or yellowfin were reported ....unspecified tuna were referred to albacore
2b no other tunas were reported ....unspecified tuna were removed from the dataset

Rule 2b was applied because of the uncertainty of the proportion albacore and other tunas in the catch.

The percentage catch records removed (rules 1a and 2b) from the dataset after these rules were applied totaled 1.6% and 7.5% from datasets 1 and 2 respectively. The percentage of unspecified tuna records that were reclassified as albacore (rule 2a) were 0.04% and 0.4% for datasets 1 and 2 respectively.

2.4 Constant multi-day catches

Skippers will at times only report the total catch weight at the end of the trip. As the data structure only allows for reporting catch per day, the data capturer will then divide the total catch by the number of days the vessel was at sea, thereby creating artificial, repetitive catch per day records. Including these data in the analysis would decrease the overall variance therefore only one of these records was included per trip. The percentage catch records removed from the datasets after this rule was applied totaled 16.3%.

2.5 Erroneous catch records

Smith and Glazer (2006) found that in some cases catch returns reported in numbers were erroneously entered into the database as weight. Consequently, a raising factor was applied to all catches less than 100 kg. In the period from 2005 onwards the data capturing and validation procedures as well as the quality of catch statistic reporting had constantly improved. Instead of applying a raising factor, which has the risk of artificially inflating small catches in cases where the reporting cannot be verified we removed catches below small thresholds. Different threshold levels (1 to 20 kg) where tested in preliminary runs, representing a maximum of 3.1% of the total records, with no marked effect on the results, therefore all data was included in its original form.

2.6 Covariates considered

2.6.1 Area

The areas defined by Penney *et al*. (1992) and used in previous analyses (Punt *et al.* 1996, Leslie 2000, Leslie *et al*. 2004 and Smith and Glazer 2007) have been modified in this analysis. These areas include the South-West (south of 33°S) and West (between 30°S and 33°S). Any catches recorded as north of 30°S were made in Namibia were not included in the analysis. In preliminary runs, we considered a finer alongshore resolution, but with very limited improvement to the model, hence we adopted the aforementioned area resolution.

2.6.2 Distance from shore

The distance fished from the shore was divided into three categories, viz.: Inshore (less than 100 km), Offshore (less than 200 km) and High seas (greater than 200 km); and included as a covariate.

2.6.3 Vessel type

The data collected from the catch statistics do not include vessel information. Determining the vessel specifications according to crew size and trip length are both deemed to be poor indicators of vessel type (Leslie *et al.* 2004, Smith and Glazer 2007). It is challenging to obtain this vessel information (gross registered tonnage (GRT), length, use of live bait and sonar information) for the entire fleet, but a classification into vessel type was attempted based on maximum and average number of crew. However, there was no significant improvement in explanatory power and given the problem with inaccurate crew reporting, *vessel type* was not considered as a covariate.

2.6.4 Seasonal effects

The albacore catches are seasonal and a majority of the catches are made from November to May (Penney *et al.* 1992; Punt *et al*. 1996). For this reason, month and quarter have been considered as co-variates. There were few catch records from the third quarter, 1.1% and 0.8% of the total catch days in datasets 1 and 2, respectively. As in previous analyses, these were removed from the analysis and only the 1st, 2nd and 4th quarter was considered.

2.6.5 Fishing tactic clusters

The availability of yellowfin tuna, which in some years occurs in high abundance around the Cape, affects the catches of albacore, which might become a secondary target. To account for this effect, we introduced the covariate *target* based on clustering fishing trips according to their similarity in catch composition. The identified clusters were assumed to be a representation of fishing tactics, which were treated as categorical variables in the GLM in order to adjust for differences in catchability associated with each cluster (Carvalho et al. 2010; Winker et al. 2013). To objectively identify clusters of fishing tactics, we applied the non-hierarchical clustering method CLARA to the proportions (by weight) of albacore and yellowfin tuna in the catches. The CLARA method is an extension for large datasets of the 'Partitioning Around Medoids' (PAM) method (Kaufman and Rousseeuw, 1990), where medoids are objects within a cluster for which the average dissimilarity to the remaining objects in the cluster is minimal. The CLARA analysis was based on 200 data subsets, each comprising 250 records. The optimal number of clusters was selected by way of iterative maximization of the 'Average Silhouette Width' (ASW) for the range of 2 to 5 clusters. The ASW can be used as a measure of within-cluster tightness and among cluster separation (Kaufman and Rousseeuw, 1990). This optimization procedure resulted in the selection of three clusters with a corresponding ASW value of 0.914. The first targeting cluster was the most frequent (n = 18387) and included all records where the proportions of albacore in catch records exceeded 0.81. The second cluster (n = 1533) included records with proportions of albacore ranging from 0.31 to 0.81, and the third cluster (n = 1366) comprised the remaining records with a proportions of less than 0.31 albacore by weight. In the last step, the indentified fishing tactic clusters for each catch composition record were aligned with the original dataset and treated as categorical variable in the GLM (Carvalho et al., 2010; Winker et al. 2013).

