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STANDARDISED CATCH RATES OF ALBACORE TUNA (*THUNNUS ALALUNGA*) FROM THE IRISH MID-WATER PAIRED TRAWL FLEET, 2003-2012

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SUMMARY

*Relative indices of abundance of albacore tuna (*Thunnus alalunga*) from the Irish mid water pair trawl fishery are presented for the years 2003-2012 in the format requested by the Working Group on Stock Assessment Methods. National landings log book data were used to estimate nominal catch rates in biomass. A standardised catch per unit effort index was produced using a Delta-lognormal model.*

RÉSUMÉ

*Des indices d'abondance relative du germon (*Thunnus alalunga*) capturé dans la pêcherie irlandaise de chaluts pélagiques en paire sont présentés pour les années 2003-2012 dans le format requis par le Groupe de travail sur les méthodes d'évaluation des stocks. Les données des débarquements nationaux des carnets de pêche ont été utilisées pour estimer les taux de capture nominale en biomasse. Un indice standardisé de prise par unité d'effort a été créé au moyen d'un modèle delta log normal.*

RESUMEN

*Se presentan índices de abundancia relativa de atún blanco (*Thunnus alalunga*) procedentes de la pesquería irlandesa de arrastre epipelágico por parejas para los años 2003-2012 en el formato solicitado por el Grupo de trabajo sobre métodos de evaluación de stock. Los datos de desembarques nacionales de los cuadernos de pesca se utilizaron para estimar las tasas de captura nominal en biomasa. Se obtuvo un índice estandarizado de captura por unidad de esfuerzo utilizando un modelo Delta-lognormal.*

KEYWORDS

Thunnus alalunga, Albacore, Mid-water pair trawl,
Standardised catch per unit effort, CPUE, Delta-lognormal model

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1. Description of the data source

(a) National landings and effort data based on a mandatory logbook system are compiled and provided annually by the Irish Department of Agriculture, Food and the Marine (DAFM). Detailed landings data from the Irish Midwater Pair Trawl (MWTD) fleet which targets albacore tuna were made available for the years 2003 to 2012 by DAFM. The Irish MWTD fleet commenced targeting albacore in 1998. Given the relatively short duration of this fishery to date, attempts were previously made to include catch information from early years in the fishery in catch per unit effort (CPUE) analyses to provide a contribution from a MWTD fleet to assessment of the North Atlantic Stock (Cosgrove, 2009). However, a number of factors contributed to restriction of the current study to the years 2003-2012.

- Data from the DAFM database were unavailable prior to 2003
- Some observer data were available prior to 2003 but there were some issues with these data:
- The years 1998 and 1999 were the first years when the MWTD method was attempted by Irish vessels. The vessels involved were inexperienced and fished under government subventions which may have resulted in varying levels of motivation to catch fish.
- No observer data were available from the MWTD fleet for the years 2000 and 2001 when observer effort was primarily focussed on drift nets before they were phased out.
- The MWTD fishery did not commence in earnest until post 2002 when drift netting was completely phased out and most of the vessels involved in the fishery in recent years commenced MWTD operations for albacore post 2002.
- Data prior to 2003 are only available in days fished whereas data available in the DAFM database from 2003 onwards are available in days at sea.

MWTD fishing involves 2 vessels towing a pelagic trawl between them close to the surface. This active fishing technique is restricted to night time when targeted fish are predominantly shallow (Cosgrove *et al*., 2014). In the early years of the fishery, vessels typically carried out a minimum of one haul each per night in an attempt to locate fish identified on echo sounders. As the fishery progressed, larger vessels with more powerful sonar systems entered the fishery. It is now common practice for vessels to restrict gear deployment until schools of albacore are detected by sonar. Albacore tuna is the only target species of this fishery although minor incidental bycatch of other species does occur.

(b) No changes to reporting requirements which have an impact on this study have been implemented since 2003.

(c) The following categorical variables were included in the index:

Year	
Quarter – 2 levels*:	June – August, Q3
September – November, Q4	
Fishing zones – 2 levels:	Ireland (north of 48 N)
	Bay of Biscay (south of 48N)
Vessel Category (m) – 5 levels:	<20, C1; 20 – 24, C2; 25 – 29, C3; 30 – 39, C4; >39, C5

*An alternative analysis based on natural quarters: July – September, Q3; October – November, Q4 is included in Annex II.

Year and Quarter temporal variables were included in the model. ICES area data available from logbook data were converted to two general zones to take account of a small number of observations in some ICES areas and the general distribution of the Irish fleet between two main areas to the west and south west of Ireland and the Bay of Biscay. Mean length of vessels involved in the fishery increased from 23m ± 2.71 (SD) in 2003 to 32m ± 12.74 (SD) in 2012. This increase may be indicative of increased fishing power in the fishery and appropriate vessel size categories were applied to the dataset. Questionnaires on changes in fishing power received from 10 vessel owners in 2012 indicated a switch to more powerful sonar in sampled vessels in the 30 – 39 m category from 2009 onwards. An initial model run on this data subset including a sonar power category revealed that this factor was significant. However sonar power was also found to be highly correlated with vessel size and more information and analyses are required before a sonar variable can be effectively included in the Irish MWTD index.

