To be presented to the ICES WGHMM 2011. ICES HQ, Copenhaguen, May 5-11.

Anglerfish (*Lophius spp.*) increasing discards in Spanish OTB fleet (VI-VII ICES). Juveniles availability or sampling artifact?

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April 25, 2011

Abstract

An update of the yearly estimates of anglerfish (black angler (*Lophius budegassa*) and white angler(*Lophius piscatorius*)) discarded by the Spanish bottom trawl operating in the Northeast Atlantic ocean are presented. Black angler discards increased sharply in the last three year , while U-Shape with a maximum in 2010 is found for white angler. A $2003 - 2010$ sampling methodology review has beeen carried out without detecting any shift in the protocol which could produce overestimation for recent years discards. Fishing covariates related to black angler discard data also indicates that fishing practices remain stable along the series. We detect a steady increase in the species first length of retention L_{50} from $21,5cm$ in 2003 to a range $23cm - 25cm$ between $2004 - 2008$ and $\sim 28cm$ since 2009. We conclude that interaction between the industry adoption of a Minimum Weigth Landing ($500g$) and the strength of recruitment indices explain the increase in amounts of angler discards.

1 Introduction

The growing importance of discards in fishery management decision-making is reflected by the increasing attention paid to the topic by international research organizations since the paper of Alverson et al. (1994). Unwanted species or sizes are discarded by most fisheries around the world, and the issue is therefore one of the main biological and political issues facing modern fisheries (Malaquias *et al.*, 2006). A common feature of discarding is its variability in space and time (Andrew and Pepperell, 1992; Alverson *et al.*, 1994; Rochet *et al.*, 2005; Kennelly, 2007). However, because of the quantity of discards and their variability, it is important to carry out sampling programmes to obtain reliable estimates of the total (retained and discarded) catch for stock assessments of commercial species (Rochet *et al.*, 2002).
The 'Spanish Discards Sampling Programme' for Otter Bottom Trawl (OTB) fleets, covering ICES Subareas VI, VII, VIIIc and North IXa, was started in 1988 to satisfy the growing demand on discard information. The program did not have yearly continuity until 2003. The guidelines established in the ICES 'Workshop on Discard Sampling Methodology and

Raising Procedures' (2003) were taken by the program from this year.

Year	Project
1988-1989	National Project
1994	EC Project: Pem/93/005
1997	EC Project: 95/ 094
1999-2000	EC Project: 98/095
2001	EC Project: 99/063
2003-2010	DCR

Table 1: Summary of funded projects which have supported the Spanish Discards Sampling Programme.

Two métiers from the Spanish bottom otter trawl fleets operating in the ICES Subareas VI and VII were considered to achieve precise discard estimations, the so-called `OTB-D21` and `OTB-D12`. During a sampled trip ramdonly or quasi-randomly selected from the métiers trip population, the onboard observer collect physical information from every haul, while biological data from both discarded and retained fraction is obtained from sampled hauls.
Angler fish species (*Lophius budegassa* and *Lophius piscatorius*) discarded by trawlers operating in the ICES VI-VII Divisions have been published using the onboard sampling data (Díaz *et al*, 2008). The authors reported that most discarded fish in Subareas VI and VII were below 23 cm in length, being found a positive relationship between discard amounts and recruitment strength estimated by scientific surveys ($\rho_{white,IGFS} = 0.9$ and $\rho_{black,EVHOE} = 0.8$) . They concluded that angler stock recruitment strength mainly explains discards. An increasing trend of black angler discards estimates has been found in the last three years and reported to the Working Group of Hake, Monk and Megrim (ICES, 2010). The 2010 WGHMM claimed that current discard estimation method could be overestimating discard (problems with raising procedure) as estimates seemed unrealistically high for both spscies. Herein we present an update of Angler discard estimations in ICES Subareas VI and VII. The large amounts ocurred in the last three years and the ICES WGHMM conclusions has motivated an investigation on possible underlying factors which could explain this trend. The investigation is structured as follows:

1. A sampling scheme revisited to investigate if any variation from original protocol could lead to overestimated discard values in recent years (WGHMM claims)
2. An investigation to determine if exists any shift in fishing behaviour/discard practices in recent years

As discard sampling scheme and effort is the same for both species, the fishing behaviour/discard practices analysis is only carried out for black angler, the species with the estimated larger discard amounts in the area.