2.7 Model framework

Based on the previous work we opted for Generalised Linear Modeling with a log normal error distribution. The model was executed in version 2.11.1 of the 'R' programming environment (R Development Core Team (2010) with the "MASS" (Venables and Ripley 2002). After several preliminary runs where different combinations of offsets, explanatory variables and thresholds were tested, the full model with all explanatory variables included was of the form:

$$Ln(CPUE + \Delta) = \beta_0 + \beta_y + \beta_m + \beta_a + \beta_d + \beta_t + \epsilon$$

where Δ is the offset which was set at 0.1. This value was chosen because it resulted in the most normal-like distribution of residuals (Butterworth 1996) (**Figure 1**), b_0 is the intercept, β denotes the coefficients for each effect, y the year effect, m the month, a the area, d the offshore distance, t the targeting cluster and ϵ the error. The model was used to predict the base-case scenario (**Table 3**).

3. Results and Discussion

The deviance analysis for the step-wise regression procedure showed that all of the co-variates considered were significant. Total deviance explained by the model was 45.1%, a considerable improvement to earlier analyses, although not directly comparable (**Table 1**). The factor *target* explained by far the largest proportion of the total deviance explained by the model, whereas *distance offshore* had the least effect. As in Smith and Glazier (2007), residuals approached normality (**Figure 1**).

The inclusion of the effect of targeting other species of tuna, yellowfin in particular, caused the greatest improvement in explanatory power. Given the history of the fishery, which started during high availability of yellowfin around the Cape in 1979, this is not surprising. When yellowfin tuna become sporadically available in the inshore waters, a part of the fishery, especially the smaller boats, switch targeting. Although the way that targeting was used here has improved the model, further analyses are required. An amendment of the catch return forms, where the target per catch day is recorded should further improve the data in this fishery.

As in Smith and Glazer (2007) the signals derived from the analysis are weak. The standardized CPUE remained fairly stable in 2011 (**Table 2 and Figure 2**), whilst the nominal CPUE indicates a downward trend (**Figure 3**). The trend over the overlapping years was similar to Smith and Glazer (2007) with slight increases in 2001 and 2003. The analyses indicate that the CPUE for the South African baitboat fishery for albacore has been stable over the last decade. Further improvements are possible on all levels i.e. better reporting of species targets and fishing position, better classification of fishing time and vessel power and possibly the inclusion of environmental parameters such as sea surface temperature derived from satellite imagery.

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Table 1. Statistics of the model fit for albacore tuna pole fishery off South Africa (1999-2011). The terms were added sequentially, first to last. All factors contributed significantly to the total deviance explained.

Parameter	Res. d.f.	d.f.	AIC	Δ AIC	Res.Dev.	Δ Dev	% explained	*p*
β_0	21285		92633		96717			
β_y	21273	12	92195	-438	94641	-2076	4.76	***
β_m	21262	11	91990	-205	93639	-1002	2.30	***
β_a	21261	1	91945	-46	93430	-209	0.48	***
β_d	21260	1	91881	-64	93143	-287	0.66	***
β_t	21258	2	79937	-11944	53133	-40010	91.80	***
% deviance explained							**45.06**	

Table 2. Results of the CPUE standardization GLM.