(d) Detailed catch at size information have been provided to ICCAT as Task II information annually since 2003.

(e) Changes in vessel size and potential changes in fishing power are described above. No change in market conditions has occurred in respect of landings from this fleet since 2003.

2. Methods

2.1 Data Reduction and Exclusions

(a) Data reductions and exclusions
Catch data prior to 2003 are excluded for the reasons outlined above. Data cleaning comprised of removal of two records where no vessel length information was available, and a number of records related to trips which occurred well outside the normal fishing season. The total number of trips in the dataset was reduced from 691 to 678 trips as a result of these exclusions.

(b) The quality of the data used in this analysis is thought to be relatively good. All of the vessels involved in this fishery are over 15m and are tracked using a satellite vessel monitoring system (VMS). Vessels are compelled therefore to submit correct information on location of fishing operations and number of days of sea. Landings are regularly inspected by the Irish Sea Fisheries Protection Authority (SFPA) which ensures that landings figures used in this study are accurate.

2.2 Management Regulations

(a) EC Ireland commenced fishing albacore tuna in 1990 through the introduction of drift netting (GILL). The fishery developed considerably in proceeding years reaching a peak of 4858 tonnes in 1999. However a phased EC ban on drift netting occurred from 1998 to 2001 with a complete ban in place by January 2002. In order to offset the negative economic repercussions of this ban, a major EU funded project was carried out in 1998 and 1999 to introduce alternative fishing methods, mid water pair trawling (MWTD) and trolling (TROL). MWTD is the predominant method use to target albacore since the drift net ban was implemented.

(b) The number of vessels involved in the fishery is restricted and the fishing quota has been fully utilised in the last two years but these measures are not thought to have a major effect on CPUE analysis.

2.3

(a) Relevant tables of observations are outlined in **Tables 1 to 3.**

(b) Detailed maps of Irish MWTD fleet days at sea during the study period are outlined in **Figure 1**. A clear shift of fishing effort from the Broader Bay of Biscay area in earlier years to a more restricted area off the south west coast of Ireland in later years of the study period is evident from these maps.

(c) Average CPUE (kg per day at sea) for each fishing trip was used as the response variable. Response variable values ranged from 0 to 38,000kg.

2.4

(a) A relatively small number of zero values in the dataset were initially dealt with by adding 1 to the response variable before log transforming the data. Problems in estimating predicted means from a log linear model of ln(CPUE + 1) were encountered (back-transformed means being sensitive to the magnitude of the small value added to the zero CPUE values), however, and a Delta-lognormal model was subsequently applied to the data to effectively deal with zero values.

(b) A binary variable taking on a value of one where CPUE>0 and zero when CPUE=0 formed the response variable of the binomial GLM component of the delta-lognormal model. The binomial model was applied to estimate the probability of obtaining a positive catch as a function of a set of covariates; and a log-normal model was applied to model the positive catches as a function of a set of covariates (Maunder and Punt, 2004). All covariates described above were initially included in both the binomial and log-normal models. Interactions with significant covariates were also considered with Year*Quarter and Year*Vessel category interactions initially included in both models. Final model runs excluded insignificant factors. The Year*Quarter interaction was significant in the lognormal model in addition to the main effect of year and vessel category. The standardized index from this model was obtained by taking an average across quarters and vessels weighted by the proportion of trips per vessel category and quarter over the entire dataset. For the non-interaction model, the most common categories of relevant categorical variables (Q4 and C2) were used as reference variables in deriving an appropriate standardised index of abundance (Maunder and Punt, 2004). CVs were not estimated in relation to the standardised CPUE index, as reliable variance estimates are difficult to obtain from delta-lognormal models and measurement error variances are better obtained as part of the assessment (Stefansson, 1996). Modelling was carried out using R version 2.15.1 and the code used is provided in Annex I.

3. Results

Final model results are outlined in **Table 4**. Significant covariates in the binomial model were Year and Vessel category. Significant covariates in the log-normal model of positive catches were Year, Vessel Category, Quarter and a Year by Quarter interaction. The Year by Vessel interaction was excluded due to the absence of some vessel category by year data. All factors included in the final model were highly significant with p-values less than 0.001 in all cases.

3.1

Model diagnostics are outlined in **Figure 2**. A skew is evident in the theoretical quantiles and histogram of residuals plots. This may be symptomatic of the way in which the fleet operates/catches fish and certainly warrants further investigation.

3.2

Standardised CPUE values are outlined in **Table 5** and **Figure 3**. Standardised CPUE by Quarter is also provided in Table 5 to facilitate inclusion of the series in this format in the Multifan-cl model at the stock assessment.

4. Discussion

The updated standardised CPUE index of the Irish Midwater Pair Trawl fleet is based on a 10 year time series of data that represents a period of consistency when all vessels were fully engaged in the commercial fishery. Notable changes in the fishery during this period include a geographic shift in effort from the Bay of Biscay to an area southwest of Ireland. Zone was not significant in the model which could suggest that differences in catch rates between the two zones were not significant. However, Zone was a relatively crude spatial categorisation. It was employed in an attempt to use ICES areas which are relatively unsuitable for this type of spatial analysis, and tells us little about spatial changes in catch rates. The observed geographic shift could be indicative of a change in migratory behaviour with albacore diverting directly for the south west coast of Ireland rather than entering the Bay of Biscay. Spatial comparisons of CPUE with other fleets could provide more information on this issue.

