Discard sampling of Plaice *(Pleuronectes platessa)* and Cod *(Gadus morhua)* in the North Sea by the Dutch demersal fleet from 2004 to 2008

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Summary

Since 2000, Wageningen IMARES monitors discards of the Dutch beamtrawl fishery (80mm mesh size) following the EC Data Collection Regulations (DCR) 1543/2000 and 1639/2001. In response to concerns about quality issues of these discard data, the Dutch beamtrawl industry initiated, in close cooperation with The Dutch Fish Product Board, its own plaice (*Pleuronectes platessa*) discards sampling program in 2004. Since then, this self-sampling program recorded discarding on more than 30 Dutch commercial trawlers fishing in the North Sea. In 2006, it was decided to include monitoring of cod (*Gadus Morhua*) discards in the program. This was done in view of the discussions as part of the cod recovery plan on possible high fishing mortality through discards by the beamer fleet.

The Dutch Fish Product Board requested Wageningen IMARES to analyse the data of the self-sampling program for the period 2004-2008. In previous studies of the self-sampling program, Dekker & van Keeken, 2005 and 2006, reported a significant difference between the self-sampling program and the Wageningen IMARES discard program (EC-DCR). Following the recommendations from these two reports the industry extended their program. They requested Wageningen IMARES to investigate the possibility to include their data in the stock assessment of North Sea plaice of ICES (WGNSSK). The recommendation is written down in Aarts & van Helmond (2007). This previous study found a significant difference between the discards estimates. Based on extensive investigations and discussions with fishermen, the difference was most likely caused by incomplete sampling of smaller individuals and taking one (selective) sample of the catch. In contrast, the DCR program samples different sections of the catch in an attempt to achieve a representative discard sample. In the previous report (Aarts & van Helmond 2007), considerable effort has been put in quantifying and understanding the observed difference. This report will provide an update on the analysis carried out and is mostly focused on addressing the following three questions

1. What are the current discard estimates based on the PVis and DCR discard sampling program and how do they compare with each other?
2. What are the spatial and temporal patterns in discarding?
3. Do the sampling methods itself inherently result in different discard estimates?

The observed average discard percentages (in volume) of Plaice in 2004-2008 based on the PVis data are 30, 28, 39, 40 and 50%, respectively. Based on the Imares DCR program, the discard estimates in those same years are 34, 44, 56, 45 and 59 (figure 2). Both sampling programs reveal an increase in discard percentage over the last few years.

Since 2006 also Cod has been sampled within the PVis program. The current discard percentage estimate for cod based on weight, volume and length measurements are 27, 21 and 11%, respectively. These estimates are probably very inaccurate, but still may provide a first indication of the level of cod by-catch.

The discard data has been used to investigate the effect of different variables on the observed discard fraction (research question 2) . Not only sampling location and time, but also gear specific characteristics (e.g. number of tickler chains, mesh size or chain mat) were included into the model. The three most important variables are spatial position, time of year and whether a chain mat was used or not. These results do not imply that other variables aren't important. For example, mesh size is strongly correlated with spatial position and it is therefore difficult to determine which of these factors is most influential.

The model reveals clear spatial and temporal patterns in discards. Plaice discards are much lower in northern offshore areas (figure 4). Furthermore, the models show higher discard percentages in July and August and lower estimates in December (figure 5).

The PVis discard data used in the analysis presented in this report clearly shows where and when most discarding takes place. Although previous analysis (Aarts & van Helmond 2007) and the latest Flatfish Benchmark Assessment (2009), indicate that the data cannot be incorporated into the ICES stock assessment, it still provides an important reference points that can be used to evaluate the current DCR discard estimates and methods used.

In 2009 Wageningen IMARES started a new DCR sampling program. The most remarkable difference with the previous program is the integration of self-sampling next to a less intensive observer program. We encourage this initiative, since the increase of discard data available over space and time will be of great value, but strongly recommend clarity of sampling procedures, thorough training and intensive communication with fishermen. Hence, inaccurate data on discards will have a significant impact on future management strategies.