	Standardized CPUE (kg boat^{-1} day^{-1})				
Year	ln(CPUE)	S.E.	CPUE	95% Confidence Interval	nominal CPUE
1999	6.40	0.0820	1820.5	1550.1 - 2137.9	1357.8
2000	6.43	0.0484	1872.4	1702.9 - 2058.7	1145.7
2001	6.59	0.0393	2200.4	2037.2 - 2376.7	1687.4
2002	6.36	0.0434	1755.3	1612.1 - 1911.2	1302.4
2003	6.47	0.0505	1947.7	1764.1 - 2150.4	1062.5
2004	6.27	0.0461	1604.3	1465.7 - 1756.0	1129.5
2005	6.71	0.0469	2488.8	2270.4 - 2728.3	1332.8
2006	6.50	0.0492	2008.1	1823.4 - 2211.6	887.6
2007	6.51	0.0456	2044.7	1870.0 - 2235.8	1312.0
2008	6.15	0.0547	1415.0	1271.2 - 1575.1	775.6
2009	6.49	0.0485	1993.8	1813.1 - 2192.6	1207.1
2010	6.42	0.0560	1862.6	1669.1 - 2078.6	1276.7
2011	6.30	0.0334	1653.4	1548.4 - 1765.4	650.8

Table 3. Reference dataset used to calculate standardized CPUE, where the target proportion of 0.9 represents the mean target value of the dataset.

year	month	offshore	cluster	zone
1999	12	<100km	1	SW
2000	12	<100km	1	SW
2001	12	<100km	1	SW
2002	12	<100km	1	SW
2003	12	<100km	1	SW
2004	12	<100km	1	SW
2005	12	<100km	1	SW
2006	12	<100km	1	SW
2007	12	<100km	1	SW
2008	12	<100km	1	SW
2009	12	<100km	1	SW
2010	12	<100km	1	SW
2011	12	<100km	1	SW

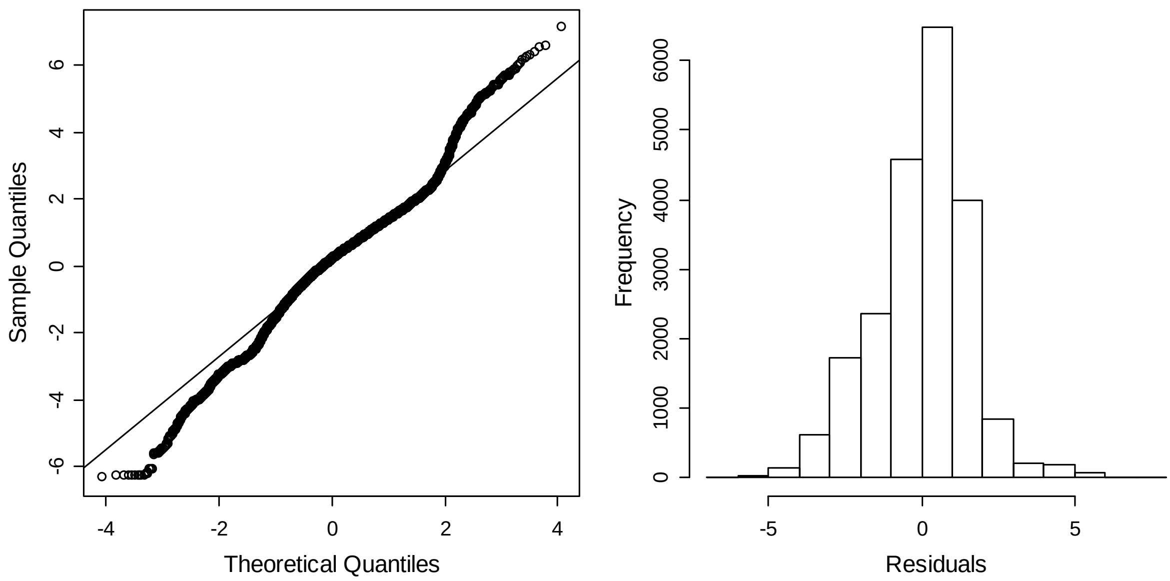

Figure 1. Diagnostic plots of quantile and residual distributions for the most parsimonious GLM with log-normal error