Another change in the fishery has been the entry of larger vessels in the 30-39 m and >39 m categories primarily since 2007 (**Table 2**). The 30-39 m vessel category has generally enjoyed comparable catch rates to the >39 m category (**Table 3**). This could be indicative of experience/skill levels in the fishery. Some of the main operators in the 30-39m category have progressed from smaller vessels and have been involved in the fishery since the early years whereas vessels in the > 40m category have simply switched effort from other fisheries for small pelagics such as mackerel and herring to the tuna fishery and have no prior experience of targeting this specific species. This could also be indicative of a maximum suitable vessel size in this specific fishery, above which, increased vessel power and potentially better fish detection systems are offset by decreased ability to manoeuvre and follow relatively fast moving fish shoals.

Differences between nominal CPUE and the final standardised CPUE (including interaction) trends indicate a marked increase in 2006 and decrease in 2007 in the standardised index which could be explained by the highly significant Vessel category in the model. The C2 category corresponding to vessels in the 20 – < 25m size range was the dominant size category in the dataset (**Table 2**) with 47% of all trips carried out by vessels in this size range. These changes in the standardised index are relatively consistent with the nominal CPUE trend of vessels in this category. Relatively little proportional difference was observed between the final standardised CPUE index including the Year by Quarter interaction and the standardised CPUE index excluding the interaction. A more detailed examination of vessel sonar and spatial factors should be considered in future CPUE analyses of this fleet.

References

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Maunder, M.N. and A.E. Punt. 2004. Standardizing catch and effort data: A review of recent approaches. Fish. Res. 70:141–159.

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Table 1. Number of trips carried out by Month, quarter and year.

	Quarter	3	4		
Year	Month 7	8	9	10	Totals
2003	7	24	45	25	101
2004	5	9	24		38
2005		2	12	14	28
2006		4	13	11	28
2007		2	14	16	32
2008		2	58	6	66
2009	1	9	50	24	84
2010		14	41	24	79
2011	2	45	25		72
2012	9	94	47		150
Totals	24	205	329	120	678

Table 2. Number of trips carried out by vessel category and Year.

	Vessel Categories					
Year	C1	C2	C3	C4	C5	Total
2003	19	63	19			101
2004	6	21	11			38
2005		21	5	2		28
2006		25		3		28
2007	2	17	3	10		32
2008		35	10	15	6	66
2009		32	20	22	10	84
2010		30	27	19	3	79
2011		18	21	18	15	72
2012	1	56	37	30	26	150
Total	28	318	153	119	60	678

Table 3. Nominal CPUE by Year and Vessel Category.

Nominal CPUE	Vessel Category					
Year	C1	C2	C3	C4	C5	Total
2003	269	946	410			718
2004	333	335	743			453
2005		1190	1111	1250		1180
2006		1659		6992		2230
2007	471	919	1302	5318		2302
2008		2165	3299	7476	3253	3643
2009		1320	2067	4635	4780	2778
2010		433	1378	3897	67	1575
2011		3092	5651	10082	12270	7498
2012	14	1214	3006	4737	3640	2773

Table 4. Delta log-normal model output.

	Binomial model of zero catches				
	Df	Deviance Resid.	Df	Resid. Dev	Pr(>Chi)
NULL			677	214.08	
Year	9	74.21	668	139.87	<0.001
Vessel.cat	4	52.09	664	87.78	<0.001

	GLM of positive catches				
	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Year	9	401.50	44.61	22.06	<0.001
Vessel.cat	4	254.69	63.67	31.48	<0.001
Quarter	1	54.15	54.15	26.77	<0.001
Year:Quarter	9	105.79	11.76	5.81	<0.001
Residuals	629	1272.20	2.02		

Table 5. CPUE values.

Year	Nominal.Q3	Nominal.Q4	Stand.Q3	Stand.Q4	Stand.Inter.Q3	Stand.Inter.Q4
2003	533	800	291	598	330	475
2004	445	458	117	242	374	469
2005	188	1257	267	546	750	1230
2006	1441	2362	798	1633	4090	3277
2007	318	2434	224	457	60	1197
2008	4945	3602	507	1036	2194	2285
2009	297	3113	239	489	144	1202
2010	203	1871	104	213	51	663
2011	7654	7206	1267	2621	3730	4574
2012	2850	2606	481	995	1534	1343