Nederlandse samenvatting

Eind 2004 startte de visserijsector, onder leiding van het Productschap Vis (PVis), een eigen discardonderzoek. Reden voor dit onderzoek was de scepsis in de visserijsector over het DCR-discardprogramma van IMARES. Vissers twijfelden of de geschatte fractie aan discards wel representatief was voor de totale vangst door de gehele Nederlandse demersale vloot. De sector veronderstelde dat IMARES die fractie te hoog schatte omdat ze niet voldoende rekening zou houden met verschillen in ruimte, tijd en de verschillende vormen van scholvisserij. Op een twintigtal Nederlandse demersale schepen nemen vissers nu zelf monsters van de vangst aan schol om de fractie aan discards te schatten. Het PV heeft IMARES eerder gevraagd deze gegevens te analyseren (Dekker & Van Keeken, 2005, 2006, Aarts & Helmond, 2007).

In Aarts & van Helmond (2007) is een zeer uitgebreide analyse aan bod gekomen waarin vooral gekeken werd naar het verschil tussen de schattingen van IMARES en het PVis discards onderzoek. Eveneens werd gekeken of de gegevens gebruikt zouden kunnen worden in de jaarlijkse bestandschatting door ICES. Verdere analyses gepresenteerd in dit rapport (figuur 6) laten zien dat de methoden zelf niet verschillend zijn, en dat het dus aan de daadwerkelijke uitvoering van de methoden aan boord van vissersschepen moet liggen. Daaropvolgende gesprekken met vissers suggereerde dat het waargenomen verschil vooral verklaard kon worden door de manier waarop de vangst aan boord bemonsterd wordt. In tegenstelling tot het PVis programma, tracht het IMARES DCR bemonsteringsprogramma een representatief monster van de vangst te nemen door verschillende segmenten van de vangst te meten. Om die reden kunnen de data in de dusdanige vorm niet worden gebruikt in de bestandschattingen berekend door ICES.

De analyse in dit rapport zal minder gericht zijn op het beschrijven en verklaren van eventueel waargenomen verschillen, maar zal vooral gericht zijn op het beschrijven en analyseren van de PVis data door antwoord te geven op de volgende vragen.

1. Hoe verhouden de discardpercentages uit het bemonsteringsprogramma van de visserijsector zich met de discardpercentages die voortkomen uit het DCR bemonsteringsprogramma van IMARES?*
2. Wat zijn de ruimtelijke en temporele patronen in het discardpercentage en wat is de invloed van visserijspecifieke karakteristieken?
3. Zijn de twee gebruikte methoden van elkaar verschillend?

De waargenomen gemiddelde discardpercentages (in volume) voor schol in 2004, 2005, 2006, 2007 en 2008 voor PVis data zijn respectievelijk 30, 28, 39, 40 en 50%. De door IMARES waargenomen gemiddelde discard percentages in diezelfde jaren zijn 34, 44, 56, 45 en 59 (figuur 2). Beide bemonsteringsprogramma's laten zien dat het discard percentage de laatste jaren is toegenomen. De standaardfouten (SE) en de 95% betrouwbaarheidsintervallen over deze gemiddeldes geven aan dat de geschatte standaardfouten in alle jaren, met uitzondering van 2007 kleiner waren voor PVis vergeleken met IMARES (onderzoeksvraag 1).

Sinds 2006 bemonsteren schepen in opdracht van PVis eveneens kabeljauw discards. De huidige geschatte discardpercentage voor kabeljauw gebaseerd op gewicht, volume en lengte metingen zijn respectievelijk 27, 21 en 11%. Een inspectie van de ruwe data laat zien dat de data onvolledig zijn. Dit vergroot het risico op onder- of overschatting. Hoewel deze schattingen veel verschillen van elkaar, levert het waarschijnlijk toch een eerste indicatie van de mate van kabeljauw bijvangst.

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* Het bemonsteringsprogramma van de visserijsector wordt in het verdere rapport aangeduid met 'PVis programma' en het DCR bemonsteringsprogramma met 'IMARES programma'.

