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A preliminary gadget model to assess the Spanish Red seabream fishery of the Strait of Gibraltar

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Abstract

This work shows the first implementation of gadget (an age-length based model) to the Spanish Red seabream fishery data from the Strait of Gibraltar: gadget is a toolbox developed to implement marine ecosystem models considering the fishing effect. Our goal is to launch a new approach for the Red seabream fishery assessment following Icelandic deepwater stocks example. Sooner or later, we would like to change the current category of this deep water fishery: from data poor to stocks with quantitative assessments. These trials should be attempted before planning a future Benchmark Group.

1. Introduction

Red seabream (*Pagellus bogaraveo*) is caught by an artisanal Spanish fleet ("*voracera*") in the Strait of Gibraltar area. The species is marketed fresh and has a large economic (and social) interest. Since 2000, all analytical assessment exercises presented for ICES Subarea IX are "not accepted" in the WGDEEP, so the ICES scientific advice was only based in landings (DLS method 5.2 for Category 5 - data-poor stocks) till 2014 where the ICES WGDEEP advice was based on commercial (CPUE) abundance index (DLS method 3.2 for Category 3 – stocks with abundance index that provide reliable indications of trends). Although progress has been made across this last years, many of the problems experienced in earlier years still persist. In 2013 ICES WKAMDEEP reports that age estimation of Red seabream is still carried out with low precision and recaptures (from tagging surveys) growth suggests overestimation from otoliths readings because some hyaline rings are uncounted and/or missing.

In this context, models based on size (instead age) may be a good choice to provide another view of the stock dynamics. Our aim is move from the current category (3) of this deep water fishery to category 1 (stocks with quantitative assessments) analysing all the information available to develop a gadget (Globally applicable Area Disaggregated General Ecosystem Toolbox) model that will be eventually reviewed within an ICES Benchmark Group: gadget is a software tool developed to model marine ecosystems taking into account the impact of the interactions between species and the impact of fishing on the species. It allows the user to include a number of features of the ecosystem into the model: [1]one or more species (each of which may be split into multiple components), [2]multiple areas with migration between areas, [3]predation between and within species, [4]growth, [5]maturation, [6]reproduction, [7]recruitment and [8]multiple commercial and survey fleets taking catches from the population. Gadget works by running an internal forward projection model based on several parameters describing the population/ecosystem to compare then the output from this model to observed data getting a likelihood score. A full description of gadget may be found in Begley and Howell (2004) and also are available at the webpage: www.hafro.is/gadget.

Gadget is distinguished from many stock assessment models used within ICES (such as XSA) because is a forward simulation model and could be structured by length (or age). It has successfully been used to investigate the population dynamics of stock complexes in Icelandic waters (Taylor and Stefansson, 2004), the Barents Sea, the North Sea, the Irish and Celtic Seas. Southernmost, it has been used to assess Hake and Anchovy in Iberian waters. Within the ICES WGDEEP is the common tool to assess Icelandic deep water stocks.

2. SoG Red seabream model definition

Model definition and the estimated parameters are conditioned by the available information. It should be remarked that this preliminary model was developed only with the Spanish target fishery information, from "*voracera*" fleet.

Unfortunately we can´t include data from Moroccan longliners, which have been fishing in the Strait of Gibraltar area since 2001. There is no quarterly information and the yearly one is only available till 2013. So there is a fraction of the population modelled, and another predator (Moroccan fleet) as well, that are missing and its effect can´t be evaluated.

On the contrary, the issue to include all the landings from ICES IX looks more difficult because historical landings data series come from by-catch fisheries (Spain and Portugal) are aggregated by year and its unknown size composition might be different than the target fishery of the strait of Gibraltar.

2.1 Data available

- Spanish data:
    - Landings and length distribution
        - 1 artisanal fleet ("*voracera*")

    - 1 area (Strait of Gibraltar)
    - Quarterly from 1983 to 2015
- Abundance indexes from "*voracera*" fleet
    - Nominal LPUEs: quarterly from 1990 to 2008
    - VMS LPUEs: quarterly from 2009 to 2015
- Spanish bottom trawl surveys both sides of the Strait of Gibraltar information (nº individuals smaller than 15 cm)
    - Alboran Sea (MEDITS): 1994 to 2015
    - Gulf of Cadiz (ARSA Spring): 1993 to 2015
    - Gulf of Cadiz (ARSA Autumn): 1997 to 2015
- Biological data
    - k estimate from tagging experiences (not estimated by the model)
    - L_∞ estimate from largest sample in the length distribution (not estimated by the model)
    - SSB everybody is mature since 35 cm

Not all the data available were included in the present model: other information like tagging experiences raw data are not implemented yet.