2 Material & Methods

2.1 Discard estimations

The $2003 - 2010$ fleet fishing effort, sampling effort and the resulting angler discard estimations with associated CVs by Effort, Landings and Target species are presented in the first section of results. Black angler discard raised by effort as the auxiliary variable were used for further investigations, as low bias between different methods were found for the species estimations.

2.2 Sampling scheme review

The sampling strategy and the estimation methodology used in the 'Spanish Discards Sampling Programme' has been little modified since 1988, and since 2003 follows the guidelines established in the ICES 'Workshop on Discard Sampling Methodology and Raising Procedures' (2003). The observers-on-board programme is based on a stratified random sampling design. Métier is the lower stratum and trips (the sampling unit considered in the former raising protocol) sampling allocation within métiers is random (for `OTB-D21`) or quasi-random (for `OTB-D12`).

Only trawl fleet is considered herein. Other fleets (i.e. long line fleet) were also evaluated, but discard levels for deep species along the areas under study (Pérez et al., 1996) was found to be negligible . Gillnet discard information is being recorded since 2008, although time series available is considered to be too short to be presented in the present document.

Possible bias from the sampling protocol ocurred in recent years is explored in the first section. The investigation is carried out within three sampling stages (Haul level,Trip level and Métier level). Fleets stratification, sampling scheme and raising procedures are detailed below:

2.2.1 Fleets stratification

Fishing area, gear and target species are the auxiliary covariates used to stratify fleets into métiers. Two métiers are considered within the Spanish bottom otter trawl fleets operating in the ICES Subareas VI and VII:

- `OTB-21` trips targeting megrim and angler spp.
- `OTB-12` trips targeting hake and angler spp.

2.2.2 Sampling scheme & raising procedures

The sampling scheme is disagreggated to the lowest sampling level in order to bring out critical steps which could affect discard estimations in higher levels:

- **Haul level**

Let h_{ij} be the j-th ($j = 1, \ldots, J$) sampled haul in sampled trip i ($i = 1, \ldots, t$). Let s_{ij} be a random sample volume extracted from the total catch discarded S_{ij}.Let

$$r_{ij} = \frac{s_{ij}}{S_{ij}} \tag{1}$$

be the ratio of the sampled weigth to the total weight of discards.

For sampled haul j within trip i,let f_{lk} be the k-th (k= 1,. . . , n) presence of fish of size l in s, and let $F_l = \sum_{k=1}^{n} f_{lk}$. Biomass by length size in s can be obtained using a species weight-length relationship,

$$F_l^w = \sum_{k=1}^{n} f_{lk} \cdot a \cdot b^l \tag{2}$$

- **Trip level**

Let

$$g_{jl} = \frac{F_{jl}}{r_j} \tag{3}$$

be the estimated numbers of individuals of size l discarded in haul j and,

$$g_{jl}^w = F_{jl}^w \cdot r_j \tag{4}$$

the estimated discards in terms of biomass. Mean of discarded for size l in trip i can be calculated as follows,

$$\bar{g} = \frac{1}{J} \sum_{j=1}^{J} g_j \tag{5}$$

with variance

$$\sigma_g^2 = \frac{1}{J-1} \sum_{j=1}^{J} (g_j - \bar{g})^2 \tag{6}$$

if all hauls from trip 'i' were sampled, the estimated total discards (in numbers) for size l is,

$$G_i = \sum_{j=1}^{J} g_l \tag{7}$$

else,

$$G_i = \bar{g} \cdot H \tag{8}$$

with H being the total number of hauls (sampled + unsampled). Variance associated to eq **??** is

$$\sigma_{G_i}^2 = (1 - \frac{J}{H}) \cdot H^2 \cdot \frac{\sigma_g^2}{J} \tag{9}$$

Métier level

- Raising by number of trips (assumed known)