Vervolgens zijn de schol discards gegevens gebruikt om met een statistisch model te onderzoeken wat het effect is van verschillende variabelen op de waargenomen discardpercentages (onderzoeksvraag 2). Daarbij zijn als variabelen niet alleen de plaats en dag van het jaar gebruikt, maar ook de maaswijdte en verschillende technische eigenschappen van het tuig, zoals bijvoorbeeld het aantal wekkers. Bij de berekening worden uiteindelijk de variabelen die het minst van invloed zijn op het discardpercentage één voor één verwijderd. Op die manier blijven alleen de variabelen die de meeste invloed hebben, over. De drie meest belangrijke variabelen zijn: ‘het gebied’, ‘de periode van het jaar’ en het wel of niet gebruiken van een kettingmat. Dit betekent echter niet dat andere variabelen niet belangrijk zijn. Maar je kunt maaswijdte bijvoorbeeld niet los zien van het gebied, omdat in De Noord ruime mazen en in De Zuid nauwe mazen worden gebruikt.

Net als aangegeven in de drie vorige rapporten (Dekker & Van Keeken, 2005, 2006 & Aarts & van Helmond 2007) zijn ook nu weer duidelijk interpreteerbare ruimte- en tijdafhankelijke patronen in discardpercentages gevonden (onderzoeksvraag 2). Het model laat duidelijk zien dat het percentage scholdiscards in de vangst kleiner worden, naarmate verder van de kust wordt gevist (figuur 4). Bovendien wordt er een duidelijk seizoensgebonden patroon waargenomen; hoge discardpercentages in juli en augustus en lage discardpercentages in december (figuur 5).
De belangrijkste bijdrage van het PVis discards bemonsteringprogramma en de analyses uitgevoerd in dit verslag, is dat het een noodzakelijk inzicht verschaft in de mate van schol (en kabeljauw) discards en welke factoren (bijvoorbeeld regionale en seizoensverschillen) een rol spelen. De data laten vooral heel duidelijk zien waar en wanneer de meeste discards plaatsvinden. Hoewel eerdere analyses (Aarts & van Helmond 2007) laten zien dat de data niet direct opgenomen kunnen worden in de internationale ICES bestandschattingen, verschaft het toch een nieuw en belangrijk referentie punt dat laat zien dat de huidige (DCR) schattingen mogelijk niet de werkelijke mate van discards van de hele vloot benaderen. Hoewel deze en voorgaande studies geen aanleiding geeft om de huidige IMARES bemonstering te wantrouwen, stimuleert het PVis discard programma een kritische evaluatie en dit zal een inzicht verschaffen in hoe accuraat de huidige methode en bijbehorende schattingen zijn.

1 Introduction

Most demersal fisheries are mixed fisheries, targeting a limited number of species that live on or near the seabed. In general other species will be thrown overboard, a practice called discarding (Van Beek, 1998). Most species that are discarded are not of commercial interest, such as sea stars and sea urchins. However, in some cases discards entail commercially valuable species like North Sea plaice (*Pleuronectes platessa*). It is this type of discarding that is of interest to this report. Commercially valuable species are discarded because the individuals caught are below a legal Minimum Landing Size (MLS), because of lack of (sufficient) quota, or because of high-grading (i.e. removing individuals of low market value) above the minimum landings size). Discards represent a threat to the sustainability of fisheries, because of the high mortality of most discarded fish and other organisms. Discarding of juvenile fish, individuals below the minimum landing size, eventually results in reduction of the number of mature fish that can be caught or reproduce. In all cases, discarding degrades the marine ecosystem and, eventually, reduces productivity of the fisheries.

Given that it is not the total amount of landings, but the total amount removed from the population (total mortality) that drives changes in population size, estimations of total amounts of discards in a fishery play an important role in stock assessments. Population estimates and their predictions form the basis of the Total Allowable Catch (TAC). Reliable estimates of discard numbers (at age) are therefore essential. Since 2000, Wageningen IMARES is using observers on board commercial vessels to sample discards of the Dutch demersal (beamtrawl) fishery. These discard data are collected following the European Council and Commission Data Collection Regulations (DCR) 1543/2000 and 1639/2001. These discard estimates are used in the stock assessment of North Sea plaice as part of the ICES Workgroup WGNSSK. The use of observers at commercial vessel is an expensive and time consuming method to sample discards. Due to these high costs, only a small percentage (<1%; 10 trips per year) of the total fishing effort is sampled. Amounts of discards vary considerably by age, season and region. As a consequence, small sample sizes (low sampling effort) could possibly result in imprecise estimations of annual discard rates. Fishery biologists are well aware of this problem and realize this can only be overcome by increasing the sampling effort in space and time.