2.2 Model implementation

As gadget works as a forward projection, needs initial estimates of recruitment (age 0) every year (1983 to 2015) and initial abundances by age (from 1 to 17) in the first year (1983). Population dynamics follows this order: fish are caught by the "*voracera*" fleet with a two different selection patterns, afterwards it dies by natural mortality and eventually growths and ages.

Area and time series

- ✓ Area: Strait of Gibraltar (ICES IXa - GFCM GSAs 1 and 2 - CECAF 34.1.11)
- ✓ Time: from 1983 to 2015 by quarter
- ✓ Ages: from 0 to 17 (length from 1 to 62 cm) by quarter

Population Model

The population model needs initial guess for abundance:

- ✓ Recruits at age 0 from 1983 to 2015 (estimated by the model)
- ✓ Abundance at age (0 to 17) in 1983 (ages O to 10 estimated by the model)
- ✓ VonBertalanfy Growth Function: L_∞=62 and k=0.147
- ✓ Length weight relationship: a=0.014 and b=3.014
- ✓ M = 0.2 for all ages and years

Fishing model

As stated above, every quarter the total catch in Red seabream biomass are fished. Fleet length distribution comprises the "*voracera*" fleet from Tarifa and Algeciras ports (SW Spain), the main ports where the species are landed. The length distribution of the catch assumed to follows the logistic model, but with two different exploitation patterns: 1983-2003 and 2004-2015. Selectivity parameters (α and L_{50}) of these two periods were estimated by the model. So, it is modelled as gadget "*exponentialL50*" function:

$$S(l,L)=1/1+e^{-(\alpha(l-l_{50})}$$

where "L" is the length of the predator ("*voracera*" fleet) with no biological meaning and "l" is the length of the prey (Red seabream).

2.3 Likelihood function

Model parameters are estimated minimizing differences among observations and model results within an optimization process. The present model includes 8 different likelihood components:

Component	Description
Landsp.ldist	1983-2015 quarterly "*voracera*" fleet landings length distribution by 1 cm length
spCpue	1983-2008 quarterly nominal CPUE from "*voracera*" fleet (30-60 cm)
vmsCpue	2009-2015 quarterly VMS CPUE from "*voracera*" fleet (30-60 cm)
medits.ldistminus15	MEDITS Alboran Sea bottom trawl survey (2^{nd} quarter) number of individuals ≤ 15 cm (10-15 cm): 1994-2015
arsafall.ldistminus15	IBTS Gulf of Cadiz survey (4^{th} quarter) number of individuals ≤ 15 cm (10-15 cm): 1997-2015
arsaspring.ldistminus15	IBTS Gulf of Cadiz survey (1^{st} quarter) number of individuals ≤ 15 cm (10-15 cm): 1993-2015
understocking	applied when there is not enough preys (fish modelled) to meet the requirements of the predator (fish landed)
bounds	penalty weight to parameters that have moved beyond the bounds

Functions for gadget *catchdistribution* likelihood component (*Landsp.ldist*) are given by next equation:

$$\ell = \sum_{time} \sum_{areas} \sum_{ages} \sum_{lengths} \left(P_{tral} - \pi_{tral} \right)^2$$

where "*P*" is the proportion of the data sample for that time/area/age/length combination and "*π*" is the proportion of the model sample for that time/area/age/length combination.

The gadget *surveyindices* likelihood components (*spCpue*, *vmsCpue*, *medits.ldistminus15*, *arsafall.ldistminus15* and *arsaspring.ldistminus15)* were aggregated from 30 to 60 cm length in the case of commercial CPUEs and from 10 to 15 cm length in the case of bottom trawl surveys indexes. The idea was improving the model with some extra information from several abundance indexes covering certain length ranges. The likelihood component used is the sum of squares of a linear regression in log scale fitted to the difference between the modelled data and every index, given by next equation below:

$$\ell = \sum_{time} \left(I_t - (\alpha + \beta N_t) \right)^2$$

where "*I*" is the log of each observed CPUEs and survey indexes, "*N*" is the corresponding index calculated in the gadget model in log scale, "β" is set to 1 and "*α*" is e^q (q:catchability).

Likelihood components weights are necessary to prevent some components from dominating the likelihood function and to reduce the effect of low quality data. Assigning likelihood weights is not a trivial matter. Commonly this has been done using some kind of "*expert judgement*" but general heuristics have recently been developed to estimate these weights objectively. Thus, the iterative re--weighting heuristic introduced by Stefansson in2003 and afterwards implemented by Taylor (2007) is used: every likelihood component weight was estimated following the iterative process in R-gadget, comparing the results obtained in every case where just one component is considered (the rest of the components are zero): the idea is giving the weight to the different components as objectively as possible, taking into account the amount of information provided (in terms of quantity and quality). Estimated weights are presented in Table I.