Mean discarded by trip for size l is estimated to be

$$\bar{G} = \frac{1}{t} \sum_{i=1}^{t} \cdot G_i \tag{10}$$

with associated variance

$$\sigma_G^2 = \frac{1}{t-1}\sum_{i=1}^{t}(G_i - \bar{G})^2 \tag{11}$$

Equations (**??**) and (**??**) can be raised to population levels using total fishing effort of the sampled métier (T), yielding an estimation of total discarded by métier and length size (D),

$$D = \bar{G} \cdot T \tag{12}$$

with variance

$$\sigma_D^2 = (1 - \frac{t}{T}) \cdot T^2 \cdot \frac{\sigma_G^2}{t} \tag{13}$$

The aggregation of discard estimates from the separated métiers produce the estimation of the total fleet discards presented in the first section of results.

2.3 Fishing behaviour and discard patterns

An investigation on the spatio-temporal haul distribution is carried out in order to find any shift in the fishing behaviour of the fleet in recent years, which could explain increase in black angler discards. Interaction plots with year as conditioned variable are the tools used in this descriptive analysis.

The between-year variation of black angler retention L_{50} is analized in the last part of the document. To obtain reliable sorting parameters, we fit a Generalized Linear Mixed Model `GLMM` via Penalized Quasi-Likelihood. The model estimated both the effect of black angler fish size (fixed effect) in sorting behaviour, taking into account main random effects (trips and hauls) which could affect variability of the fixed parameters.The function `glmmPQL` from library `MASS` (R Core team, 2009) were used. Convergence Problems in some years lead to pool the data to trips level, leaving out within trip variability, which was found to be lower than the between trip variation. Yearly sorting curves and Confident Intervals were estimated with the model. L_{50} parameter from the estimated curves were extract for comparison between years. The model followed a logistic structure,

$$p(Y = 1|\eta) = \frac{\exp(\eta)}{1 + \exp(\eta)} \tag{14}$$

Being Y a binomial random variable determining the probability of a given individual to be retained onboard ($Y = 1$) or discarded ($Y = 0$), and

$$\eta = \beta_0 + \beta_1 \cdot l + b_i \cdot trip_i$$

being the right hand side a vector containing the fixed and random effects.

3 Results

3.1 Angler discard estimates

Discard estimates (*tons*) and associated coefficients of variation (CVs) are showed in Table **??** and Figure **??**.As low differences were found between raising procedures we will focus on the estimations raised by effort of the fleet hereafter. Black angler series show a steep slope between 2007 and 2008 values (from 248 *tons* in 2007 to 1190 *tons* in next year). Values from 2008 to 2010 are clearly higher than previous years and the maximun value were found in 2009. Estimated CVs showed a decreasing trend in the last three years with a minimum found for 2010 estimations (19.8%).White angler discards are lower than those for black angler (Table **??**), showing an U shape along the series with a minimum found in 2007. Estimates from 2010 by effort is much higher than previous years, reaching similar values to black angler estimates from the same year.

3.2 Sampling scheme review

3.2.1 Métier level

Multivariate analysis on landing data (Castro *et al*, 2007) yield two métiers differing from each other in fishing deep, fishing objectives and vessel port. These defined métiers match with those proposed by the former discard program. As no significant changes within fleet stratification have occurred along the sampled years, low error in sampling allocation is estimated in our sampling scheme. Yearly fishing effort and sampling effort by métiers are presented in Table **??**. Fishing effort by the `OTB-D12`has had remained at similar levels from 2003 to 2008, being noticed some decline in recent years. Sampling effort on this métier ranged from 2 sampled trips (2003) to 6 (2009). `OTB-D21` métier shows an increasing trend in fishing effort from the lower value (785 fishing trips) in 2006, to a maximum of 871 fishing trips during 2009. Sampling effort ranges from 7 to 9 trips along the time series. Count of sampling trips (pooled métiers, Figure **??**) shows that sampling effort were distributed homogeneously among the four quarters.

3.2.2 Trip level

Figure **??** shows the ratio between Total hauls (H) and sampled hauls (J) within sampled trips. Number of hauls in `OTB-D12` trips range from 20 to 56, and the sampling coverage range from 13 to 34. Number of hauls by trip is clearly higher in `OTB-D21`, ranging from 44 to 94. Numbers of sampling hauls associated for this métier ranges from 22 to 53. Sampling coverage exceed 50% for both métiers along the years sampled. Sampled hauls are uniformly distributed along haul secuence $(1, \cdots, H)$ in order to capture the possible spatio-temporal trip variations.

