

**UPDATED STANDARDIZED AGE SPECIFIC CATCH RATES FOR
ALBACORE, *THUNNUS ALALUNGA*, FROM THE SPANISH TROLL FISHERY
IN THE NORTHEAST ATLANTIC: 1981 to 2011**

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SUMMARY

*Trends in relative abundance indices by age group of albacore (*Thunnus alalunga*) caught by the Spanish troll fleet in the North Eastern Atlantic were estimated using catch in number of fish and effort data from trips collected for the period 1981-2011. Standardized CPUE'S in number of fish per fishing day for age groups 2 and 3 years old albacore were estimated separately through the General Linear Modelling approach by applying the lognormal error distribution model with a constant variance.*

RÉSUMÉ

*Les indices relatifs d'abondance par groupe d'âge du germon (*Thunnus alalunga*) capturé par la flottille de surface espagnole de ligneurs ont été estimés à partir de la capture en nombre de poissons et de l'effort en jours de pêche à partir des sorties échantillonnées au cours de la période 1981-2011. Les taux de capture (CPUE) de cette flottille pour les groupes d'âge 2 et 3 ont été standardisés en appliquant un Modèle linéaire généralisé à chaque groupe d'âge, en postulant une distribution lognormale d'erreurs et une variance constante.*

RESUMEN

*Los índices relativos de abundancia por grupo de edad de atún blanco (*Thunnus alalunga*) capturado por la flota de superficie española de cacea se estimaron a partir de la captura en número de peces y el esfuerzo en días de pesca a partir de las mareas muestreadas en el período 1981-2011. Las tasas de captura (CPUE) de esta flota para los grupos de edad 2 y 3 años se estandarizaron aplicando el modelo lineal generalizado a cada grupo de edad, asumiendo una distribución log-normal de errores y varianza constante.*

KEYWORDS

*Thunnus alalunga, Albacore, Troll fleet, Catch rates, GLM model,
Abundance indices, North Atlantic, Age specific*

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1. Introduction

Data collected of albacore nominal catch rates by age group of individual trip from the Spanish surface commercial fleet have been used to develop relative abundance indices by age of immature albacore from the North Atlantic stock (Mejuto and Garcia, 1997; Ortiz de Zárate and Ortiz de Urbina, 2010). In the absence of other independent sources of information from the population, the standardized catch rates derived by means of the General Linear Modeling approach are used as indicators of abundance indices to tune the VPA analysis of the north Atlantic stock (Anon., 2010). The SCRS had used standardized catch rates from the troll fleet as an index of relative abundance for juvenile albacore ages 2 and 3 of north Atlantic stock (Anon., 2010).

This paper presented an updated information on trends in relative catch rates indices by age group for albacore targeted by troll fleet from 1981 to 2011. The standardized age-specific catch rates for ages 2 and age 3 were estimated by means of a general linear model GLM assuming the log-normal error distribution model in the analysis. Likewise, individual observations for catch rates age 2 and age 3 were added in a single group and analyzed applying the same GLM model.

2. Material and methods

Information on trips from commercial troll vessels was recorded at landing ports through interviews to skippers for the annual fishing season, that begins in Jun and extends to November in some years. Based on the monitoring of this fleet activity. The following data was obtained for each trip: date of landing, number of fishing days on the trip, location of effort on approximately 2°x2° degrees, catch in number, catch in weight (k), as well the catches landed by commercial categories accordingly to fishing market were randomly sampled to the nearest centimeter (FL= 35–120 cm range) on each single trip recorded (Ortiz de Zárate *et al.*, 2011). This fleet operates in the Bay of Biscay area and offshore waters in the North east Atlantic.

Age length keys applied to age the catch-at size composition of each trip sampled were estimated from length distribution analysis of north Atlantic albacore catch at size for the period 1975-1999 applying the Multifan length frequency analysis method (Santiago, 2001). Then age length keys calculated on the third quarter of a given year for the period considered were applied to age the catch length composition of albacore by trip. The last 1999 age-length key estimated by Santiago and Arrizabalaga (2001) was extended up to 2011 to obtain catch-at-age composition from the catch at size of each single trip that was monitored. Because of the deterministic method applied for slicing the length distribution of albacore caught by trip, the number of fish obtained by age 2 and 3 were afterwards added, to derive a new age group 2 plus 3. This approach would avoid the potential bias in allocating fishes into different age groups 2 and 3, which represent the target immature population of North Atlantic albacore stock caught by this fleet.

In 2010 and 2011, the catch distribution of the troll fleet was located in the offshore waters in the North eastern Atlantic and in the Biscay waters (Ortiz de Zárate *et al.*, 2012; 2013). The stratification of fishing area, which represents the spatial distribution covariate in the GLM model fit is the same as in previous analyses (Ortiz de Zárate and Ortiz de Urbina, 2011), defined as a variable factor ZONE with four levels (NE, SE, NW, SW) that cover the Bay of Biscay area and the offshore North eastern Atlantic waters as shown in **Figure 1**. The temporal covariate was defined by aggregation of month into three strata in order to have enough observations as in previous analyses. Accordingly, the variable factor QUARTER was defined with three levels artificially named: QUARTER 1 (May, June and July), QUARTER 3 (August and September) and QUARTER 2 (October and November).

The present analyses used the GLM approach assuming the log-normal error distribution model and the following explanatory variables: Year, Zone and Quarter to model the logged CPUE for ages 2 and 3 groups caught from 1981 to 2011. As well as the catch rates in number of fishes of ages 2 and age 3 of albacore were added in a single group, named age 23 and then modeled as logged CPUE 23 using the same GLM approach.

$$\text{LOG (CPUE)} = \mu + Y_i + Z_k + Q_l + \varepsilon_{ikl}$$

where

μ = overall mean

Y = factor year; levels: 1981-2006

Z = factor zone: NW, NE, SW, SE in **Figure 1**.