Concerned about these quality issues, the Dutch Fish Product Board questioned the representativeness of the discard estimates produced by Wageningen IMARES. The Product Board suspected that (by chance) unrepresentative sampling of IMARES in space and time was leading to an overestimation of discards. As a response to these concerns the Dutch flatfish industry decided to start their own discard sampling programme for plaice in 2004. During the period 2004-2008 around 20 vessels participated in this self-sampling project, each participant collected data of two hauls each week. Compared to the observer programme of Wageningen IMARES this was a substantial increase in sampling effort. In 2006, sampling of cod (*Gadus Morhua*) was also included in the program. This was done in view of the discussions as part of the cod recovery plan on possible high fishing mortality through discards by the beamer fleet.

Previous studies (Dekker & Van Keeken, 2005; Dekker & Van Keeken 2006; Aarts & van Helmond, 2007) already concluded that the discard data of the self-sampling project gave interpretable results. Statistical analyses provided evidence for clear trends in time, spatial patterns, and differences between gears and individual vessels (Aarts & Van Helmond, 2007).

Estimated discards rates of both programmes differ significantly. Discard rates of the self-sampling programme are consistently lower than the estimations of the observer programme (Dekker & Van Keeken 2006; Aarts & van Helmond, 2007). Based on results of a comprehensive statistical analyses Aarts & Van Helmond (2007) concluded that the difference between the two sampling programmes could not be explained by difference in spatial and temporal sampling effort. At that time, it remained unclear what was causing the discrepancy between the estimates, advise was given not to incorporate the Product Board data in the stock assessment of North Sea plaice (WGNSSK).

In an attempt to explain the differences in discard rates further research was instigated on the sampling methodology of both discard programmes in 2007 and 2008. One possible explanation is that difference in discard rates are caused by an inaccurate sampling methodology. Especially, Wageningen IMARES implements a complex procedure to estimate discard fractions. An experimental study was set up to re-evaluate both sampling protocols. Although research at the time of reporting was still ongoing, preliminary results showed that discards rates estimated by both sampling *methods* are not significantly different (Aarts & van Helmond, 2007). This gave an important indication that the methods itself not inherently result in different discards estimates.

This report is a continuation of the previous study of Aarts & van Helmond (2007). In the previous report (Aarts & van Helmond 2007), considerable effort has been made to quantify and understand the observed difference. This report will provide an update on the analysis carried out using the most recent data (2004 to the first half of 2008), but places less emphasis on explaining the observed differences in discard rates.

2 Assignment

The Dutch Fish Product Board requested Wageningen IMARES to analyse the data of the discard self-sampling program of the Dutch demersal fishery industry of the period 2004 – 2008 (first half), and to answer the following questions:

1. How do the discard estimates of the self-sampling program and the discard sampling program of Wageningen IMARES compare?
2. What are the spatial and temporal patterns in discard rates during the period 2004 – 2008?
3. Do the sampling methods itself inherently result in different discard estimates?

By mutual agreement, the Dutch Fish Product Board and Wageningen IMARES, decided to conduct this study as a continuation of the previous report (Aarts & van Helmond, 2007). It was agreed not to compare model residuals, section 3.6 in Aarts & van Helmond (2007), as done in the previous analyses. Furthermore, the exact same statistical models are used to answer the research questions described above. In addition to the report of 2007, the final result of the experimental study on sampling methodology (question 3) are presented and discussed.