3.2.3 Haul level

f_{lk}, the presence of individuals of a given size in sample volume (s), could be affected both by changes in sampling coverage (r_{ij} (equation **??**)) and violations in sampling theory when drawn s. Figure **??** plots the within haul sampling coverage. The bulk of the collected samples represent less than 10% of the volume of discarded (S). Altough higher values of r_{ij} can

be seen for 2009, no increasing trend in sampling coverage is found during the last three years. In the other hand,s randomness could be seriously affected if collected by fishers instead the observer. Nevertheless, our observers claimed that crew willingness to cooperate in sampling hauls has not varied in recent years, and therefore accessibility to catch fraction allow to collect themselves the sampling volume.

3.3 Study of fishing behaviour and discard practices

Figure **??** shows spatio-temporal fishing sets and the related discard amounts (in numbers). Grand sole bank (southern Ireland) and Porcupine bank (eastern Ireland) were the fishing areas where the bulk of discards took place. Warm colors increase in frequency over the last three years. Deeper hauls were performed by the fleet since 2006 (Figure **??**), however, this pattern did not affect discard estimations as largest amounts of discarded ocurred at depths $\sim 200\ m$. `OTB-D12` fishing activities ocurred at deeper waters than `OTB-D21` ones. Discard amounts not depended on temporal secuence of hauls, as no clear trend is found in any sampled year (Figure **??**).Increasing amounts of discarded at haul levels have raised trip estimations values in recent years (Figure **??**).

Figure **??** shows the yearly onboard sorting curves and CIs estimated by the `GLMM`. In general, all curves show a steep profile meaning that sorting decisions vary in a small range of sizes (between 20 to 30 cm). Only 2003 show clear differences in curve slope, but clear differences can be found among intercepts. Results yield a L_{50} steady increase from 2003 ($21.3cm$) to 2008 ($24.9\ cm$), and a sharp increase up to $27.9\ cm$ for 2009,the year with the highest discard estimations. L_{50} estimated for 2010 reached $28.3\ cm$.

4 Conclusions

The sampling review carried out in the first section of this document has demonstrated that fishing effort, sampling effort and sampling allocation has no suffered any shift along the $2003 - 2010$ series and therefore we reject the WGHMM hypothesis on that recent years estimates are being overestimated. We also demonstrate that no significant change occurred in the studied métiers fishing practices. In the other hand, it is known that year-class strength is highly related with discard practices (Rochet and Trenkel, 2005), especially for species under landing regulations and/or juveniles low market value. Díaz *et al* (2008) found relation between recruitment indices and discards data series ($1994 - 2006$). The updated data keep showing good relationship between discards and recruitment indices. Black angler discard estimates in last years are positively related with recent recruitment indices ($2003 - 2009$) obtained by French $EVHOE$ and English $EW - FSP$ surveys (see ICES ,2010). White angler discards was also found to be highly correlated with the $2003 - 2009$ $IR - IGFS$. The wide CI (estimated by pooling the error term (σ_e) and the deviation obtained by the random effect term (σ_a)) found for the estimated sorting curves indicates that further statistical effort must be paid in order to establish significant yearly differences in onboard sort-

ing behavior. Even assuming this inferential restriction, we interpreted the mean first retention lenght (L_{50}) increase for black angler catches as a progressive industry adoption of the EU Council Regulation 2406/96, which fixes a minimum landing weight (MLW) of $500g$ for both angler species. We conclude that the interaction between these two main factors (juveniles availability and degree of rule enforcement) induce an additive effect which explains the high levels of discards in recent years.