2.4 Parameters estimated

The **estimated parameters** in the present model are presented in the next Table:

name	**number**	**description**
*age1 to age17**	11	abundance at age for the initial population in 1983 (age 1 to age 17, but from age 11 all are estimated as a fraction of age 10)
rec83 – rec15	33	abundance in recruits per year (age 0) from 1983 to 2015
meanlengthREC	1	mean length at age 0 (1st quarter)
SPalph and *SPL50*	4	catch selection parameters in function *ExponentialL50* (a and L50) for the two periods (with different exploitation pattern)

Total: 49 parameters

Other parameters used like L_∞, k and beta (growth variability) are, in our aces, fitted by the user.

3. Results

3.1 Likelihood scores

Table I gives the score and the weighted score for very component considered. The model fit quality is quantified by likelihood scores. It can be used as a priori estimates of the variance in each subset of the data. The final likelihood function is the sum of these 8 (6+2) individual functions weighted by its corresponding factors: eventually a well defined model will have a zero likelihood score from *understocking* and *bounds* components.

Almost the 90% of the model variability resides in the information from the landings length composition which has the lower score value. Higher scores´ values (from bottom trawl surveys components) have minor influence on the model variability because its weighted scores (less than 5%).

Table I: Likelihood scores (final result and by component)

Component	Function Type	Weight	Score	Weighted Scores
Landsp.ldist	*catchdistribution*	3658.600	1.164	4258.610 (89%)
spCpue	*surveyIndices*	21.524	11.580	249.243 (5%)
vmsCpue	*surveyIndices*	20.543	4.194	86.157 (2%)
medits.ldistminus15	*surveyIndices*	0.140	129.800	18.200 (1%)
arsafall.ldistminus15	*surveyIndices*	0.259	160.200	41.524 (1%)
arsaspring.ldistminus15	*surveyIndices*	0.136	370.800	50.355 (1%)
understocking	*understocking*	10^{12}	0	0 (0%)
bounds	*penalty*	10	0	0 (0%)
The final model score was			**4704**	

The likelihood components of Survey Indices type are fitted to a fix slope regression so only likelihood value is obtained. The landing lengths component scores´ distributions, by year and quarter, are presented in Figure 1. There are no quarterly trends in the mean values while those are more clearly over the time series with higher mean score values in the initial and certain recent years (mainly 2013).

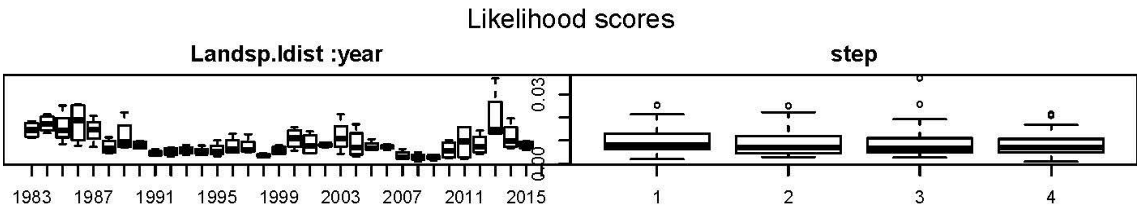

Figure 1. Likelihood landing length distribution component scores distribution by year and quarter

3.2 Model results

Estimated model parameters values are the following for the initial population:

Age	Abundance ($N*10^6$)	Age	Abundance ($N*10^6$)
age1	8.858	**age6**	4.636
age2	16.329	**age7**	5.826
age3	3.785	**age8**	$1.007*1^{-10}$
age4	8.216	**age9**	0.503
age5	1.588	**age10**	0.301

***Remember that forms age 11 all the ages are related to age 10 numbers (age11=0.3*age10, age12=0.3*age10, age13=0.01*age10, age14=0.003*age10, age15=0.001*age16 and age17=0.0003*age10).**

And for every year Recruitment´s estimate is presented below:

Year	Recruits (age0) ($N*10^6$)	Year	Recruits (age0) ($N*10^6$)
1983	21.954	2000	22.164
1984	15.086	2001	13.112
1985	12.063	2002	18.059
1986	25.141	2003	12.659
1987	13.436	2004	16.66
1988	23.056	2005	8.425
1989	15.582	2006	7.014
1990	17.613	2007	8.313
1991	23.364	2008	8.277
1992	28.780	2009	6.801
1993	28.046	2010	8.596
1994	29.349	2011	0.010
1995	14.829	2012	3.588
1996	13.100	2013	4.540
1997	10.075	2014	0.010
1998	9.447	2015	32.427
1999	6.886		

Mean length at recruitment parameter got a value of 4.6 cm.

