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Discards and by-catch in Spanish fleet targeting Greenland halibut (*Reinhardtius hippoglossoides*) in NAFO Divisions 3LMNO: 2008 and 2009.

by

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Abstract

This study analyses the discard and by-catch composition of the Spanish fleet targeting Greenland halibut (*Reinhardtius hippoglossoides*) in NAFO divisions 3LMNO. During 2008 and 2009 the sampling coverage of the fishing effort was 20.6% and 16.5%, respectively. Data showed a reduced (4.3 % in weight) but highly variable discard rate. The main discarded species were the macrourids *Macrourus berglax*, *Coryphaenoides rupestris* and *Nezumia bairdi*, together with other 2 fish species: *Antimora rostrata* and *Amblyraja radiata*. The target species (Greenland halibut) was intermittently discarded. The discard rate showed no pattern no trend. No significant catches of benthic invertebrate taxa indicators of vulnerable marine ecosystems (VMEs) were recorded.

Introduction

Discard is defined as the proportion of the catch representing the total organic matter of animal origin that is dumped or thrown back to the sea for whatever reason. It does not include plant material and post-harvest waste such as offal. The discard may be dead or alive.

The effects of discards and by-catch have been described at different levels. Incidence over non-target species (Saila, 1983; Alverson *et al.*, 1994); alteration of the benthopelagic ecosystem balance (Bailey *et al.*, 2006; Heithaus *et al.*, 2008, Morato *et al.*, 2006) and of the benthic ecosystem balance (Collie *et al.*, 1997; Jennings and Kaiser, 1998; Hall, 1999; Koslow *et al.*, 2001; Jennings *et al.*, 2001). These effects are more marked in deep-water ecosystems due to their ecological features and to the biology of their species (Devine, 2008; 2009; Leys *et al.*, 1998; Sherwood, *et al.*, 2009).

Discard reasons have been reviewed by different authors demonstrating that their variability is dependent on fishing gear, mesh size, local biodiversity and species abundance (Morizur *et al.*, 2004).

Recently, there has been an increase in the number of studies dealing with the issue of discarding. The bulk of these papers are descriptive and primarily seek to estimate the amount or proportion discarded, as well as the species and length compositions of discards (Rochet and Trenkel, 2005). The utilization of these estimates is slowly turning from improving catch estimates and fishing mortality rates in single-stock assessments to assessing the impact of fishing on fish communities. One of the difficulties in estimating discards is their high variability between fisheries, gears, ports, seasons, years, areas, trips and hauls. This variability causes sampling programmes to be very expensive, even to achieve a relatively low precision (e.g, Allen *et al.*, 2002; Rochet *et al.*, 2002). A variety of methods have been suggested to limit these costs by making use of additional information, e.g. stratified sampling (Stratoudakis *et al.*, 1999; Tamsett and Janacek, 1999), sampling proportional to vessel size (Allen *et al.*, 2001; Cotter *et al.*, 2002), ratio estimators based on landings (Saila,1983) and length structure-based (Macer and Brown, 1987; Pálsson, 2003) or

species composition-based methods (Medley, 2001). Some of these methods are widely used (see below). However, all of them rely on implicit assumptions not tested about the factors determining the variability of the discards.

The most commonly accepted assumptions are: (i) The most widely-used hypothesis to estimate discards assumes that they are proportional to the catch or to the deployed fishing effort, even if this assumption is not supported by published data. (ii) Environmental conditions and fishing methods have an influence on discard quantity and composition, but the stratification of these factors does not necessarily improve the accuracy of the estimations due to the high variability of the discards. (iii) Many factors interact influencing the discards of a given fishery (Rochet and Trenkel, 2005).

Before choosing the methodology to study discards, the underlying assumptions must be validated by analysing the processes which generate the discards.

Even if the discards are a highly relevant concern, only a few studies have dealt with this topic in the NAFO area (Durán *et al.*, 1996; Kulka, 1998 and 2001).

Spanish fishery on deep grounds in the NAFO area started in 1990, and the fleets have been targeting Greenland halibut since 1991 (Junquera *el al*, MS 1992) in waters deeper than 700 m (de Cárdenas *et al.*, MS 1996; González *et al.*, MS 2004). The youngest individuals of this species are mainly found at minor depths (Jørgensen, 1977), whereas the biggest specimens live in deep waters (Bowering and Chumakov, 1989). This study presents discard and by-catch data from the Spanish fishery targeting Greenland halibut in 2008 and 2009, and covers 531 fishing days observed.

Material and Methods

The fishing gear used by Spanish vessels targeting Greenland halibut is a *rockhopper* bottom trawl with 130-135 mm of mesh size in the codend.