Q = factor time, three artificially created quarters: 1, 2, 3.

ε_{ikl} = log-normal error distribution

Analyses were done using the Generalized Linear Model (GLM) procedure of S-PLUS 2000 statistical software (Professional release 2) which includes the contrast treatment option to estimate the coefficients relative to the first level of each factor in the model.

Relative indices of abundance by age group 2 and 3 of albacore catch rates (N° fish/fishing day) were estimated by GLM model respectively. The least squares means (LSmeans) estimates were bias corrected using the algorithm of Lo *et al.*, (1992) and back-transformed estimates of CPUE's expressed in number of fish by fishing day were calculated for age 2 and age 3 groups. Because of the fix method applied for slicing the length distribution of albacore caught by trip, the number of fish obtained by age 2 and 3 were afterwards aggregated, to and analysed as a single time series of catch rate observations named CPUE 23 that was analysed using, the same procedure GLM model analyses that the one fit to standardized catch rates of age 2 and age 3 independent time series.

3. Results and discussion

Total number of observations included in the analyses were 7787 trips for age 2 group and 7855 CPUE's observations for age 3 group albacore. Meanwhile a total of 8232 observation were summarized for CPUE of age 2 and 3 added. The summary of observations aggregated by the time (QUARTER) and area (ZONE) covariates included in the GLM model of the three time series are included in **Table 1**.

The summary of model fit and statistics of the ANOVA Type I significance test for fixed factors for the albacore standardization by age group 2 and age group 3, as well as age group 2 plus 3 were shown in consecutive in **Table 2**. As it was presented, the GLM model fit for age 2 CPUE albacore accounted for 39.5 % of the variability of the observed log-CPUE while model fit for age 3 observed albacore CPUE the 21 % of the variance. In addition, the GLM model fit to CPUE 23 time series, accounted for 45 % of the variability of the observed log-CPUE for ages 2 and 3 aggregated, representing an increase in the explained variance.

Diagnostics of the GLM model fits to catch rates in number of fish of age 2 were shown in **Figure 2a** and **Figure 2.b**, simultaneous in **Figure 3.a** and **Figure 3.b** were described for age 3 model and **Figure 4.a** and **Figure 4.b** represented the diagnostics for age 2 plus 3 model.. Density distribution plots of the response variables lnCPUE for ages 2 and 3 groups show an approximate normal distribution. Plots of standardized residuals of model fit and the normalized cumulative residuals (or QQ-residual plots) from log -CPUE modelled show a reasonable overall fit of residuals. While same pattern of reasonable overall fit of residuals were seen in the case of the aggregated 2 and 3 age groups CPUE.

Standardized catch rates (CPUE) of age group 2 and age group 3, their standard error and estimated coefficients of variation and 95% confidence intervals estimated by the two models are presented in the consecutive **Table 3.a** and **Table 3.b** for CPUE's by independent age group, respectively. Meanwhile, **Table 3.c** presented the same estimated values for the standardized catch rates (CPUE) of age 2 plus 3 group.

Trends of the standardized CPUE indices and their estimated 95 % confidence intervals obtained for ages 2 and 3 roll fleet as well as the corresponding log scale nominal CPUE are shown in **Figure 5** and **Figure 6**. Additionally, in **Figure 7**, was represented CPUE age 3 group with one year lag to compare with trend of CPUE age 2 group corresponding to the same cohort in a given year of the time series. As shown, there is some discrepancy in the trend over the years analyzed. This point was highlighted, and it was appointed the aging procedure as one of the reason for this results. Therefore another GLM analyses was done using the aggregated age group 2 plus 3. Consequently, in **Figure 8** was shown the trend of the standardized CPUE index and their estimated 95 % confidence intervals obtained for this age 2 plus 3 group catch rates of troll fleet as well as the corresponding log scale nominal CPUE.

The albacore ages 2 and 3 are presently targeted by the troll fleet and could be considered as abundance indicators of the immature albacore population in the North stock.

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Table 1. Summary of observations of CPUE age 2, CPUE age 3 and CPUE age 23 for covariates quarter and zone analysed in the model. troll fleet 1981-2011.

age 2 group albacore CPUE				age 3 group albacore CPUE				age 23 group albacore CPUE			
QUARTER	N°obs	ZONE	N°obs	Q	N°obs	ZONE	N°obs	Q	N°obs	ZONE	N°obs
1 (June-July)	3755	1 (NE)	1674	1	3718	1 (NE)	1674	1	3775	1 (NE)	1751
2 (Oct-Nov)	485	2 (SE)	1533	2	493	2 (SE)	1533	2	613	2 (SE)	1868
3 (Aug-Sept)	3547	3 (SW)	1298	3	3644	3 (SW)	1298	3	3844	3 (SW)	1304
		4 (NW)	3282			4 (NW)	3282			4 (NW)	3309
Total	7787		7787	Total	7855		7855	Total	8232		8232

Table 2. Summary of fit of the GLM model and ANOVA (Type I test) for CPUE age 2, CPUE age 3 and CPUE age 23 aggregated.