5 References

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Black anglerfish	Aux. variable	2003	2004	2005	2006	2007	2008	2009	2010
Weigth	Effort	68	238	186	320	248	1190	1196	932
	Landings	82	187	186	354	196	1089	1328	
	Target species	71	231	154	326	237	1020	1188	
CV	Effort	32.70	35.50	28.90	46.20	45.50	43.10	26.80	19.80
	Landings	26.90	36.70	18.50	50.80	39.80	37.80	25.60	
	Target species	32.20	34.60	26.90	45.90	42.60	41.10	25.80	
White Anglerfish	Aux. variable								
Weigth	Effort	250	587	280	89	16	191	298	987
	Landings	268	463	190	86	12	198	247	
	Target species	265	570	231	90	16	173	295	
CV	Effort	35.40	42.60	36.10	42.30	26.20	37.10	42.30	13.50
	Landings	39.40	42.90	48.60	43.70	38.10	47.10	47.20	
	Target species	36.90	46.50	36.50	42.40	32.30	34.20	41.20	

Table 2: Estimations of discarded by different raising procedures and CVs (only values raised to effort available for 2010).

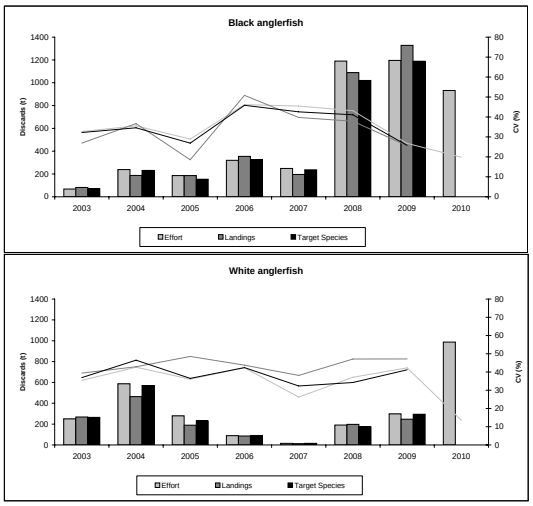

Figure 1: Angler discard estimations (bars) and related CVs (lines) for VI-VII Spanish OTB fleet (2003 to 2010).

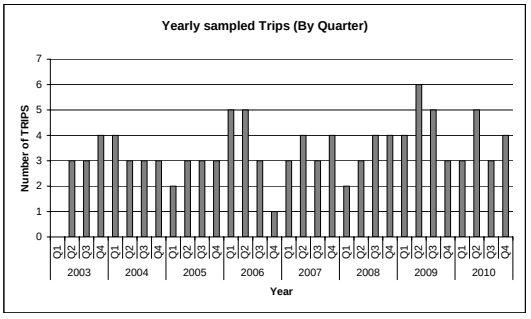

Figure 2: Yearly sampling effort (number of trips) by quarter (both métiers pooled).

	2003	2004	2005	2006	2007	2008	2009	2010
OTB-D12 Fishing effort	467	501	491	508	492	383	416	
Sampling effort	2	3	3	4	3	4	6	4
OTB-D21 Fishing effort	808	814	806	785	850	823	871	
Sampling effort	7	8	7	9	9	7	9	9

Table 3: Fishing and sampling effort (Number of trips) by métiers.

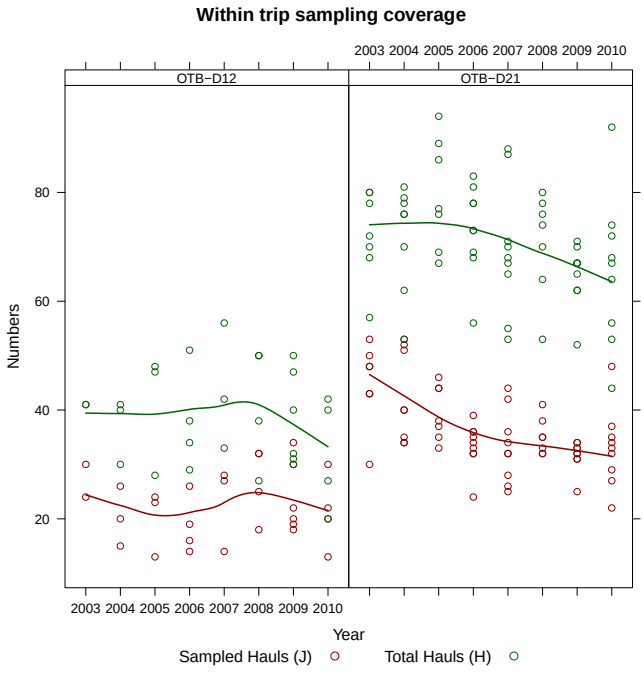

Figure 3: Differences between total hauls H and sampled hauls J. Sampling coverage within trip remains stable along the years.