Data have been collected by scientific observers onboard supported by the project PNBD funded by the UE and Spanish Administration (IEO) during the two-year period 2008-2009 in NAFO Divisions 3LMNO The fishing effort coverage of the project during 2008 and 2009 was of 20.6% and 16.5%, respectively (González *et al.*, 2009; González *et al.*, 2010).

The term “discard rate” used throughout this paper refers to the total discard rate in weight. The total discard rate is derived from the set of hauls complete records observed and is the summed discards as a percentage of summed retained catches plus summed discards.

Discard rate as % = Biomass Discard (kg)* 100/ Total Catch Biomass (kg) (retained+discard)

Directed fishery for Greenland halibut takes place from 700 feet deep, as reflected by the absence of this species in the catches shallower. Data were gathered from a total of 646 hauls performed at depths varying from 43 to 1698 m but only 414 hauls targeted Greenland halibut at depths greater than 700 m. Catches of this species were not relevant at depths around 600 m.

Table 1 shows the fishing hauls targeting Greenland halibut by quarter, year and NAFO division.

The fishing days were concentrated on division 3L, where 74.3% of the hauls were carried out. Table 1 shows data from fishing hauls, with average depth by stratum and on a quarterly basis during the biennium studied (2008-2009).

Some errors in the species identification and underestimation of the total weight are possible due to the difficulty of sampling the by-catch and discards onboard. Nevertheless, the estimations of the discarded biomass regarding total catch and/or retained catch obtained during the scientific observers programme from 2005 to 2007 showed similar values, never surpassing 6% within a year.

Data collected during the EU research survey cruises in NAFO area during 2008 and 2009 were used to uncover the eventual errors of the observers in the species identification or in their bathymetric distribution.

The total discarded weight in the observed sets with high biomass caught were estimated using different methods (Duran et al., 1996), and when it was possible the integrity of the catch was weighted. The retained catch weight was estimated from the processed catch using the specific conversion factors for each species and type of processing, regularly calculated by the scientific observers onboard.

Results and Discussion

The characteristics of the hauls directed to the Greenland halibut, depth (m) and fishing time (h) are shown as box plots (Figures 1 and 2).

Haul descriptive statistics for discarded biomass (Kg) by Division are presented in Table 3.

A total of 66 taxa were identified in the discards. Invertebrates and those fish genus whose specific identification was difficult (*Sebastes* spp, *Lycodes* spp), were grouped in major taxonomical ranges. Of the 66 identified taxa, 41 represented less than 0.1% of the total discarded catch (Table 4).

The total discarded biomass amounted to 4.3% of the total catch of the 414 analysed hauls targeting Greenland halibut at depths greater than 700 m.. Taking into account the eventual underestimation due to onboard working and sampling conditions, especially with high catches, the discard percentage is significantly lower than those observed in other trawling fisheries, generally multi-specific (Allain *et al.,* 2003; Morizur *et al.,* 2004). The discard rate of the Spanish fishery was also lower than the values obtained for the different areas of the Atlantic Ocean (Table 5).

The average discard rate was higher in division 3N and lower in division 3L, even if some high values were observed (Figure 3).

No relationship was observed between the discard rate and the haul duration (h) ($r^2 = 0.0778$; $p = 0.00000$), with depth ($r^2 = 0.0447$; $p = 0.000001$), or with yield (kg/h) of Greenland halibut ($r^2 = 0.0040$; $p = 0.1825$).

When analysing the specific composition of the discarded biomass (4% of the total catch), the main species were the macrourids *M. berglax* (24.5%), *C. rupestris* (22%), and *N. bairdi* (11.8%), followed by Greenland halibut (10.7%), Greenland shark *S. microcephalus* (8.7%), *Antimora rostrata* (4%), and *Amblyraja radiata* (3.4%). The discard specific composition was similar to the above described (Duran *et al.,* 1996).

The 60% of the Greenland halibut discards was concentrated in 6 hauls in the same fishing trip. This discard might be determined by the vessel's strategy. The average discarded catch of this species in the remaining hauls was 10.6 kg/haul, mainly corresponding to poor condition specimens.

The main discarded species, *M. berglax* and *C. rupestris* are slow-growing and late maturing benthic species (Murua *et al.,* 2000). Other species highly discarded, such as *A. radiata* and *A. rostrata,* have similar biologic features (Sulikowski *et al.,* 2005; Kulka *et al.,* 2006; Fossen *et al.,* 2006).