Model GLM	df	Residual SE	Adj R-Square	Pr(F>0)
CPUE age2	7387	0.853	0.395	< 2.2e-16
CPUE age3	7591	0.8152	0.2107	< 2.2e-16
CPUE age23	7899	0.8144	0.449	< 2.2e-16

Analysis of Variance Table (Sum of Squares Type I)

Response: Incpuenage2

	Df	Type I SSq	Mean Sq	F value	Pr(>F)
YEAR	30	1006.1	33.54	46.086	< 2.20E-16
QUARTER	2	1234.6	617.32	848.34	< 2.20E-16
ZONE	3	1332.7	444.24	610.491	< 2.20E-16
residuals	7387	5375.4	0.73		

Analysis of Variance Table (Sum of Squares Type I)

Response: Incpuenage3

	Df	Type I SSq	Mean Sq	F value	Pr(>F)
YEAR	30	841.0	27.134	40.830	< 2.20E-16
QUARTER	2	92.1	46.071	69.326	< 2.20E-16
ZONE	3	470.3	156.759	235.883	< 2.20E-16
residuals	7591	5044.7	0.665		

Analysis of Variance Table (Sum of Squares Type I)

Response: Incpuenage23

	Df	Type I SSq	Mean Sq	F value	Pr(>F)
YEAR	30	882.0	29.40	44.329	< 2.20E-16
QUARTER	2	1461.4	730.70	1,101.789	< 2.20E-16
ZONE	3	1967.7	655.89	988.982	< 2.20E-16
residuals	7899	5238.6	0.66		

Table 3.a. Standardized CPUE (number fish per fishing days), standard error, coefficient of variation and 95% confidence limits (based on a Normal approximation), and log nominal CPUE for albacore age 2.

YEAR	lsmean	SE	low.CL	up.CL	CV (%)	Standardized			Nominal
						CPUE _n	low.CL	up.CL	Age 2 lnCPUE _n
1981	3,18	0,15	2,88	3,48	4,84	34,69	25,65	46,92	3,40
1982	3,46	0,10	3,27	3,64	2,78	45,62	37,79	55,07	3,65
1983	3,23	0,09	3,05	3,41	2,89	36,42	30,33	43,75	3,51
1984	3,09	0,10	2,90	3,27	3,11	31,50	26,10	38,01	3,61
1985	2,73	0,09	2,55	2,92	3,41	22,15	18,45	26,59	2,91
1986	3,31	0,08	3,15	3,47	2,44	39,29	33,55	46,01	3,61
1987	3,31	0,15	3,02	3,61	4,50	39,53	29,51	52,94	3,78
1988	3,34	0,07	3,21	3,47	1,98	40,76	35,81	46,40	3,44
1989	2,91	0,06	2,80	3,03	1,97	26,52	23,70	29,68	3,27
1990	3,33	0,05	3,23	3,43	1,48	40,15	36,45	44,22	3,57
1991	3,72	0,05	3,63	3,81	1,28	59,48	54,20	65,28	4,06
1992	3,47	0,05	3,37	3,57	1,49	46,10	41,66	51,02	3,72
1993	3,39	0,05	3,29	3,49	1,54	42,62	38,47	47,22	3,65
1994	3,78	0,06	3,66	3,89	1,55	63,01	56,18	70,67	4,10
1995	3,66	0,05	3,56	3,76	1,40	55,94	50,58	61,87	4,03
1996	3,75	0,06	3,64	3,86	1,48	61,39	55,04	68,47	4,00
1997	3,44	0,05	3,33	3,55	1,59	44,98	40,39	50,08	3,98
1998	3,19	0,05	3,08	3,29	1,70	34,83	31,32	38,74	3,53
1999	3,00	0,05	2,91	3,10	1,63	29,01	26,36	31,93	3,41
2000	2,54	0,05	2,44	2,65	2,05	18,30	16,52	20,27	3,09
2001	2,79	0,05	2,69	2,88	1,81	23,31	21,11	25,73	3,30
2002	2,67	0,05	2,56	2,77	2,00	20,71	18,65	23,00	3,04
2003	2,72	0,05	2,62	2,83	1,94	21,89	19,73	24,28	3,17
2004	3,52	0,05	3,43	3,61	1,32	48,62	44,39	53,25	3,94
2005	3,77	0,05	3,68	3,87	1,33	62,69	56,83	69,17	4,25
2006	3,65	0,05	3,55	3,75	1,36	55,32	50,18	60,99	4,11
2007	3,50	0,05	3,41	3,60	1,40	47,85	43,48	52,66	3,97
2008	3,71	0,06	3,60	3,83	1,55	58,96	52,67	65,99	3,92
2009	3,29	0,06	3,18	3,40	1,71	38,48	34,46	42,96	3,99
2010	3,72	0,05	3,62	3,81	1,31	59,32	53,91	65,28	4,06
2011	2,69	0,05	2,59	2,79	1,94	21,23	19,17	23,52	3,24

Table 3.b. Standardized CPUE (number fish per fishing days), standard error, coefficient of variation and 95% confidence limits (based on a Normal approximation), and log nominal CPUE for albacore age 3.