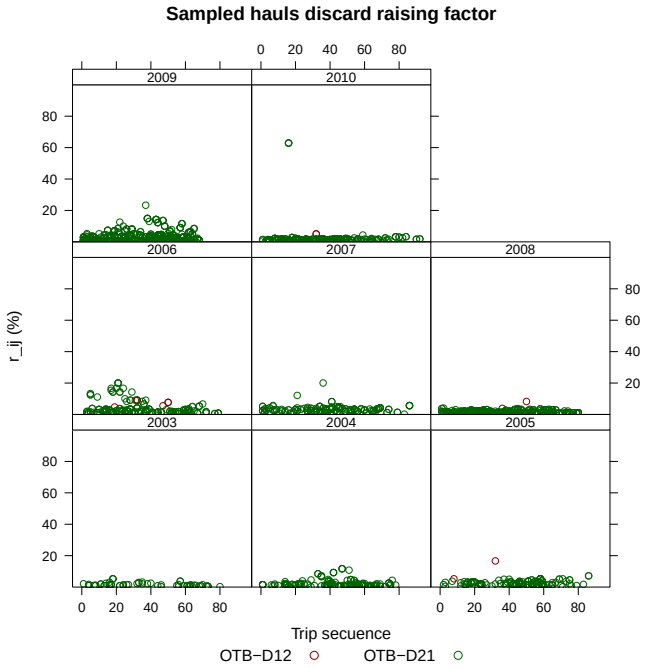

Figure 4: Discard raising factor to haul level. Sampling coverage within haul remains stable along the years.

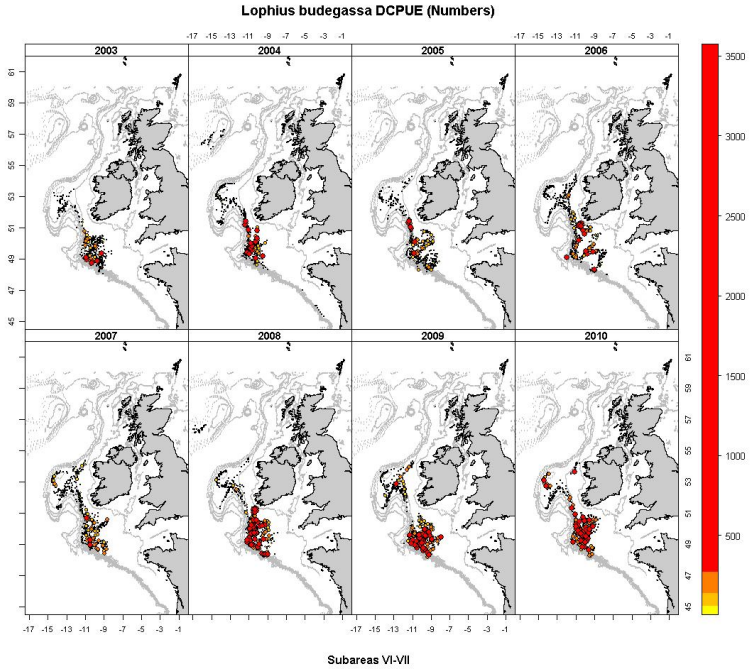

Figure 5: Haul distribution and black angler DPUE recorded in sampled hauls.Both métiers included.