The discarded invertebrates were unrepresentative and mainly composed of bentho-pelagic crustaceans, cephalopods, and echinoderms. Even if some of these vulnerable specimens are distributed throughout the fishing grounds (Fuller *et al*., 2008; Murillo *et al*., 2010), the scarcity of their presence in the catch is probably due to the fishing gear used, the difficulty of noting small catches, and the concentration of the fishing effort in areas already damaged by trawling activities depleting sessile and erectile suspensivore and filtration species.

In terms of biomass, the discarded rate referred to the total catch per division is similar for 3M and 3N divisions, even if some differences in the species' discarded biomass were observed. In division 3L, the percentage of discard is much lower, as well as the distribution of the discarded biomass by species and the number of unwanted species/taxa.

Values of the discarded biomass in terms of the total catch, per division and on a quarterly basis, were highest in division 3M due to the higher catch of macrourids, mainly *M. berglax* and *C. rupestris* (species with higher discard rates), as well as the occasional discard of Greenland halibut. Due to the concentration of the effort in division 3L and, to a lesser extent, in division 3M, the available data for the remaining divisions were insufficient for analysis (Table 1).

Division 3L. A total of 43 species/taxa registered percentages lower than 3%. The discarded biomass of this division stands for only 3.2% of the catch and was mainly due to the following species: *S. microcepahalus* (Greenland shark), *M.berglax*, *N. bairdii*, Greenland halibut, *C.rupestris*, and *A. rostrata*, accounting for more than 3% of the total discarded catch.

The main discarded species in terms of biomass, *Somniosus microcephalus*, was infrequent, its high contribution in weight being due to the big size of the individuals of this species. Macrourids accounted for more than 45% of the discarded biomass (Table 3, Figure 4).

Division 3N. A total of 51 species/taxa were identified in the discarded catch, of which 38 accounted for less than 0.5%. As the Greenland halibut fishing effort concentrates on divisions 3L and 3M, the number of hauls in this

division was low. Discarded biomass represented 4.3% of the total catch. Discards composition was dominated, in biomass, by the macrourids *M.berglax, N. bairdii,* and *C.rupestris,* which together accounted for 61.2% of the total discarded biomass. The fourth species was *A. rostrata* (Table 3 and Figure 5).

Division 3M. A total of 30 species/taxa were identified, of which 23 accounted for less than 2.1% of the discarded catch (Table 3 and Figure 6). This division showed the highest discard rate, due to the high catch of macrourids, mainly *C. rupestris*, almost totally discarded (94%). This species, together with *M. berglax*, accounted for more than 47% of the discarded catch. Other discarded species, relevant in terms of biomass, were Greenland halibut and *A. radiata*.

Analyzing the discard rate for all divisions by quarter in the period, January 2008 to December 2009, the discard rate showed no temporal pattern nor trend (Figure 7).

Conclusions

From 2008 to 2009, the Spanish bottom trawl fleet targeting Greenland halibut discarded less biomass (4.3%) than other trawl fisheries. Despite the low rates of total discard, the most discarded species were mainly vulnerable slow-growing and late-maturing benthic species. The most discarded species were macrourids, with *C. rupestris* having the highest discard rate. Mostly fished in division 3M, this species' discard increased the total discarded biomass in this division.

The discards were highly variable, with no identified relationship between the duration of the haul, neither depth, nor Greenland halibut yields (kg/h). Discards of the target species were neither associated with its yields nor with the fishing of other species, but were probably dependent on the fishing vessel's operative conditions such as the exceeding of the available quota or the saturation of onboard storage space.

No seasonal variability pattern was observed; however more data would be needed to confirm this fact.

The discards of invertebrate megafauna taxa considered as vulnerable were not relevant as far as bottom trawl fishery is concerned and taking into account the onboard sampling and identification difficulties.

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Table 1.- Spanish Greenland halibut fishery 2008-2009. Number of sampled hauls and mean depth (m) by NAFO division and quarter. (*) Including 2 hauls in 3O Division.

Division / Period	3N nº /mean depth m.	3L nº /mean depth m.	3M nº /mean depth m.	Total hauls observed
1º Quarter 08	25 / 1056.1	29 / 1073.2	26 / 1199.9	82 (*)
2º Quarter 08	2 / 921.7	6 / 999.1	23 / 1069	31
3º Quarter 08	3 / 866.7	130 / 908.6	9 / 1020.7	142
4º Quarter 08	--	--	--	--
1º Quarter 09	--	1 / 1125.5	--	1
2º Quarter 09	--	48 / 1090.8	10 / 1041.8	58
3ºQuarter 09	--	32 / 891.5	9 / 1039.6	41
4º Quarter 09	1 / 839	57 / 1141.8	1 / 1063	59
Total observed hauls	31	303	78	414 (*)

Table 2.- Spanish Greenland halibut fishery 2008-2009. Number of observed hauls, discard rate (%) and species number on discard by NAFO Division. Depth hauls > 700 m.