YEAR	lsmean	SE	low.CL	up.CL	CV (%)	Standardized			Nominal
						CPUE _n	low.CL	up.CL	Age 3 lnCPUE _n
1981	2,35	0,147	2,06	2,64	6,26	14,61	10,95	31,15	2,44
1982	2,93	0,091	2,75	3,11	3,11	26,06	21,80	34,80	2,99
1983	3,04	0,088	2,87	3,22	2,90	29,28	24,63	25,85	3,21
1984	2,74	0,092	2,56	2,92	3,36	21,58	18,02	17,14	3,02
1985	2,34	0,086	2,17	2,51	3,68	14,48	12,23	23,73	2,37
1986	2,69	0,075	2,54	2,83	2,79	20,48	17,69	23,80	2,78
1987	2,56	0,142	2,28	2,84	5,57	18,00	13,62	23,64	2,81
1988	2,71	0,061	2,59	2,83	2,26	20,96	18,59	17,51	2,75
1989	2,43	0,052	2,33	2,53	2,15	15,81	14,28	14,02	2,56
1990	2,22	0,046	2,13	2,31	2,09	12,80	11,68	17,00	2,28
1991	2,41	0,047	2,31	2,50	1,97	15,49	14,11	19,81	2,58
1992	2,56	0,050	2,46	2,65	1,95	17,97	16,30	20,55	2,63
1993	2,59	0,050	2,50	2,69	1,91	18,65	16,92	14,27	2,66
1994	2,21	0,057	2,10	2,33	2,56	12,77	11,43	18,08	2,30
1995	2,47	0,049	2,37	2,56	2,00	16,41	14,90	7,94	2,62
1996	1,63	0,056	1,52	1,74	3,44	7,12	6,37	12,42	1,70
1997	2,08	0,052	1,98	2,19	2,50	11,21	10,13	13,96	2,34
1998	2,21	0,050	2,11	2,30	2,28	12,65	11,46	16,84	2,30
1999	2,40	0,048	2,30	2,49	2,02	15,32	13,93	15,86	2,59
2000	2,34	0,046	2,25	2,43	1,97	14,49	13,24	18,25	2,49
2001	2,48	0,048	2,38	2,57	1,94	16,61	15,12	7,20	2,72
2002	1,55	0,048	1,45	1,64	3,10	6,55	5,96	8,92	1,63
2003	1,76	0,049	1,67	1,86	2,76	8,11	7,37	14,10	1,88
2004	2,23	0,042	2,15	2,31	1,89	12,99	11,96	14,60	2,38
2005	2,26	0,045	2,17	2,35	1,97	13,37	12,25	17,42	2,41
2006	2,43	0,048	2,34	2,53	1,99	15,84	14,41	16,79	2,64
2007	2,40	0,044	2,32	2,49	1,83	15,41	14,13	18,02	2,56
2008	2,45	0,054	2,35	2,56	2,18	16,23	14,61	20,50	2,52
2009	2,59	0,052	2,49	2,69	2,00	18,53	16,74	24,80	2,92
2010	2,79	0,046	2,70	2,88	1,64	22,68	20,74	16,91	2,92
2011	2,40	0,051	2,29	2,50	2,13	15,29	13,84	1,39	2,71

Table 3.c. Standardized CPUE (number fish per fishing days), standard error, coefficient of variation and 95% confidence limits (based on a Normal approximation), and log nominal CPUE for albacore age 23.

YEAR	lsmean	SE	low.CL	up.CL	CV (%)	Standardized			Nominal
						CPUE _n	low.CL	up.CL	Age23 lnCPUE _n
1981	3,67	0,15	3,38	3,96	4,00	54,74	41,04	73,00	3,88
1982	3,93	0,09	3,75	4,11	2,31	70,75	59,20	84,54	4,14
1983	3,92	0,09	3,75	4,09	2,23	70,13	59,07	83,25	4,21
1984	3,50	0,09	3,33	3,68	2,59	46,33	38,78	55,35	4,06
1985	3,27	0,09	3,10	3,44	2,60	36,60	30,98	43,24	3,35
1986	3,69	0,07	3,55	3,84	2,02	56,02	48,38	64,87	3,95
1987	3,69	0,14	3,41	3,97	3,85	55,95	42,34	73,93	4,19
1988	3,81	0,06	3,69	3,93	1,61	62,76	55,66	70,76	3,90
1989	3,39	0,05	3,29	3,50	1,52	41,52	37,52	45,94	3,66
1990	3,59	0,05	3,50	3,68	1,26	50,50	46,21	55,18	3,74
1991	3,91	0,04	3,82	4,00	1,13	69,47	63,69	75,78	4,19
1992	3,82	0,05	3,72	3,91	1,27	63,46	57,71	69,77	4,02
1993	3,81	0,05	3,72	3,91	1,28	63,01	57,26	69,35	4,03
1994	4,01	0,06	3,91	4,12	1,38	77,20	69,24	86,08	4,33
1995	3,89	0,05	3,80	3,99	1,23	68,39	62,27	75,11	4,21
1996	3,85	0,05	3,75	3,96	1,36	65,77	59,36	72,86	4,04
1997	3,59	0,05	3,49	3,68	1,40	50,24	45,53	55,44	4,05
1998	3,52	0,05	3,42	3,62	1,41	47,08	42,73	51,88	3,76
1999	3,28	0,04	3,19	3,37	1,36	37,04	33,94	40,42	3,61
2000	3,00	0,05	2,91	3,09	1,52	27,88	25,50	30,49	3,40
2001	3,21	0,05	3,12	3,30	1,46	34,62	31,57	37,96	3,73
2002	2,85	0,05	2,75	2,94	1,65	24,01	21,89	26,32	3,06
2003	2,98	0,05	2,89	3,07	1,59	27,48	25,03	30,16	3,29
2004	3,64	0,04	3,56	3,72	1,14	52,91	48,77	57,41	3,94
2005	3,70	0,04	3,61	3,79	1,20	56,35	51,65	61,48	4,05
2006	3,86	0,05	3,77	3,95	1,22	66,24	60,40	72,66	4,35
2007	3,72	0,04	3,63	3,80	1,18	57,24	52,53	62,36	4,05
2008	3,96	0,05	3,86	4,07	1,34	73,25	66,00	81,30	4,18
2009	3,54	0,05	3,44	3,64	1,45	47,92	43,32	53,01	4,20
2010	3,97	0,05	3,88	4,06	1,14	74,01	67,73	80,87	4,34
2011	3,08	0,05	2,99	3,18	1,57	30,42	27,67	33,46	3,60