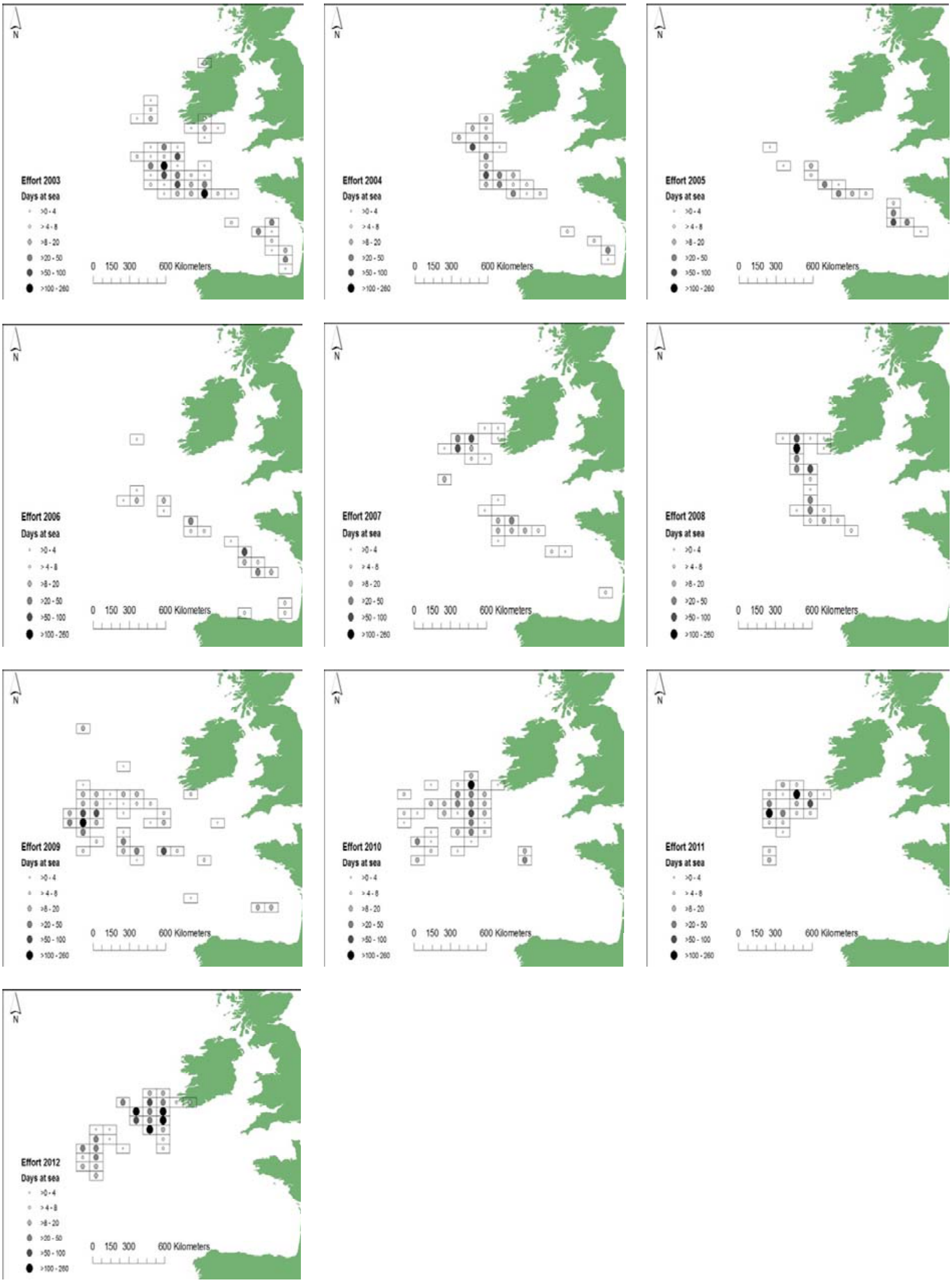


Figure 1. Maps of Irish Midwater Pair Trawl effort (days at sea) (2003-2012).