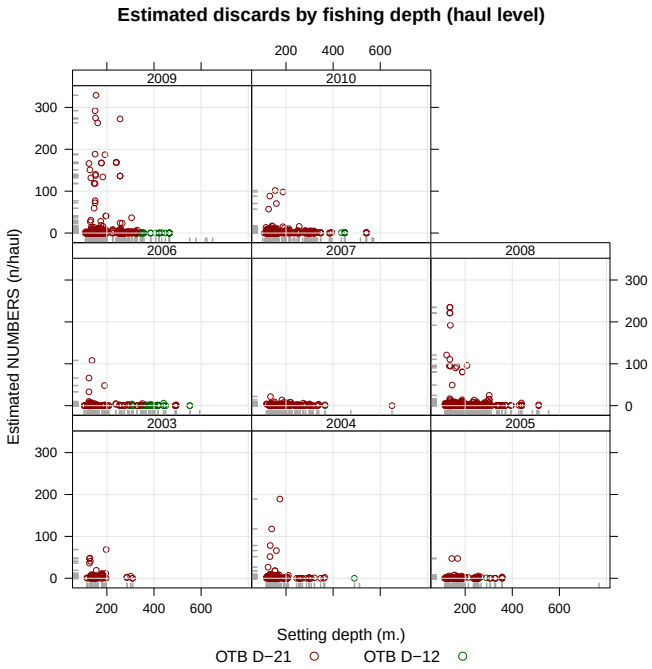

Figure 6: Numbers of black angler discarded by fishing deep. The Larger amounts are found in OTB-21 at depths below 200 m.

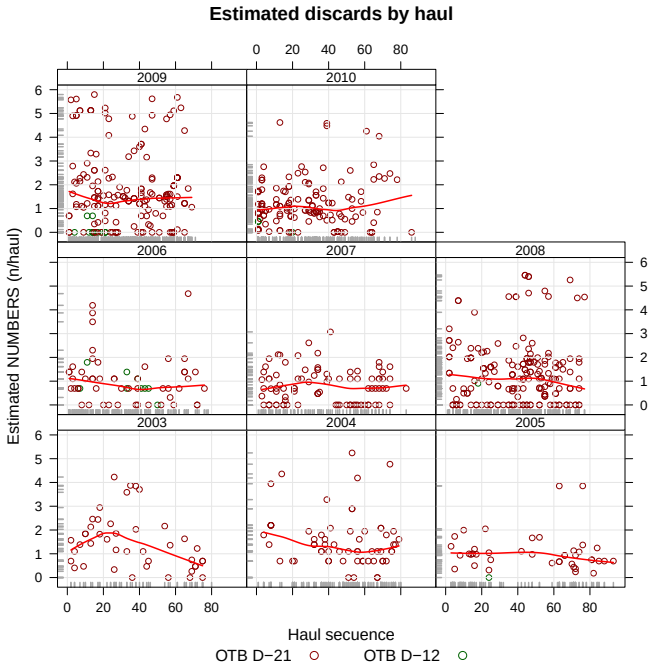

Figure 7: Numbers of black angler discarded by haul secuence.

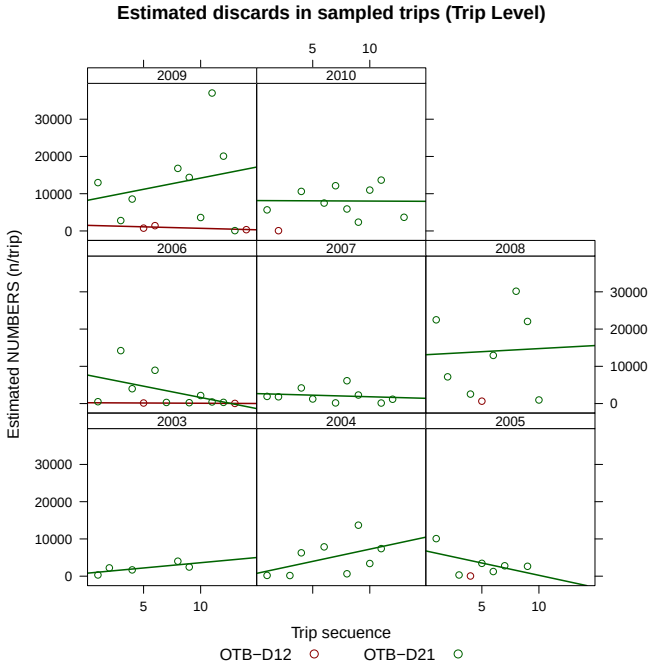

Figure 8: Estimated numbers of individuals discarded at trip level for both métiers. Intersect values from linear regression applied to `OTB-D21` data shows a rising trend from 2008.