Division	**3N**	**3L**	**3M**	**Total**
Haul sampled (%)	7,5%	73,5%	18,9%	100%
Bathymetric range (m)	751-1698	728-1348	826-1337	728-698
Biomass retained (%)	91.51	97.85	91.85	95.86
Biomasa discarded (%)	8.48	2.14	8.14	4.3
Nº spp on Discard	57	49	24	66

Table 3.- Spanish Greenland halibut Fishery 2008-2009. Haul descriptive statistics for discarded biomass (Kg) by Division.

		Biomass Discarded (kg)				
Division	**Haul N**	**Mean**	**Minimum**	**Maximum**	**Coef.Var.**	**Standard Error**
3M	78	646	25	3200	106.868	78.238
3N	31	552	30	1543	69.547	69.036
3L	303	128	0	3944	213.634	15.692
3O	2	291	77	506	104.071	214.550
Total	414	257	0	3944	174.231	21.989

Table 4- Spanish Greenland halibut fishery 2008-2009. Code, name and discards rate (%) of the species discarded by Division (* discard rate < 0.1 %).

Discarded species		NAFO DIVISION		
Sp Code	**Scientific name**	**3N**	**3L**	**3M**
RNG	*Coryphaenoides rupestris*	1,22	0,23	3,04
RHG	*Macrourus berglax*	2.11	0.49	1.71
NZB	*Nezumia bairdi*	1.74	0.50	0.26
GHL	*Reinhardtius hippoglossoides*	0.11	0.35	0.83
GSK	*Somniosus microcephalus*	-	0.27	-
ANT	*Antimora rostrata*	0.97	*	0.13
RJR	*Raja radiata*	*	*	0.44
LUM	*Cyclopterus lumpus*	*	-	0.26
1 68	*Urophycis sp.*	-	-	0.24
GPE	*Phycis chesteri*	*	*	0.30
GDE	*Onogadus ensis*	0.25	*	*
CFB	*Centroscyllium fabricii*	0.25	*	*
CAB	*Anarhichas denticulatus*	*	*	*
PLA	*Hippoglossoides platessoides*	0.38	*	-
RJG	*Raja hyperborea*	0.16	*	*
RED	*Sebastes spp.*	0.18	*	*
WIT	*Glyptocephalus cynoglossus*	0.27	*	-
LCT	*Lycodes reticulatus*	*	*	-
1 94	*Cottunculus thompsonii*	0.10	*	*
1 59	*Notacanthus nasus*	*	*	*
CAT	*Anarhichas spp.*	-	*	*
2 2	*Neolithodes grimaldi*	*	*	*
1 60	*Lycodes spp.*	*	*	*
3 96	*Opisthoteuthis sp.*	*	*	-
HCR	*Harriotta raleighana*	*	*	-
CVP	*Cottunculus microps*	*	*	*
ATX	*Actinaria* indet.	*	*	*
API	*Apristurus spp.*	*	*	*
CYH	*Hydrolagus mirabilis*	*	*	-
SKA	*Raja spp.*	-	*	-
COD	*Gadus morhua*	*	-	-
ALH	*Alepocephalus sp.*	*	*	-
STF	*Asteroidea*	*	*	*
ALC	*Alepocephalus bairdii*	*	*	*
ARU	*Argentina silus*	-	*	-
3 88	*Cirroteuthis sp.*	*	*	*
SCU	*Myoxocephalus spp.*	-	*	-
RJQ	*Bathyraja spinicauda*	*	*	*
CYO	*Centroscymnus coelolepis*	*	-	-
5 3	*Porifera* indet.	*	-	*
3 30	*Gasteropodae* indet.	*	*	-
CAS	*Anarhichas minor*	*	-	-
4 1	*Echinoidea* indet.	*	*	*
SSK	*Synaphobranchus kaupii*	*	*	*

Table 4 (Cont.).- Spanish Greenland halibut fishery 2008-2009. Code and name and discards rate (%) of the species discarded by Division (* discard rate < 0.1 %).