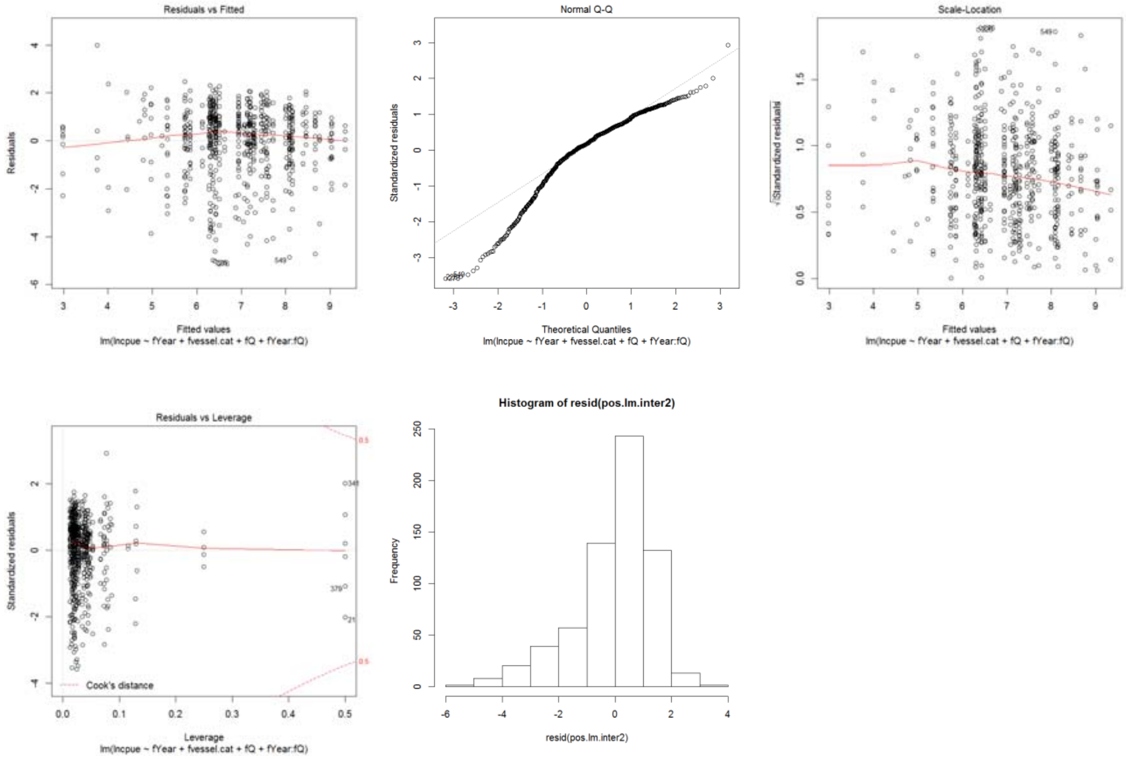


Figure 2. Model diagnostics from lognormal model with main effects of Year, Quarter, Vessel category and Year by Quarter interaction.

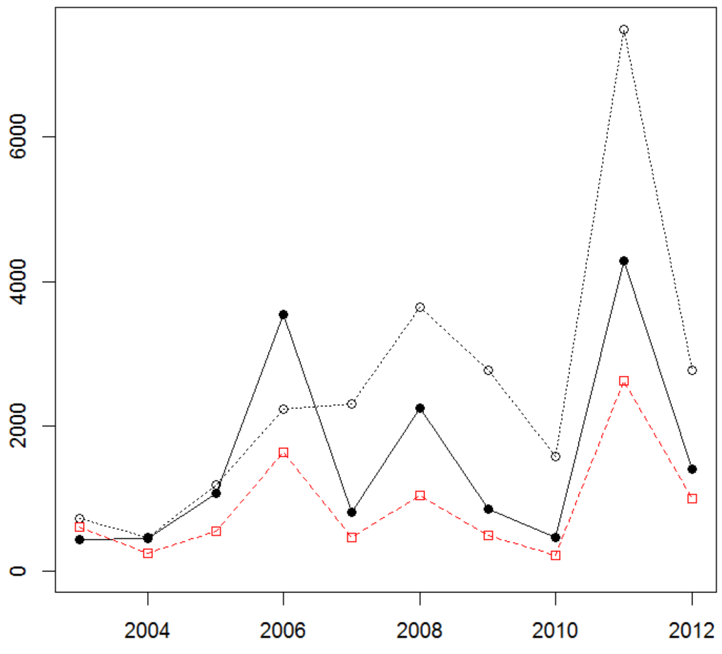


Figure 3. Nominal (clear circles, dashed line), Standardised (red squares, dashed line) and Standardised including intearction CPUE (black circles, solid line) indices (kgs) for Irish Midwater Pair Trawl Fleet.