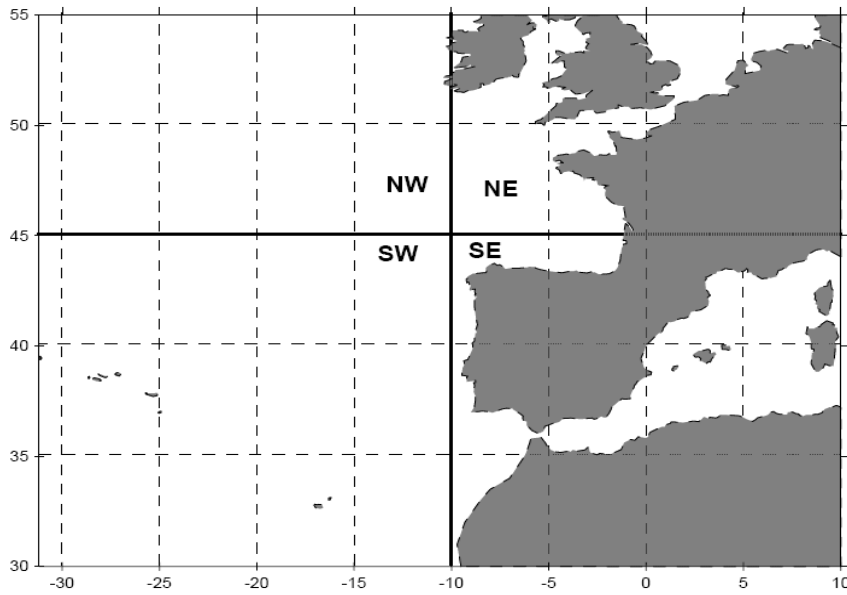
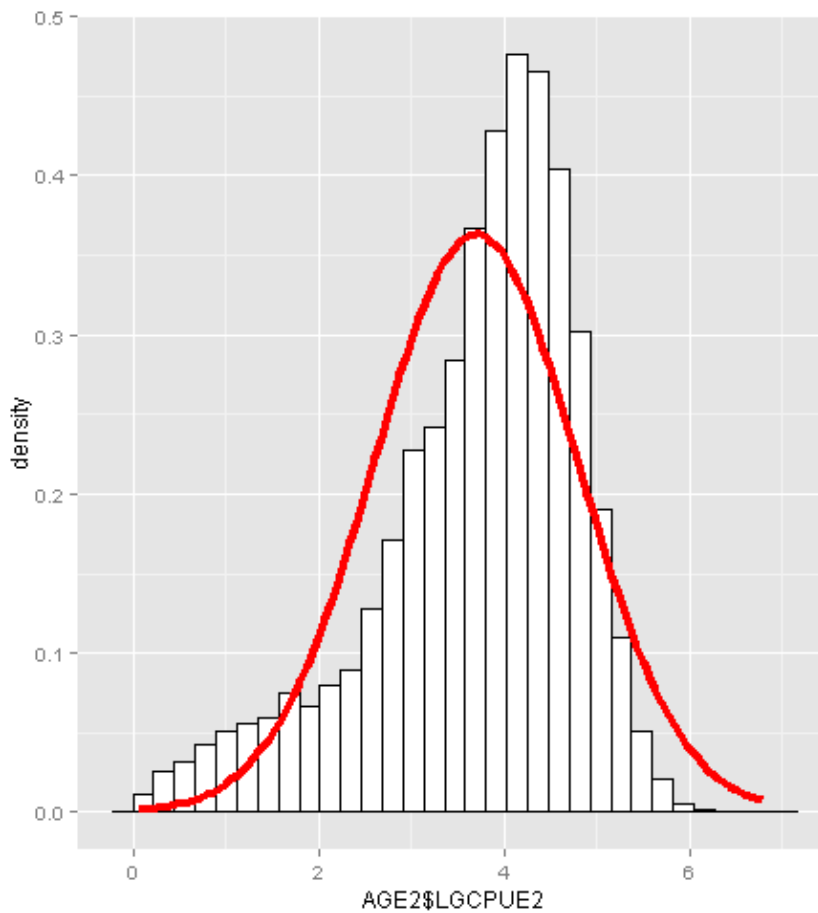


Figure 1. Geographic area stratification used in the analysis of Atlantic albacore troll fleet CPUEs by age group



2 and 3.

Figure 2.a Density and frequency distribution of total observed nominal CPUE (log-scale) in number of fish per fishing day for age group 2, for the troll fleet in period:1981-2011.