In certain cases, after the gadget optimization process some parameters' estimate got its values from the lower of their ranges: age 8 in the initial population and recruitments in 2011 and 2014. Besides last year´s recruitment (2015) is the highest one because there is no "*tuning*" information (from length distributions or abundance indexes neither).

Figure 1 (in the Annex) shows how modelled proportion at length for "*voracera*" fleet (by quarter) fits the observed proportions from the gadget model. Figure 2 (in the Annex) presents the considered abundance indexes (nominal and standardized VMS-CPUEs and bottom trawl surveys) residuals plot. The model converges and the residuals are bigger in those components with small likelihood weight.

Figure 2 shows the two selection patterns estimated by the model. "*Voracera*" fleet selection patterns fit to a logistic function fits L_{50} at 35 cm in the first period (1983-2003) and 30 cm in 2004-2015.

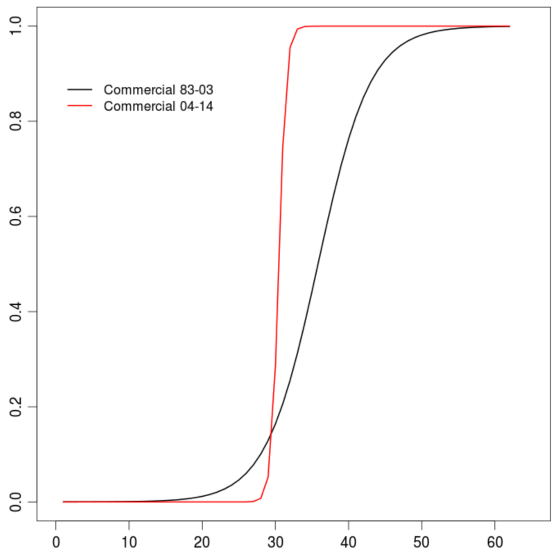

Figure 2. Spanish "*voracera*" fleet estimated selection patterns from gadget model

Standard assessment outputs for Recruitment at age 0 (R), Spawning Stock Biomass (SSB) and Biomass (B), $FBAR_{5\text{-}9}$ (F) and Landings (Removals) are presented in Figure 3. Biomass (and SSB) trend are quite clear: crease to minimum levels as a consequence of fishing mortality (and landings) increasing since 1990s.

Recruitment in recent years is uncertain: in 2011 and 2014 has the same value than the lower range from the parameters file. However these recruitments failure might be also a result of the decreasing of Spawning Stock Biomass from 2010 onwards.