Annex 1

Rcode by Coilin Minto

```
##-------------------------------
## delta-lognormal analysis of
## Irish albacore midwater CPUE
## Output by quarter in this file
##------------------------------

##setwd("C:/R/Data")

alb.dat<-read.csv(file="../data/ALB_dataset.csv")
summary(alb.dat)

## create categorical vessel length category
alb.dat$vessel.cat<-with(alb.dat, ifelse(Length<20, "C1",
            ifelse(Length>=20 & Length<25, "C2",
            ifelse(Length>=25 & Length<30, "C3",
            ifelse(Length>=30 & Length<40, "C4",
             ifelse(Length>=40, "C5", NA))))))

alb.dat$fvessel.cat<-factor(alb.dat$vessel.cat)

## get quarter from month
alb.dat$Q<-with(alb.dat, ifelse(Month%in%c(1,2,12), "Q1",
                       ifelse(Month%in%c(4,5,3), "Q2",
                       ifelse(Month%in%c(7,8,6), "Q3",
                       ifelse(Month%in%c(10,11,9), "Q4",NA)))))
alb.dat$fQ<-factor(alb.dat$Q)

## sonar rating from Sonar - RC have explained in paper why we are not using this
alb.dat$S<-with(alb.dat, ifelse(Sonar%in%c(1), "S1",
                              ifelse(Sonar%in%c(2), "S2",
                              ifelse(Sonar%in%c(3), "S3",
                              ifelse(Sonar%in%c(4), "S4",
                              ifelse(Sonar%in%c(5), "S5", NA))))))
alb.dat$fS<-factor(alb.dat$S)

## plot the data
with(alb.dat,plot(Landing.Year, log(CPUE+1)))

## new response variable
alb.dat$fYear<-factor(alb.dat$Landing.Year)
alb.dat$fQ<-factor(alb.dat$Q)
alb.dat$fZone<-factor(alb.dat$Zone)
alb.dat$fvessel.cat<-factor(alb.dat$vessel.cat)
alb.dat$lncpue<-log(alb.dat$CPUE)
alb.dat$bin<-ifelse(alb.dat$CPUE>0,1,0)
##
alb.dat$fYear<-as.factor(alb.dat$Landing.Year)

bin.glm<-glm(bin~fYear+fvessel.cat+fQ+fZone, family="binomial", data=alb.dat)
pos.lm<-lm(lncpue~fYear+fvessel.cat+fQ+fZone, data=alb.dat[alb.dat$CPUE>0,])
anova(bin.glm,test="Chisq")
anova(pos.lm)

## reduced fits (only significant main effects)
bin.glm2<-glm(bin~fYear+fvessel.cat, family="binomial", data=alb.dat)
pos.lm2<-lm(lncpue~fYear+fvessel.cat+fQ, data=alb.dat[alb.dat$CPUE>0,])
```

```
anova(bin.glm2,test="Chisq")
anova(pos.lm2)

##----------------------
## 25-30, Q4 prediction
##----------------------
years<-2003:2012
pred.df.q4<-data.frame(fYear=as.factor(years),
                fvessel.cat=as.factor("C2"),
                fQ=as.factor("Q4"))

pred.pos.obj.q4<-predict(pos.lm2, newdata=pred.df.q4, se.fit=TRUE)
## predicted mean on the original scale
pred.pos.mean.q4<-exp(pred.pos.obj.q4$fit+pred.pos.obj.q4$se.fit^2/2)

## predicted probabilities of +ve trip
pred.prop.q4<-predict(bin.glm2, newdata=pred.df.q4, type="response")
stand.mean.q4<-pred.prop.q4*pred.pos.mean.q4

##----------------------
## 25-30, Q3 prediction
##----------------------
pred.df.q3<-data.frame(fYear=as.factor(years),
                fvessel.cat=as.factor("C2"),
                fQ=as.factor("Q3"))

pred.pos.obj.q3<-predict(pos.lm2, newdata=pred.df.q3, se.fit=TRUE)
## predicted mean on the original scale
pred.pos.mean.q3<-exp(pred.pos.obj.q3$fit+pred.pos.obj.q3$se.fit^2/2)

## predicted probabilities of +ve trip
pred.prop.q3<-predict(bin.glm2, newdata=pred.df.q3, type="response")
stand.mean.q3<-pred.prop.q3*pred.pos.mean.q3

## straightforward mean CPUE by year and quarter
nom.mean<-with(alb.dat, tapply(CPUE, list(Landing.Year,fQ), mean))
## comparison plot
matplot(years, nom.mean, type="l", ylim=c(0, max(nom.mean)), col=1, lty=c(1,2))
matlines(years, cbind(stand.mean.q3,stand.mean.q4), type="l", lty=c(1,2), col="blue")

##----------------------------
## NOTE - removed code for other vessel category here
## as not used
## See: Maunder and Punt (2004)
##----------------------------

##--------------
## INTERACTIONS
##--------------
bin.glm.inter<-glm(bin~fYear+fvessel.cat+fQ+fZone+fYear:fQ+fYear:fvessel.cat, family="binomial",
data=alb.dat)
pos.lm.inter<-lm(lncpue~fYear+fvessel.cat+fQ+fZone+fYear:fQ+fYear:fvessel.cat,
data=alb.dat[alb.dat$CPUE>0,])
anova(bin.glm.inter,test="Chisq")
anova(pos.lm.inter)

## note year x vessel interaction not supported
## reduced fits (only significant main effects)
bin.glm.inter2<-glm(bin~fYear+fvessel.cat, family="binomial", data=alb.dat)
pos.lm.inter2<-lm(lncpue~fYear+fvessel.cat+fQ+fYear:fQ, data=alb.dat[alb.dat$CPUE>0,])
```

```
anova(bin.glm.inter2,test="Chisq")
anova(pos.lm.inter2)
##
years.vec<-2003:2012
vessel.vec<-unique(alb.dat$fvessel.cat)
q.vec<-unique(alb.dat$fQ)

pred.inter.df<-expand.grid(fYear=as.factor(years.vec), fvessel.cat=vessel.vec, fQ=q.vec)
##pred.inter.df<-expand.grid(fYear=as.factor(years.vec), fQ=q.vec)

pred.inter.pos.obj<-predict(pos.lm.inter2, newdata=pred.inter.df, se.fit=TRUE)
## predicted mean on the original scale
pred.inter.pos.mean<-exp(pred.inter.pos.obj$fit+pred.inter.pos.obj$se.fit^2/2)

## predicted probabilities of +ve trip
pred.inter.prop<-predict(bin.glm.inter2, newdata=pred.inter.df, type="response")

pred.inter.df$stand.mean<-pred.inter.prop*pred.inter.pos.mean

library(lattice)
xyplot(stand.mean~fYear|fQ+fvessel.cat, type="l", data=pred.inter.df)

## get weights ## equation 11 of maunder and punt these are the z values
ntotal<-dim(alb.dat)[1]
## Note changed this so it sums to one in each quarter

weight.tab0<-with(alb.dat, table(fQ,fvessel.cat))

weight.tab<-weight.tab0/apply(weight.tab0,1,sum)

pred.inter.df$weight<-NA
for(i in 1:dim(pred.inter.df)[1]){
  pred.inter.df$weight[i]<-weight.tab[pred.inter.df$fQ[i],pred.inter.df$fvessel.cat[i]]}

stand.inter.mean<-matrix(NA,ncol=2, nrow=length(years.vec))

for(i in 1:length(years.vec)){
  ## Q3
  dat.q3<-subset(pred.inter.df,fYear==years.vec[i]&fQ=="Q3")
  stand.inter.mean[i,1]<-sum(dat.q3$stand.mean*dat.q3$weight)
  ## Q4
  dat.q4<-subset(pred.inter.df,fYear==years.vec[i]&fQ=="Q4")
  stand.inter.mean[i,2]<-sum(dat.q4$stand.mean*dat.q4$weight)
}

matplot(years, nom.mean, type="l", ylim=c(0, max(nom.mean)), col=1, lty=c(1,2))
matlines(years, cbind(stand.mean.q3,stand.mean.q4), type="l", lty=c(1,2), col="blue")
matlines(years, stand.inter.mean, type="l", lty=c(1,2), col="red")


## output
iccat.rep.tab.byQ<-cbind(years.vec, nom.mean, cbind(stand.mean.q3,stand.mean.q4), stand.inter.mean)

iccat.rep.tab.byQ.df<-data.frame(iccat.rep.tab.byQ)

names(iccat.rep.tab.byQ.df)<-
c("Year","Nominal.Q3","Nominal.Q4","Stand.Q3","Stand.Q4","Stand.Inter.Q3","Stand.Inter.Q4")

write.csv(x=iccat.rep.tab.byQ.df, file="./iccat_rep_tab_byQ.csv", row.names=FALSE)
```