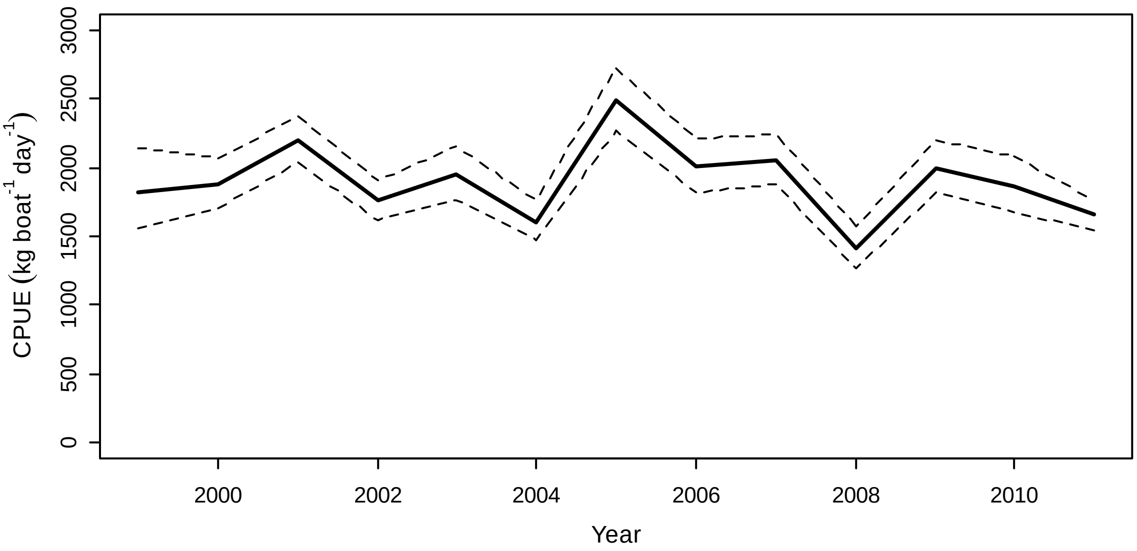

Figure 2. Standardized CPUE trends for the albacore tuna pole fishery off South Africa. 95% confidence intervals are shown by the stippled lines.

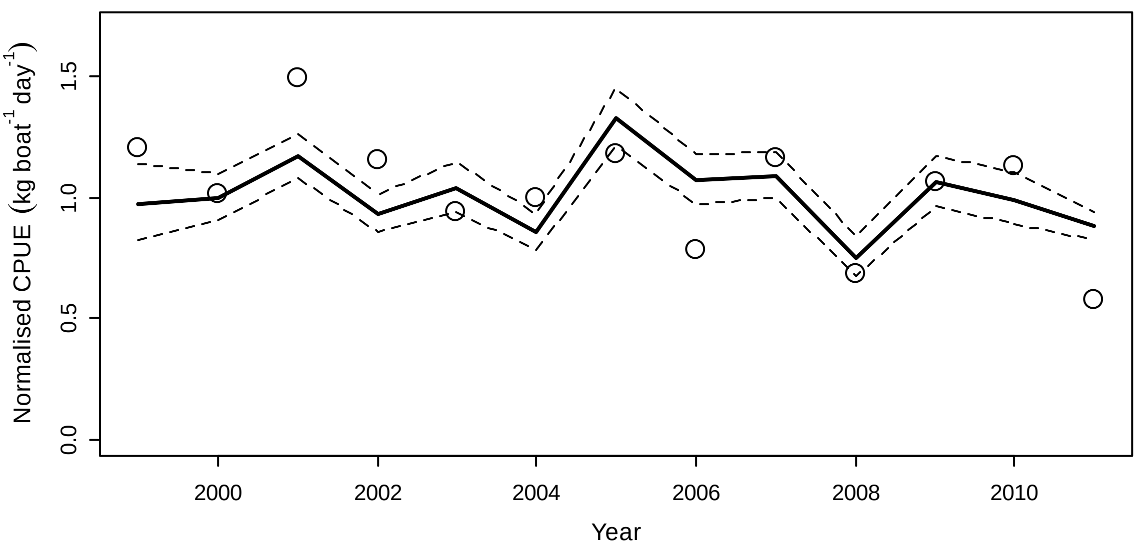

Figure 3. Normalised CPUE for the albacore tuna pole fishery off South Africa. 95% confidence intervals are shown by the stippled lines, nominal CPUE is depicted by open circles.