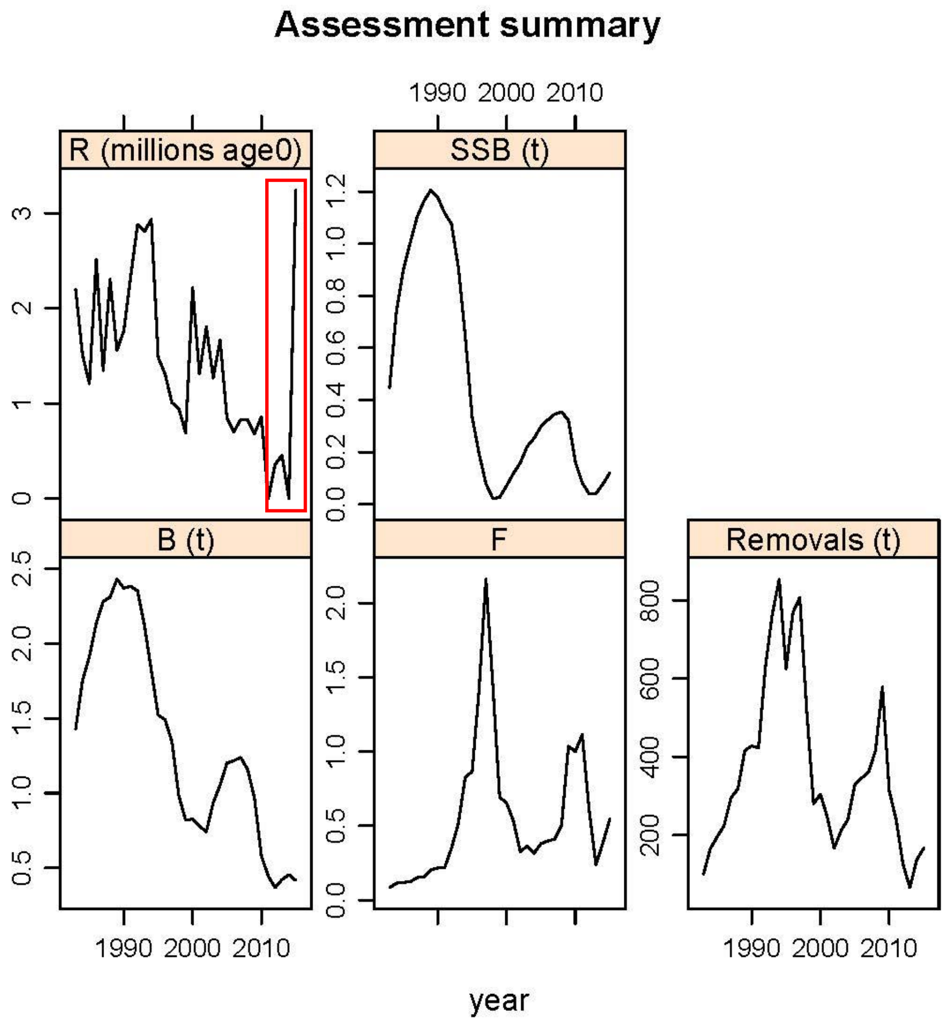

Figure 3. Summary results from gadget model for Spanish "*voracera*" fleet of the Strait of Gibraltar

As it was previously mentioned 2015 recruitment estimate are totally inaccurate (actually the highest of the series). This point is not critical because it is usually solved replacing its value with a mean from previous years.

4. Conclusions

One of the main limitations is the lack if information for a more complete time series. It should be remembered that model includes only the Spanish information. The effect of the inclusion of Morocco data is unknown but it is desirable a future incorporation. Te fact of Recruitment´s uncertainty should be further investigate because its relevance for predictions and management considerations.

Growth parameters can be estimated by the model if the information is good enough. In our case are fitted, so the growth implementation could be considered as a weak part of the presented model.

Aside the limitations of this implementation of gadget to the Spanish Red seabream fishery of the Strait of Gibraltar, this preliminary model may be useful to get a picture and provide a more detailed explanation of the relations among fishing and Red seabream population dynamics.

So in conclusion, the next steps are (not necessarily in the same order): [1]still improving the model to get more stability and avoid uncertainty in last year's estimates, [2]evaluate the effect on the model with the inclusion of Morocco information (if it is possible), [3]explore short and long term predictions and link outputs with management simulations (HCRs), [4]the integration of tagging recapture data and lastly [5]including other species in the model such as Atlantic bluefin tuna (*Thunnus thynnus*).

6. Acknowledgements

We are really grateful for the kindly assistance provided from our Icelandic colleagues (Gudmundur Thordarson at HAFRO). Margarita Rincón (ICMAN-CSIC) was also ready to lend a hand....Thanks everyone for your patience and for still improving first author´s (gadget) skills ☺

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Annex

Figure 1. Expected (red line) and observed (bars) length distribution in "*voracera*" fleet landings by quarter