Discarded species		NAFO DIVISION		
Sp Code	**Scientific name**	**3L**	**3M**	**3N**
BSF	*Aphanopus carbo*	-	*	-
5 1	*Scyphozoa* indet	*	*	-
NRD	*Notolepis rissoi*	-	*	-
MHJ	*Halargyreus johnsonii*	*	-	-
NTW	*Penatulacea* indet.	*	*	*
5 4	*Polychaeta* indet.	*	-	-
CSS	*Scleractinias inde.*	*	-	-
2 30	*Sabinea hystrix*	*	*	-
OCT	*Octopodidae* indet.	*	*	-
CUX	*Holothurioidea* indet.	*	*	-
OWP	*Ophiuroidea* indet.	*	*	*
3 33	*Graneledone sp.*	*	*	-
ORY	*Hoplostethus atlanticus*	-	-	*
CVN	*Chiasmodon niger*	*	-	*
HKW	*Urophycis tenuis*	*	*	-
5 68	*Anthomastus sp.*	*	-	-
CDN	*Chauliodus sloani*	-	*	-
SSH	*Plesiopenaeus edwardsianus*	*	-	*
RJY	*Raja fyllae*	*	-	-
PWJ	*Pycnogonida* indet.	*	-	-
HQZ	*Hydrozoa* indet.	*	-	-

Table 5.- Atlantic Ocean. Discard rate and indicative coverage for some areas.

FAO Statistical Area	Discard rate (%)	Indicative coverage (%)
Atlantic Northwest (*)	9.3	43
Atlantic Northeast (*)	13.0	83
Atlantic Western Central (*)	37.7	81
Atlantic Eastern Central (*)	10.5	84
Greenland halibut NAFO Spanish fishery 2008-09	4.3	18.5

(*) Source: Kelleher, K. 2005.

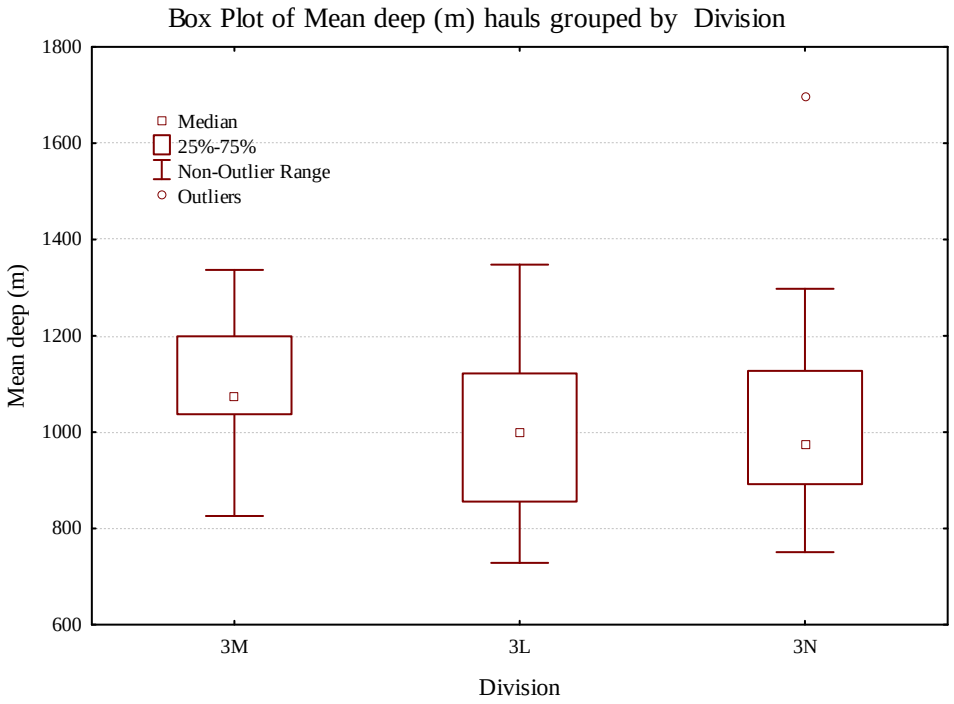

Figure 1.- Spanish hauls targeting Greenland halibut 2008-2009, box plot of mean depth (m) by Division.