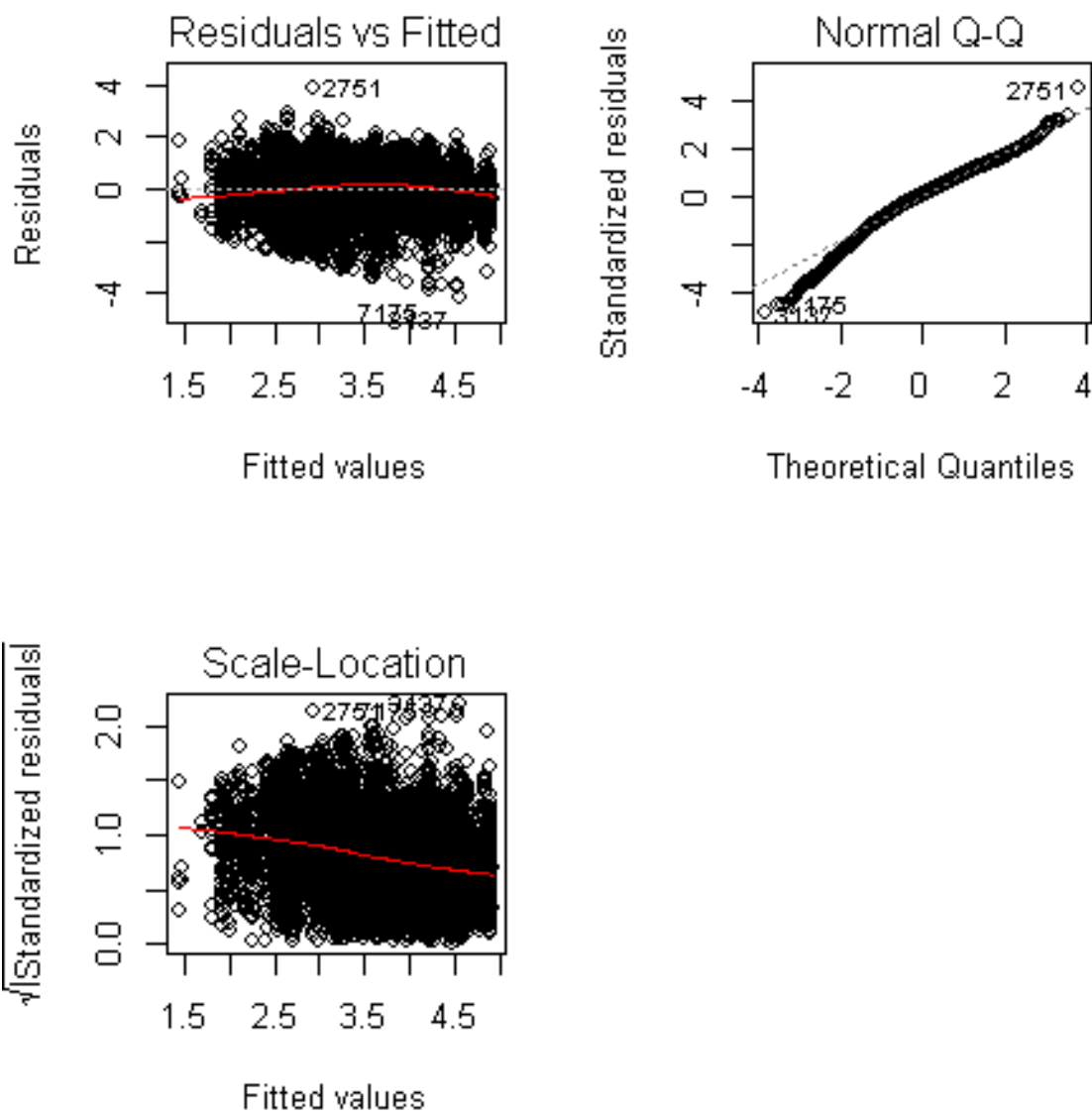


Figure 2.b Model fit diagnostics (clockwise from top to down). Residual versus fitted values, quantiles of standard normal, $\sqrt{|\text{abs}(\text{residual})}$ versus fitted). Log-Normal model CPUE age 2 of troll fleet. Years: 1981-2011.

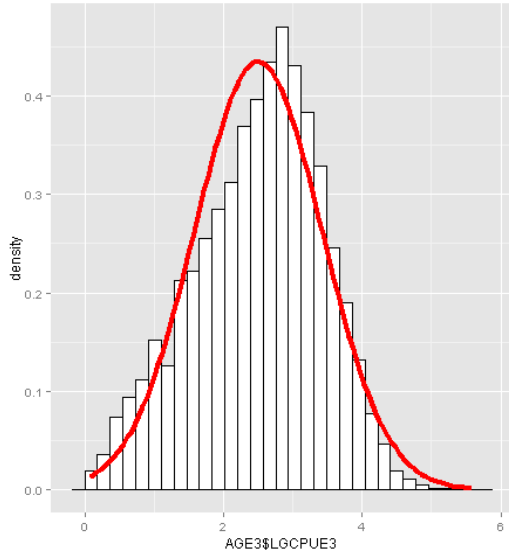


Figure 3.a Density and frequency distribution of total observed nominal CPUE (log-scale) in number fish per fishing day for age group 3, for troll fleet in period : 1981-2011.

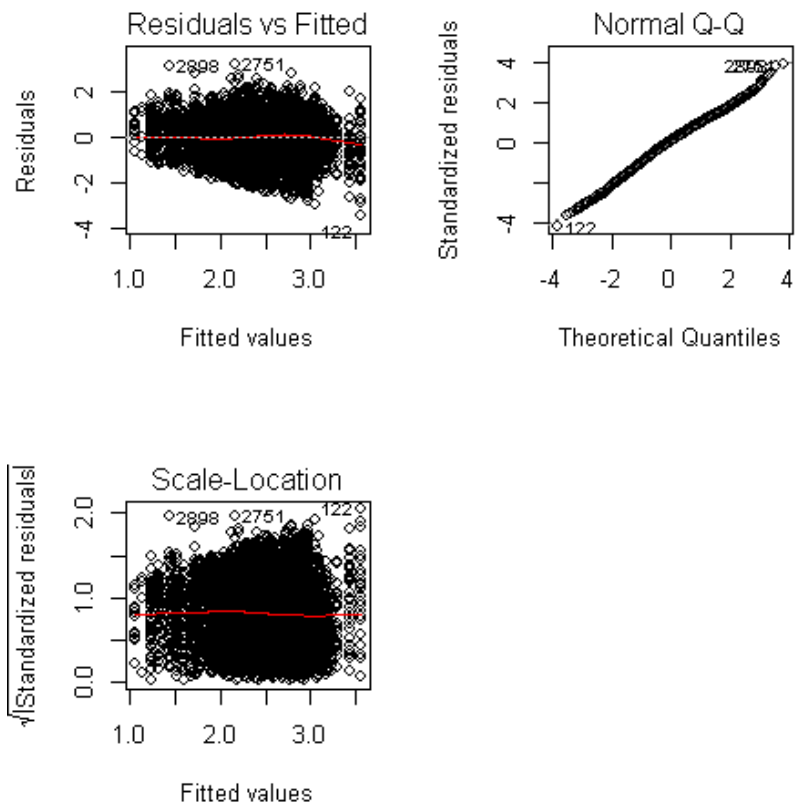


Figure 3.b Model fit diagnostics (clockwise from top to down). Residual versus fitted values, quantiles of standard normal, $\sqrt{|\text{abs}(\text{residual})}$ versus fitted). Log-Normal model CPUE age 3 troll fleet. Years:1981-2011.