3 Materials and Methods

3.1 Self-sampling program: Collection of plaice discard data

The discard self-sampling program set up by the Dutch Fish Product Board is based on a sampling scheme on demersal beamtrawl vessels which participate on a voluntary basis. The discard program requests vessels to estimate the discard fraction of plaice during two hauls per week. The first sampled haul is after 4:00 PM on Tuesday and the second haul is the haul after 4:00 PM on Thursday. From the total catch in a single haul a sub-sample of one or two boxes (approximately 40 or 80 litre, respectively) is taken. The total number of boxes of plaice above minimal landing size (27 cm, excluding the sample) from the complete haul is registered.
From the sub-sample, plaice above ("sized") and below minimum landing size ("undersized") are selected and placed in separate 20 litre buckets. Total volume (in litres) of each sample is registered. Fishermen measure length (in centimetres) of a random selection of 50 individuals of each group (sized and undersized). All data are recorded, as well as information on date and time location, gear type, haul number, and haul duration. For instruction manual (in Dutch) see appendix D.

3.2 Self-sampling program: Collection of cod discard data

All cod, both above and below minimum landing size (35 cm) of all hauls combined (i.e. complete trip) should be kept apart and stored for future measurements. At the end of the trip total weight of sized as well as under-sized cod is registered and recorded. From a random selection of 50 individuals of the total catch (from the complete trip) of each group (sized, undersized) length is measured and recorded. Eventually all sized cod is weighed and landed. The undersized cod is kept a side and is weighed under supervision of an employee of The Dutch Product Board. For instruction manual (in Dutch) see appendix D.

3.3 Self-sampling program: Data collection and pre-processing

Data of all vessels are combined in a dataset by the Dutch Fish Product Board and made available to Wageningen IMARES for further analysis. The data spans week 41 in 2004 until week 25 in 2008. In total 33 vessels participated, resulting in a dataset with 2221 records (see table 1). However, the dataset is not complete. We counted 20 missing records (empty cells) for 'mesh size', 182 missing records for 'number of tickler chains', 141 missing records for 'number of trawl head chains' and 134 missing records for 'use of chain mats'.

The cod discards fraction expressed in weight was only recorded in 62 unique cases. The cod discard fraction in volume had 76 complete records, even though it is practically very difficult to measure quantities of cod in volumes. The weights of cod from the category class I to V, were recorded in some cases, but total weights of undersized cod were often missing, even though the crew of the vessel did record length measurements of discards during that week. So this clearly indicates that there are no complete records.

In this report most emphasis will be placed on estimating discard fractions of plaice and its spatial and temporal properties. Due to the high number of missing data (empty cells) in the cod data set we will restrict ourselves to a rough estimate of the discard fraction for this species.

Table 1. *Summary of the number of observations per year, gear type and mesh size.*

year	ships	gear	mesh size	n observations
2004	17	Beam trawl	80	223
			100	6
		Quodrig	80	5
2005	16	Beam trawl	80	596
			100	62
			120	17
		quodrig	80	23
		twinrig	80	3
2006	16	Beam trawl	80	526
			100	26
			120	12
		twinrig	80	47
2007	12	Beam trawl	80	493
			100	21
			120	11
		twinrig	80	27
			110	8
2008	7	Beam trawl	80	111
		twinrig	80	4