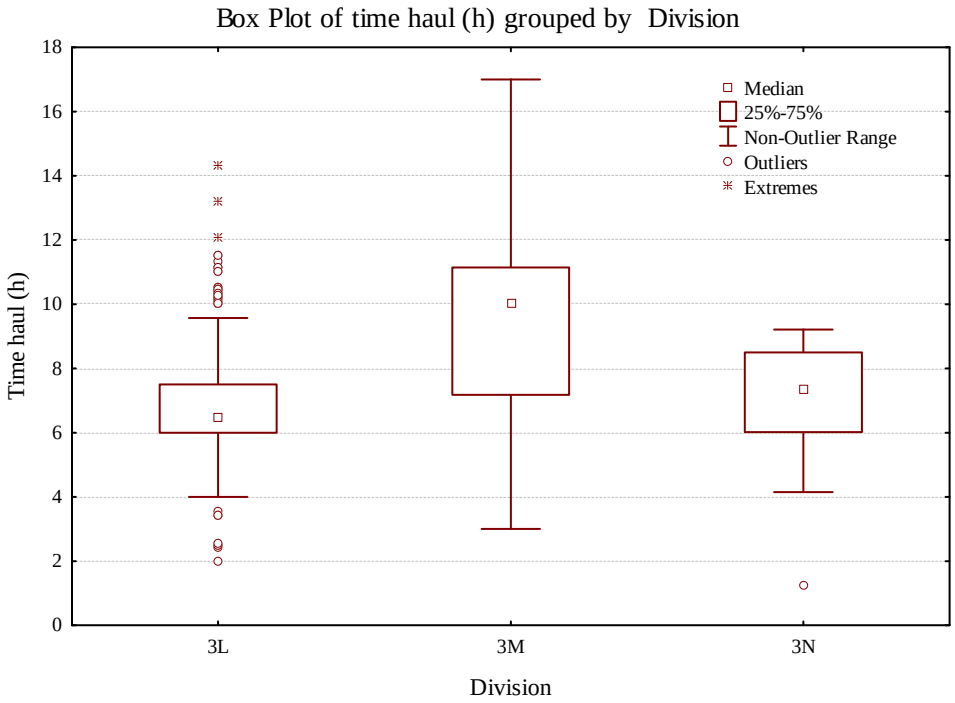

Figure 2.- Spanish hauls targeting Greenland halibut 2008-2009. box plot of time haul (h) by Division.

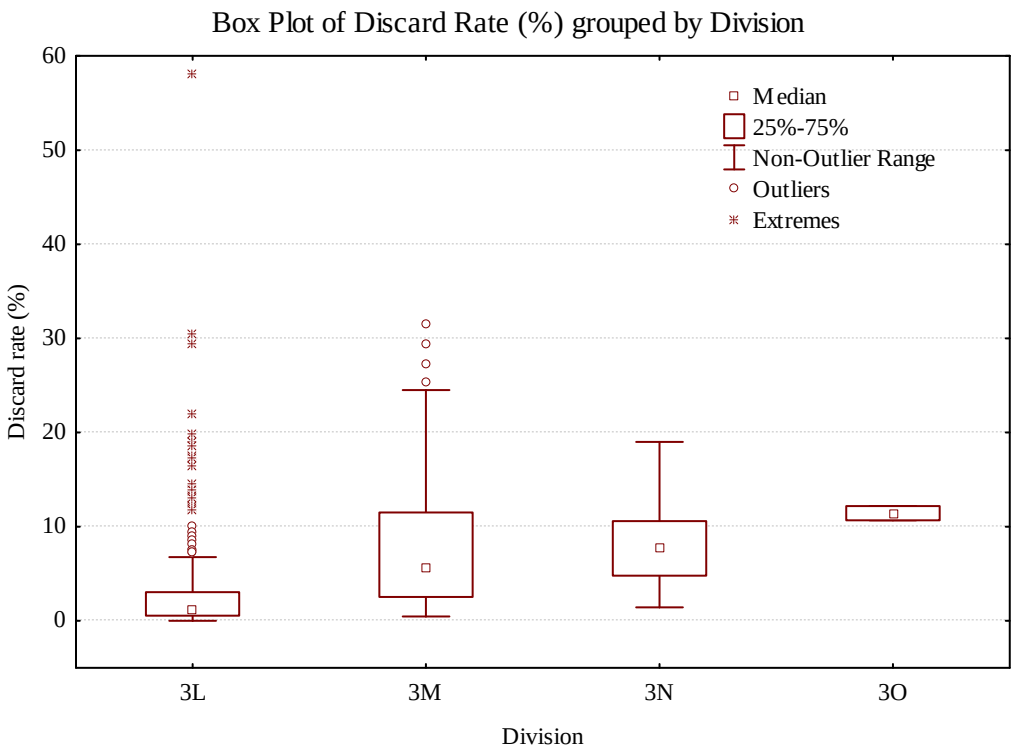

Figure 3.- Spanish fishery targeting Greenland halibut 2008-2009. Discard rate (%) by Division.