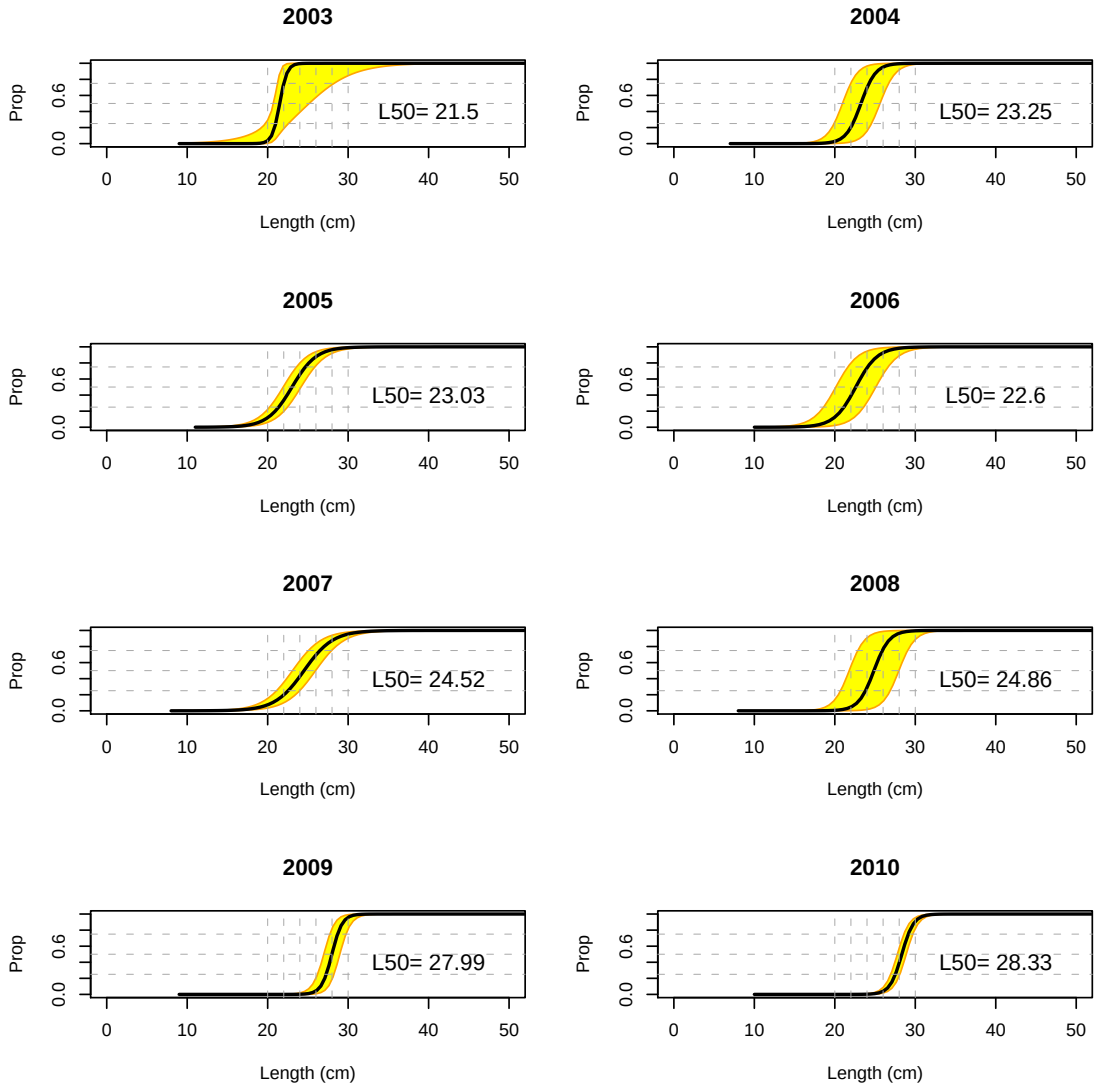

Figure 9: Sorting curves and Confidende Intervals obtained by the fitted `GLMM`.
L_{50} shows a increasing trend in recent years.