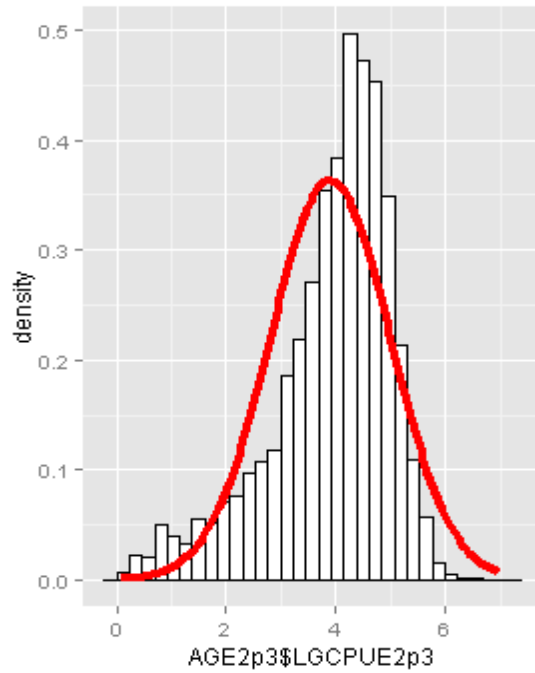


Figure 4.a Density and frequency distribution of total observed nominal CPUE (log-scale) in number fish per fishing day for age group 2 plus 3, for troll fleet in period: 1981-2011.

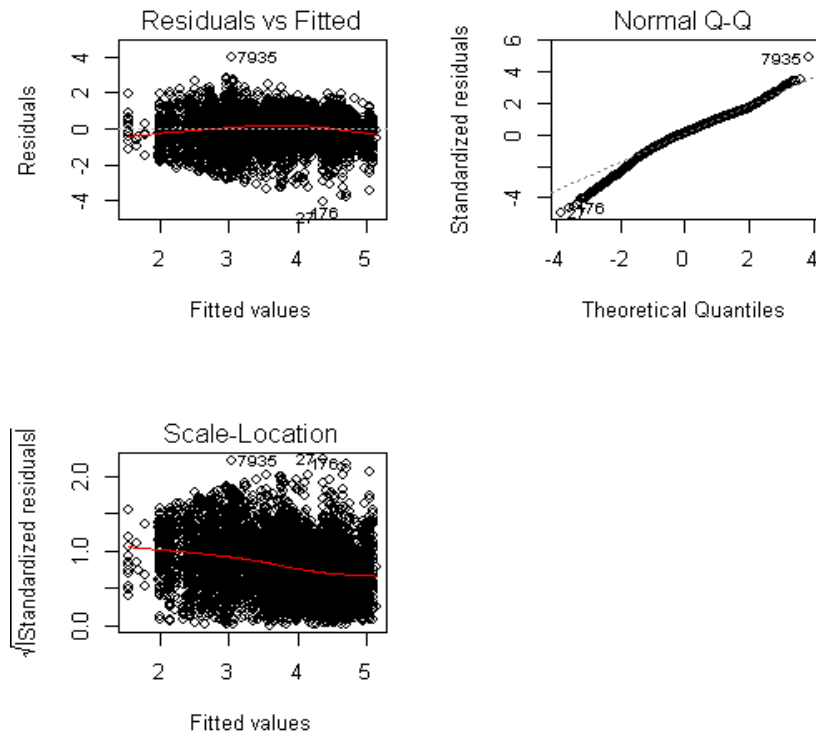


Figure 4.b Model fit diagnostics (clockwise from top to down). Residual versus fitted values, quantiles of standard normal, $\sqrt{|\text{abs}(\text{residual})}$ versus fitted). Log-Normal model CPUE age 2 plus 3 troll fleet. Years:1981-2011.

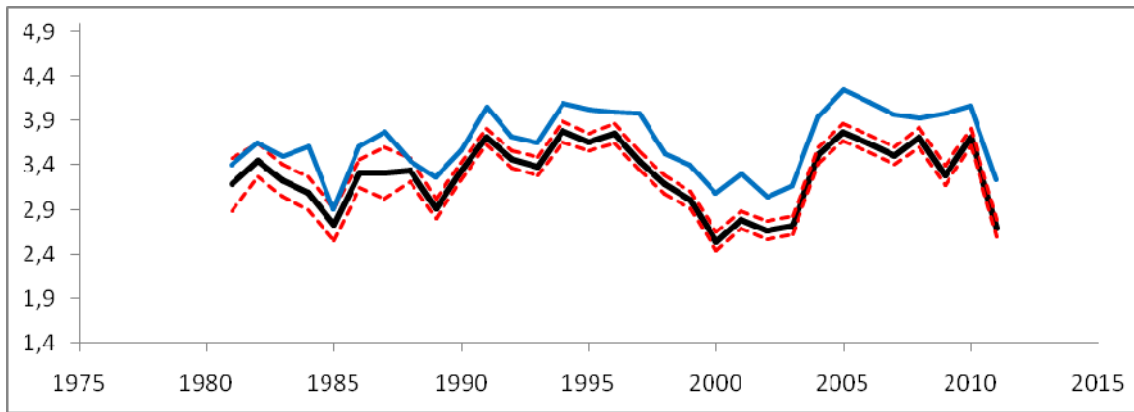


Figure 5. Observed CPUEa ge2 in log-scale (blue line), estandarized CPUE age2 (log-scale, black line) and confidences intervals of response variable (dotted red line) .