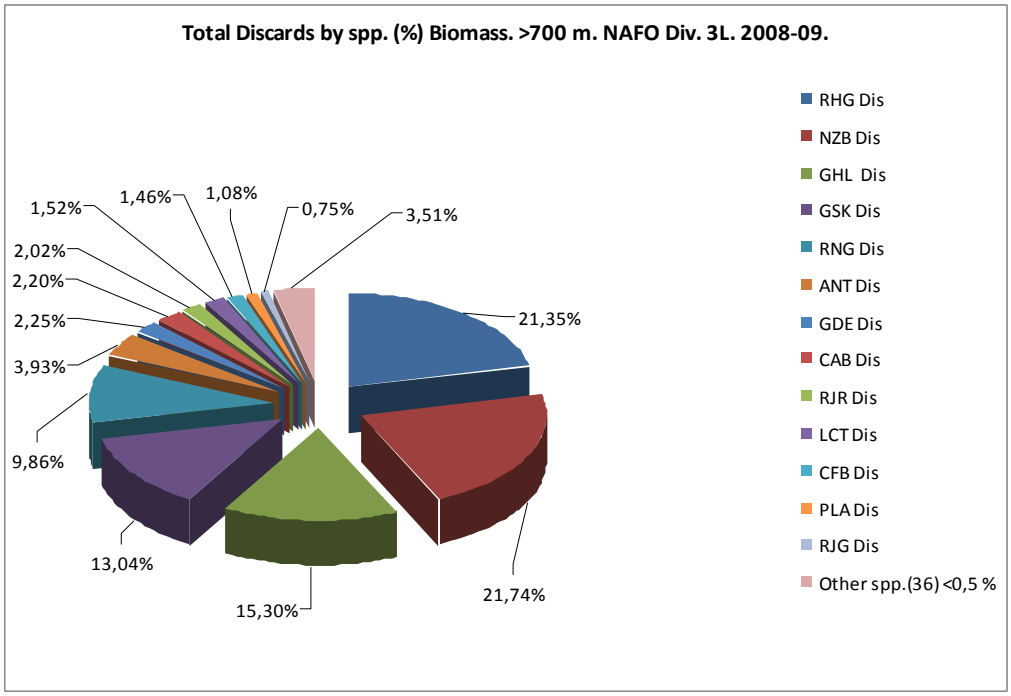

Figure 4.- Spanish fishery targeting Greenland halibut 2008-2009. Total discards in weight by spp. (%) NAFO Division 3L.

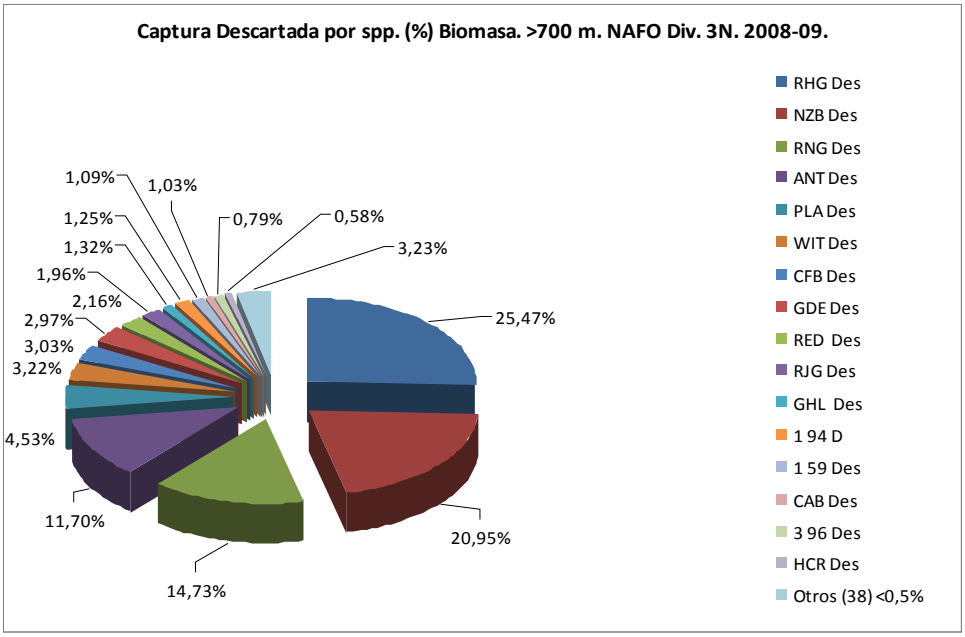

Figure 5.- Spanish fishery targeting Greenland halibut 2008-2009. Total discards in weight by spp. (%). NAFO Division 3N.