Annex 2.

Standardised CPUE results based on Natural Quarter

Table 1. Delta lognormal model results – Irish Mid Water Trawl Natural Quarter.

Binomial model of zero catches					
	DF	Deviance Resid	DF	Resid.Dev	Pr(>Chi)
NULL			677	214.08	
fYear	9	74.209	668	139.871	<0.001
fvessel.cat	4	52.089	664	87.782	<0.001
fQ	1	10.111	663	77.671	<0.001

GLM of positive catches					
	Df	Sum Sq	Mean Sq	F value	Pr(>F)
fYear	9	401.5	44.611	21.1304	<0.001
fvessel.cat	4	254.69	63.672	30.159	<0.001
fYear:fQ	7	97.85	13.979	6.6211	<0.001
Residuals	632	1334.29	2.111		

Table 2. Nominal and standardised CPUE by Natural Quarter.

Year	Nominal.Q3	Nominal.Q4	Stand.Q3	Stand Q4
2003	849	319	495	140
2004	453		411	
2005	1358	1002	1152	1155
2006	2375	2006	2948	3884
2007	1870	2733	683	1408
2008	3922	848	2656	695
2009	3357	1330	1419	385
2010	1037	2808	249	1350
2011	7498		3825	
2012	2773		1402	

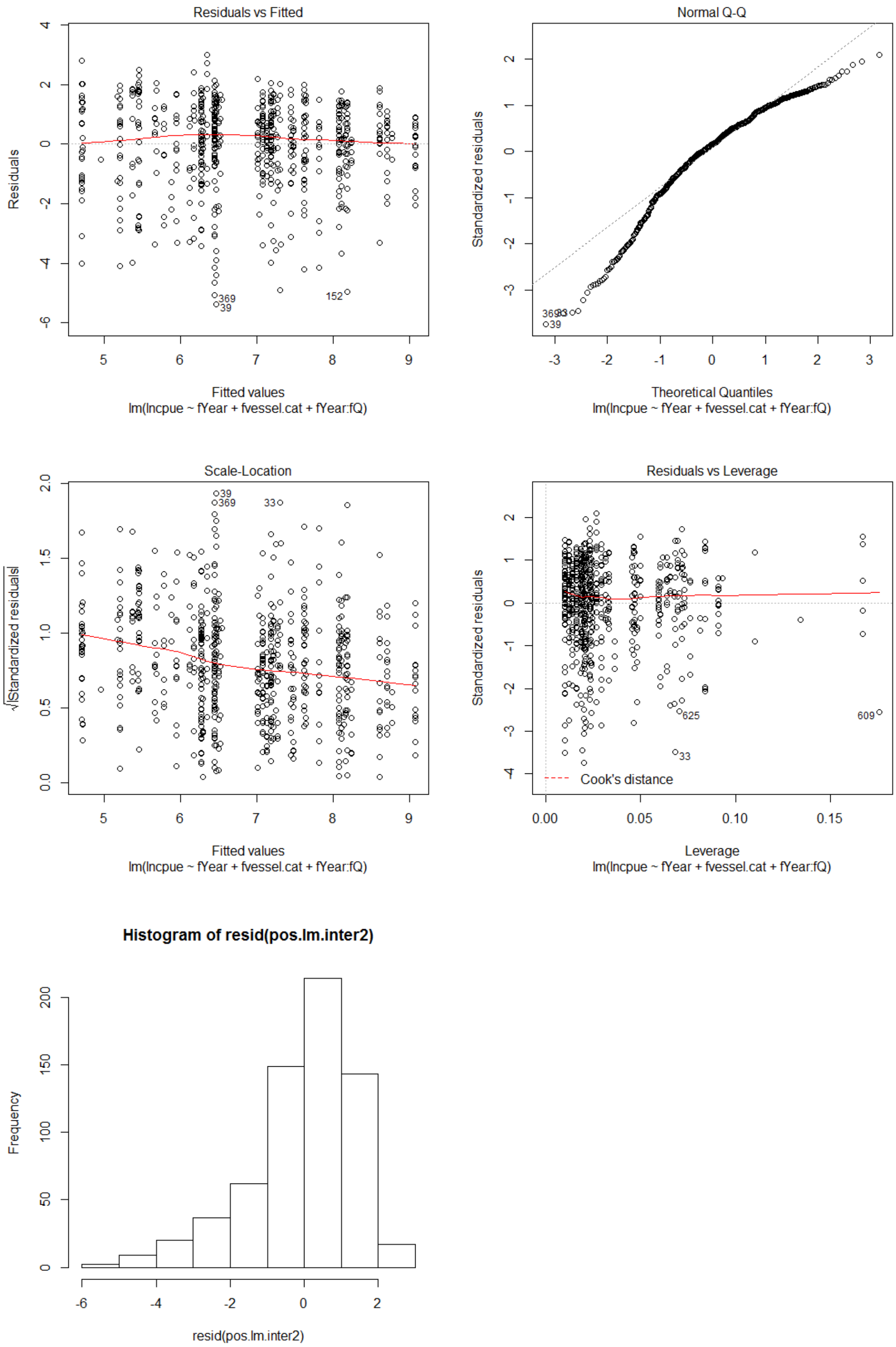
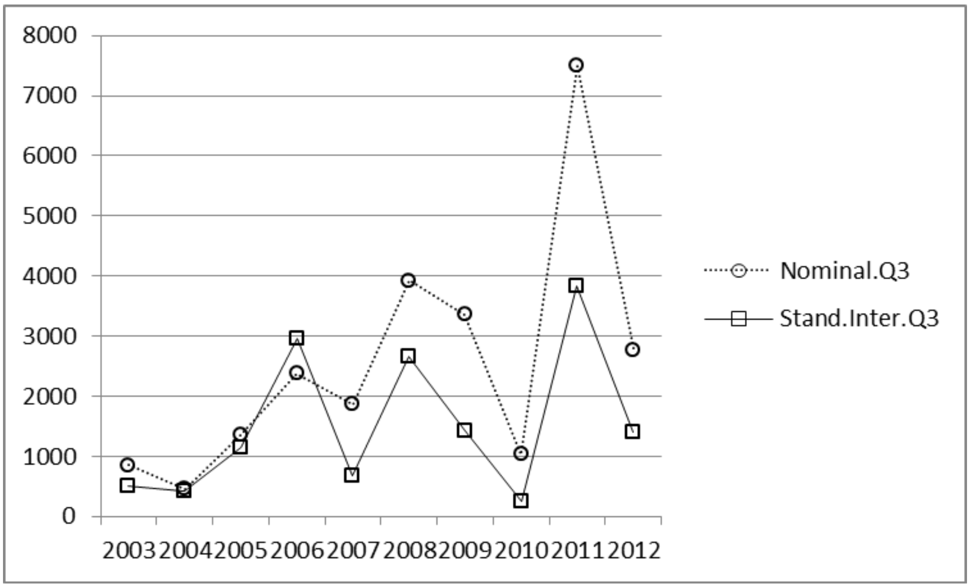


Figure 1. Model Diagnostics - Irish Mid Water Trawl Natural Quarter.



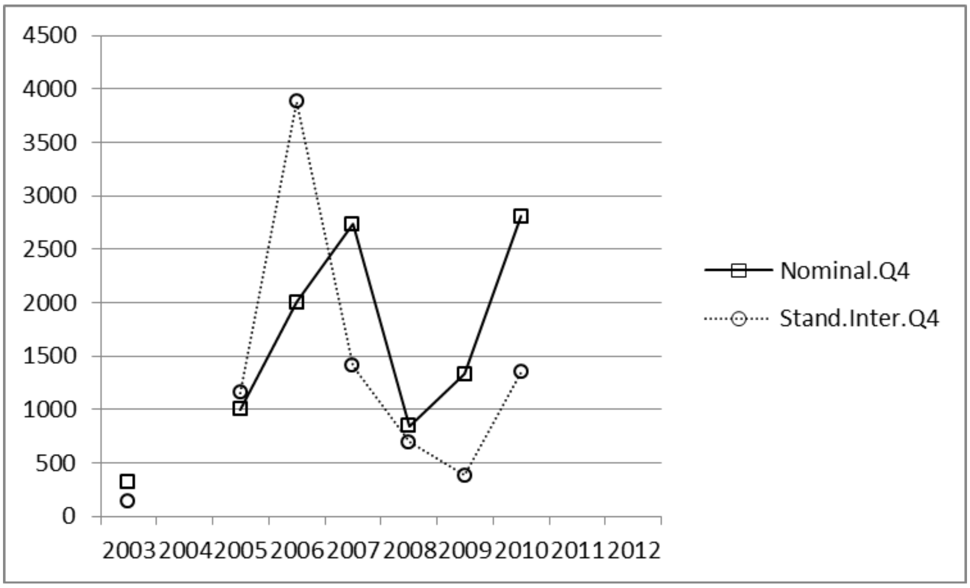


Figure 2. Nominal and standardised CPUE indices by natural quarter.