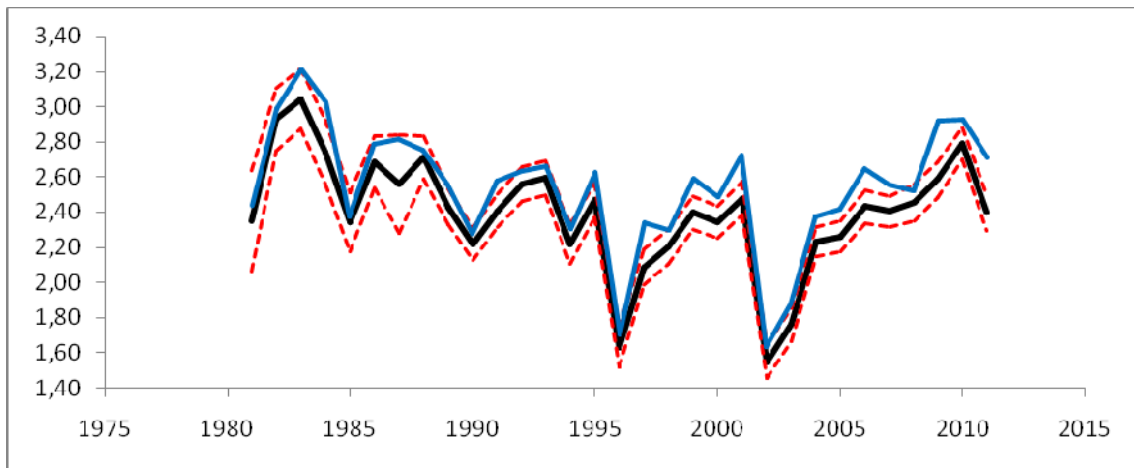


Figure 6. Observed CPUE age3 in log-scale (blue line), estandarized CPUE age3 (log-scale, black line) and confidences intervals of response variable (dotted red line).

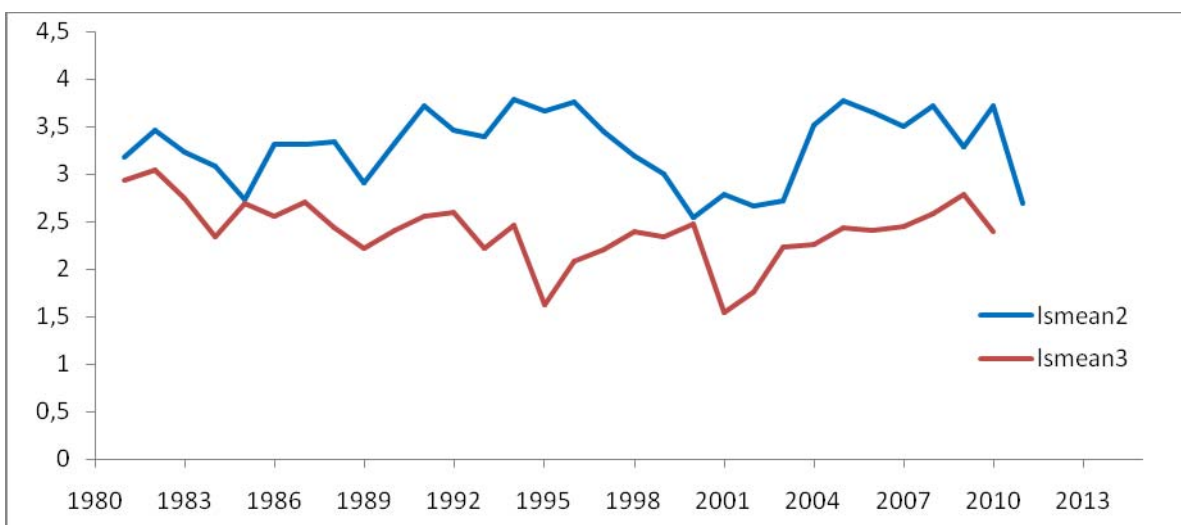


Figure 7. One year lag lsmeans age3 (red line) compare with lsmeans age 2 (blue line) of same cohort.

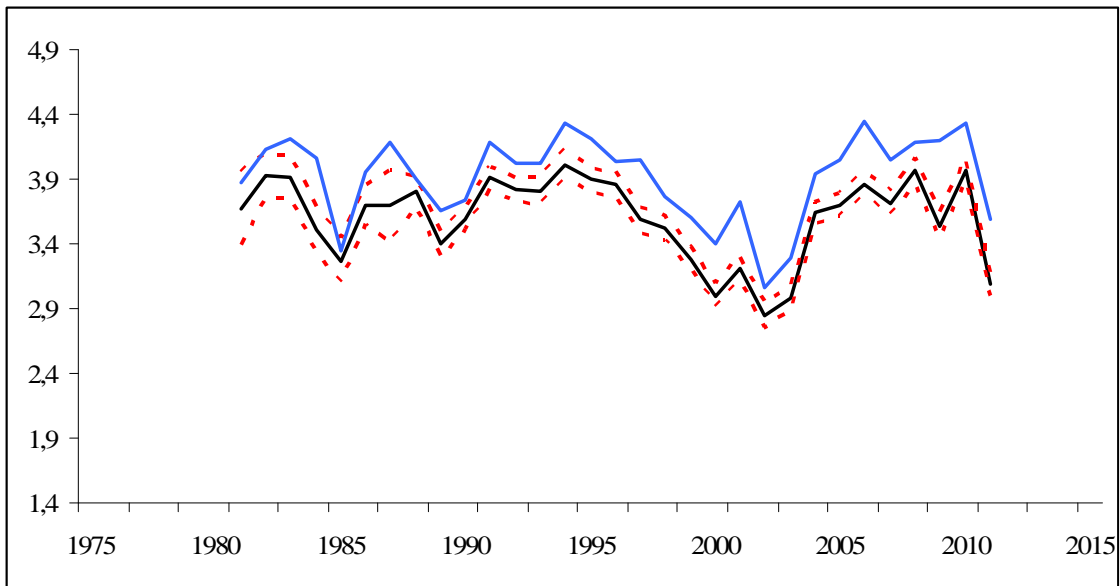


Figure 8. Observed CPUE age 23 in log-scale (blue line), estandarized CPUE age 23 (log-scale, black line) and confidences intervals of response variable (dotted red line).