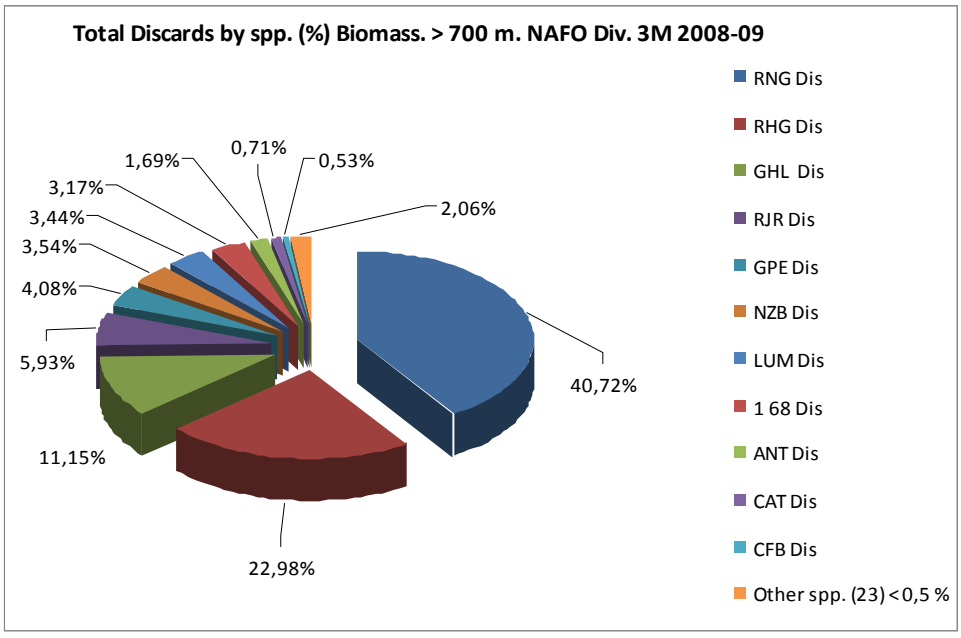

Figure 6.- Spanish fishery targeting Greenland halibut 2008-2009. Total discards in weight by spp. (%). NAFO Division 3M.

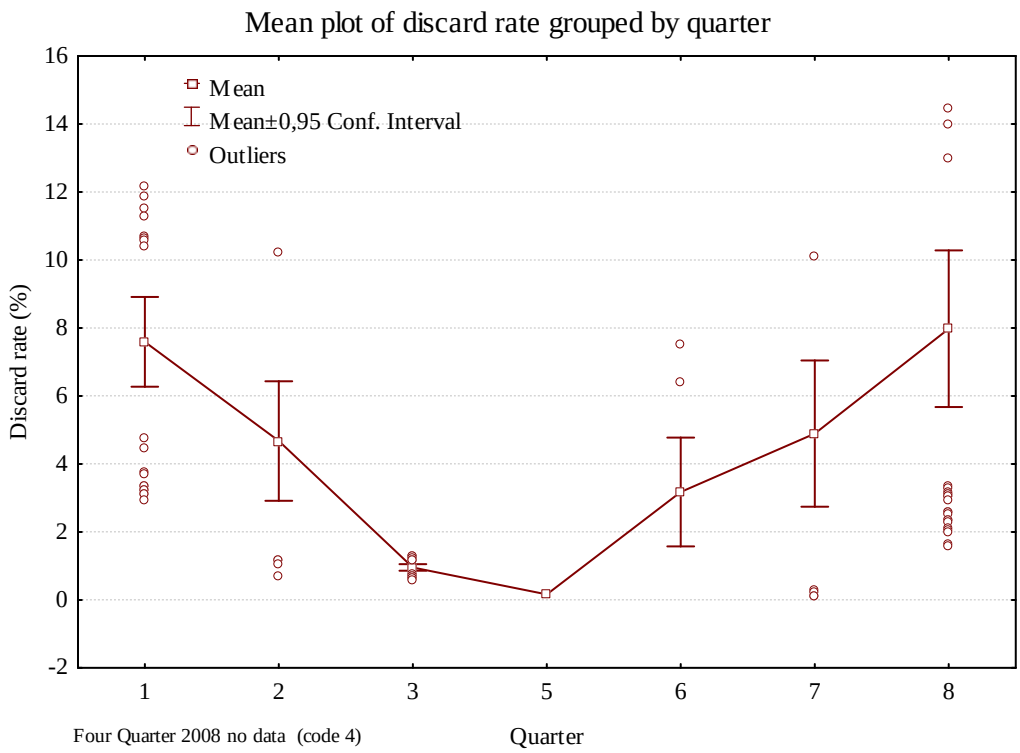

Figure 7.- Spanish targeting Greenland halibut, 2008-2009. Discard rate (%) by quarter for 3LMN Divisions.