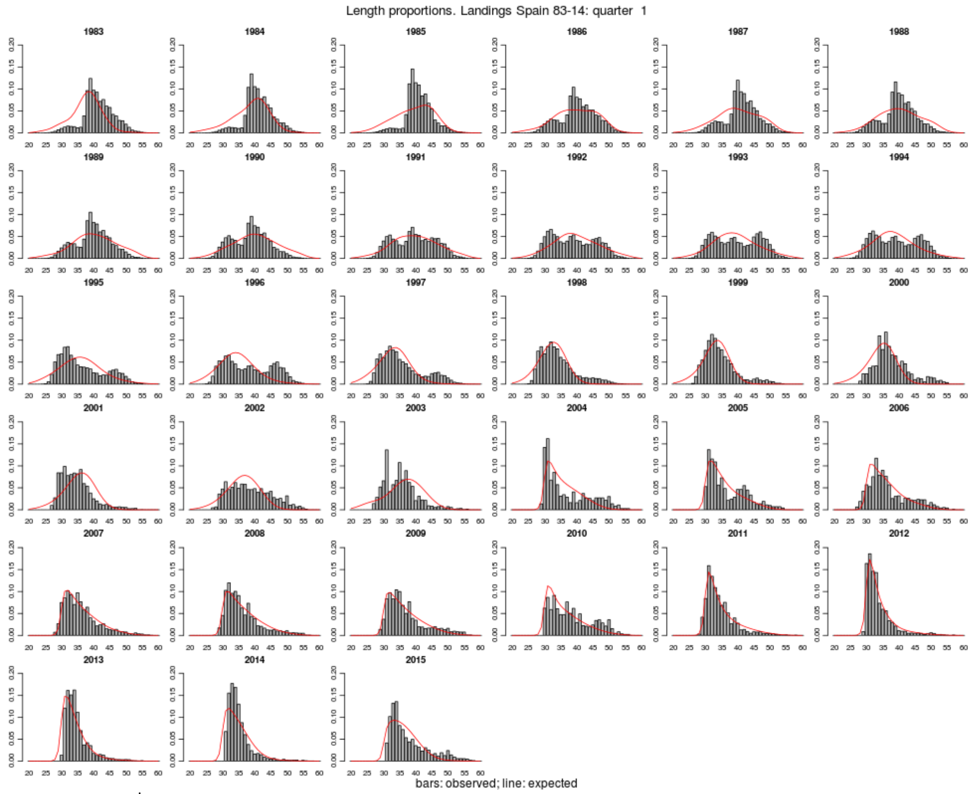


Fig 1.a. 1st quarter

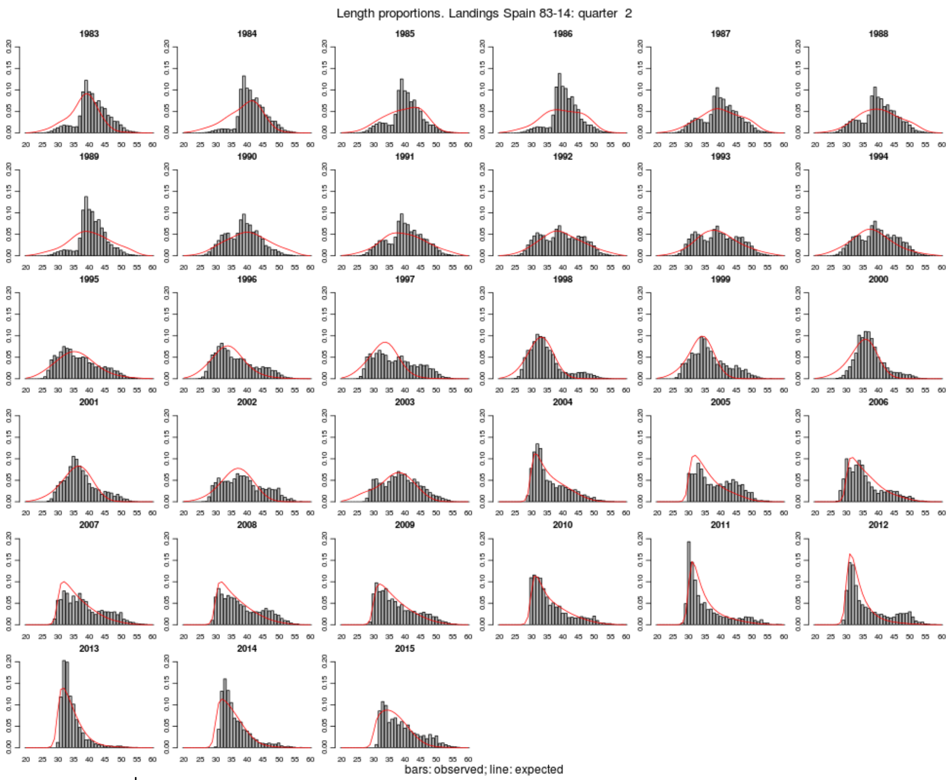


Fig 1.b. 2nd quarter

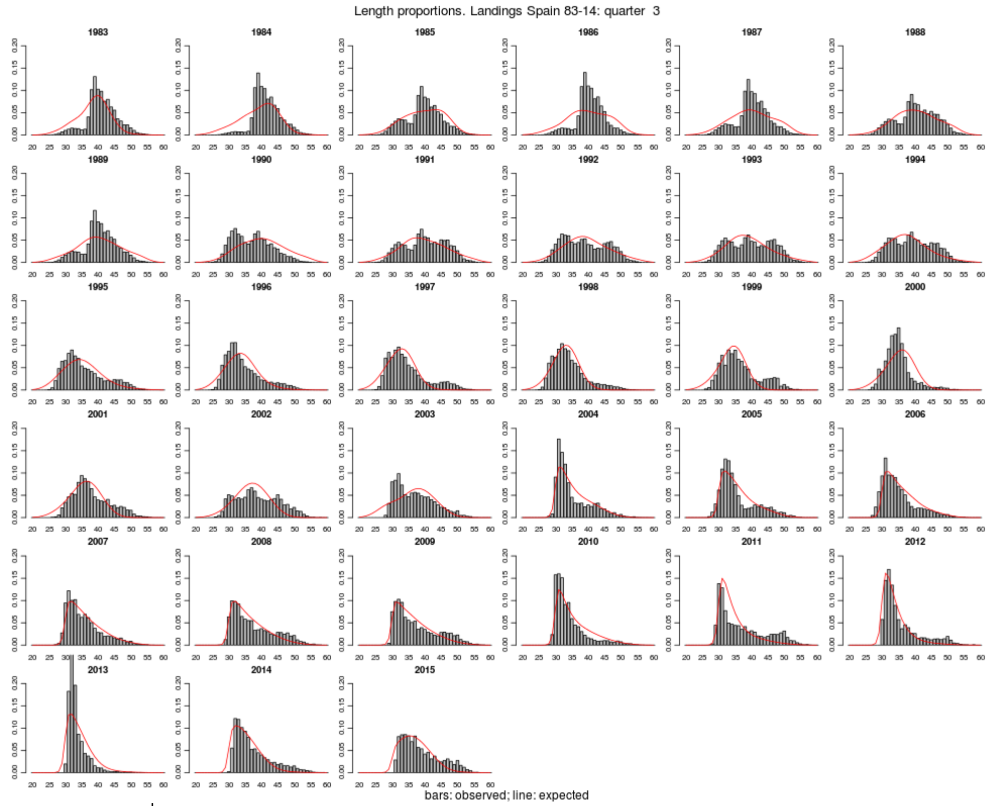


Fig 1.c. 3rd quarter

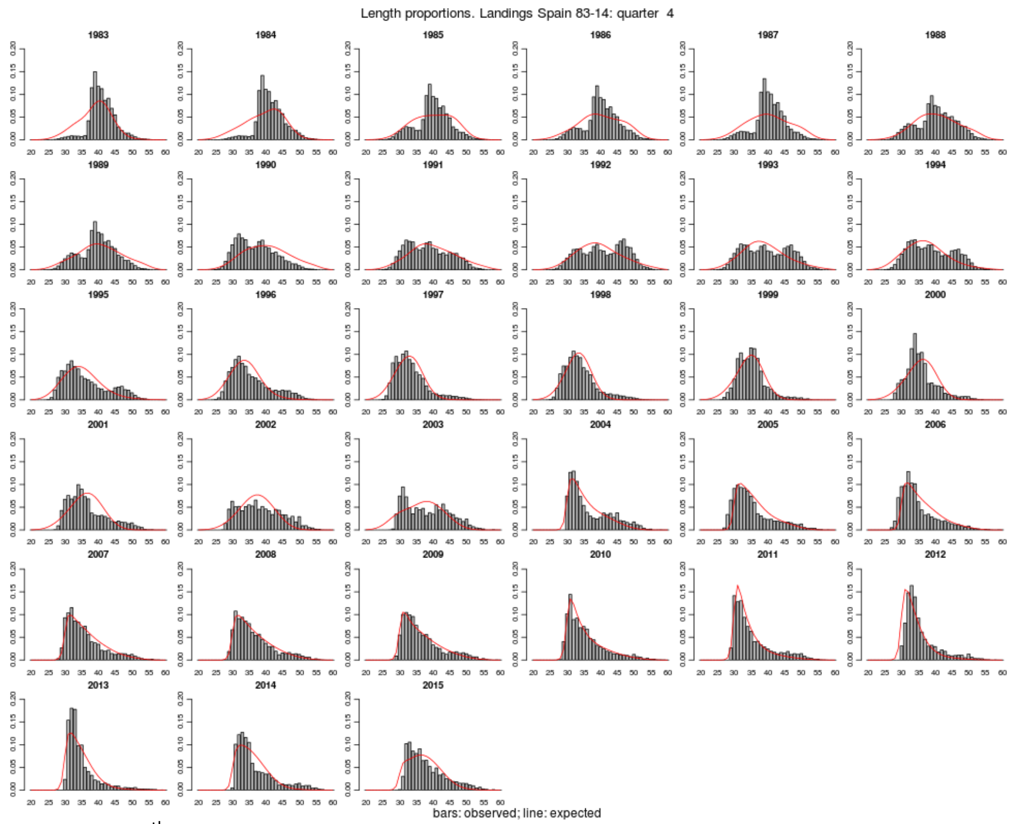
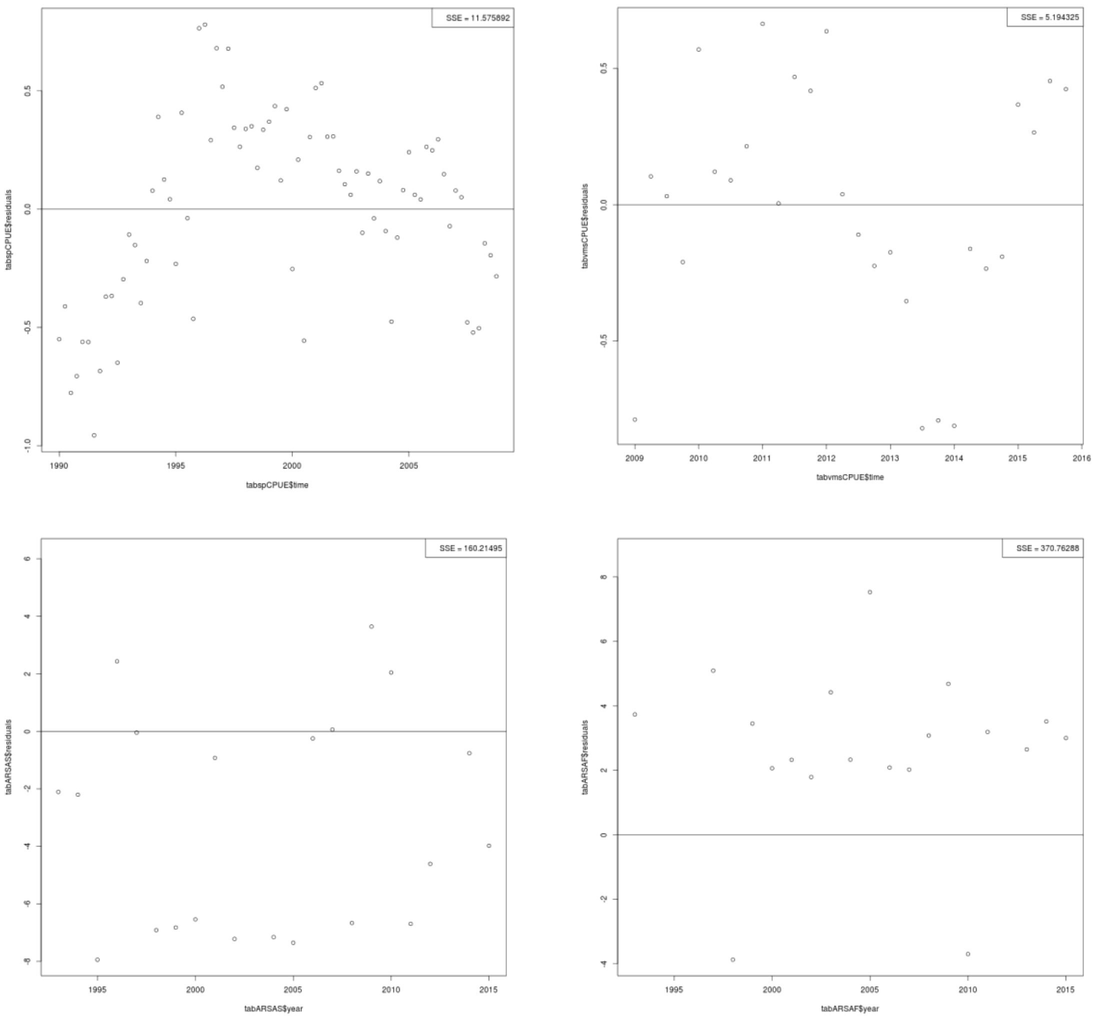
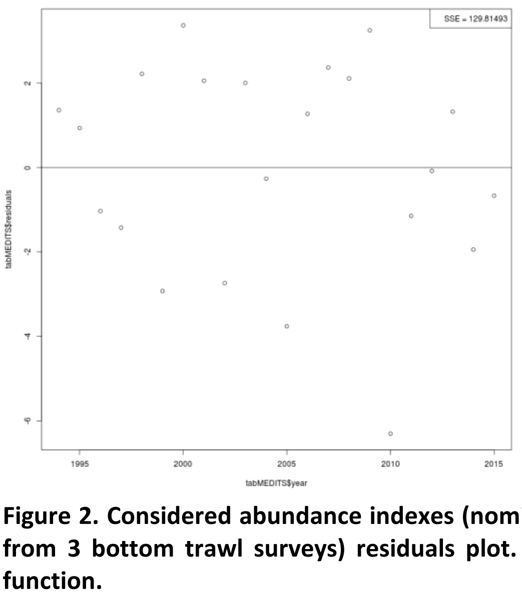


Fig 1.d. 4th quarter





Top left: (nominal) CPUE (SSE=11)
Top right: VMS (standardized) CPUE (SSE=5)
Middle left: ARSA Spring survey (SSE=160)
Middle right: ARSA Autumn survey (SSE=371)
Bottom left: MEDITS survey (SSE=130)

Figure 2. Considered abundance indexes (nominal and vms CPUEs and number of individuals ≤ 15 cm from 3 bottom trawl surveys) residuals plot. Top right includes the SSE value from the regression function.