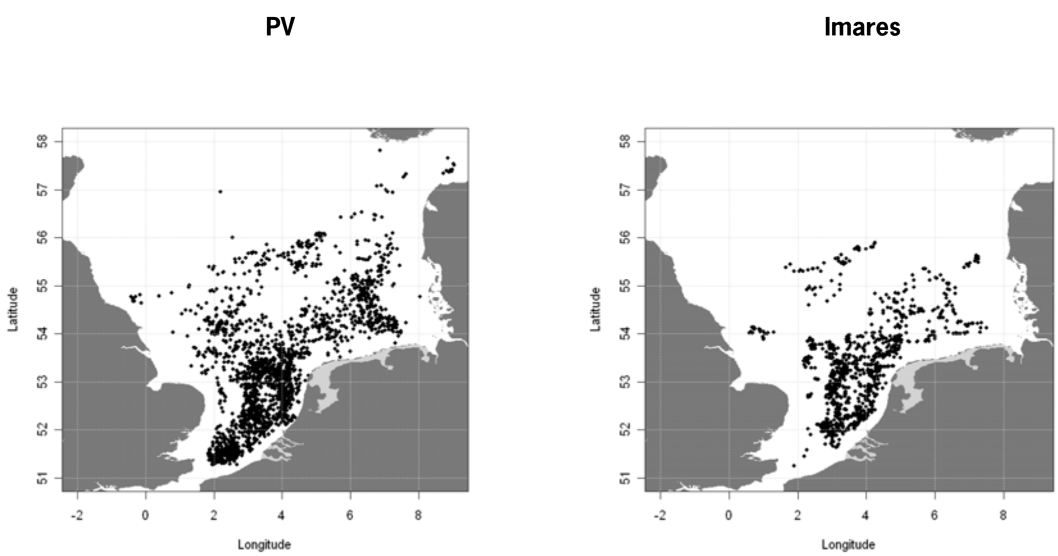


Figure 1. *Distribution of data for both sampling programs over the period 2004 – 2008.*

3.4 Observer programme Wageningen IMARES: Data collection and pre-processing

Selection of the vessels in the IMARES discard data collection is quasi-random and based on co-operative sampling, e.g. trips are only observed in agreement with the skipper. This means that the skipper of the beam trawl vessel may refuse to participate. Vessels from different regions were selected to obtain a widespread coverage. From fall 2004 until spring 2008 a total of 41 trips were made on board beam trawl vessels. For every discard sampling trip, two observers went onboard a vessel, sampling at least 60% of the hauls (van Helmond & van Overzee, 2008). For each sampled haul, fish within a sub-sample of the discards were counted and measured. Benthic invertebrates were only counted. On a regular basis, otoliths were collected from the most important discarded fish species (plaice, sole, dab, cod, whiting) for age determination. Estimating total discards of a species (e.g. plaice) is a complex procedure. In section 3.5 we explain in detail how this is done. In appendix A, a schematic representation is provided.

Wageningen IMARES takes samples of the total catch in one haul after fishermen remove all commercially valuable individuals. The landings were recorded and verified with the auction data. The remaining section contains non-commercial species (e.g. sea stars, urchins) and undersized individuals (e.g. undersized plaice). From these discards, a sample (40 litre) is taken. In most cases the length of all individual fish in that sample are measured, only when a species is extremely abundant in the discard sample, a smaller fraction is measured. Using species specific weight-length relations, we can use the measured length and estimate the weight of each individual. Next the estimated total catch, the sample size (40 litres) and the sub-sampling fraction can be used to estimate the total amount of discards of that species in the sampled haul.
Finally, to conform to the data collected by PV, total weight of plaice discards and landings, are transformed into volumes by multiplying by 0.89 and 0.83 respectively. A detailed description and an example of the raising procedure used can be found in appendix B.

3.5 Estimating the mean discard percentage of plaice

For explanatory purposes, the level of discards will be presented as percentages. However, model development and estimation will be based on discard fractions. Discard fractions, like any fraction, exhibit two statistical properties that have to be accounted for when estimating their means. First of all discard fractions are not normally distributed (e.g. they are not symmetric around the mean). Second the accuracy at which discards fraction estimates are made, are not the same for all observations, but they depend on the total volume of plaice in the sample. For example a discard percentage of 25% based on 30 litres of landings and 10 litres of discards, is more informative than an estimate of 0% based on only 1 litre of landed plaice in the subsample. To accommodate both aspects (non-normality and unequal variance) we calculate the maximum likelihood estimate of the mean discard fraction assuming a binomial distribution for the response variable and weight observations based on the total number of plaice in the sample. This means that those discard estimates based on a small sample size (i.e. low volume of plaice in the sample), will have a low impact on estimated mean discard fractions.

3.6 Estimating the mean discard percentage of cod

In total there are 62 complete records on discard percentages expressed in weights and 76 complete records on discard percentages expressed in volume of cod. Additionally, there are records were length of a maximum of 50 individuals from each group, sized and undersized, were measured. After May 2006, the participants were asked to count all extra individuals. In practice, these values were often unknown. Furthermore, in some cases (e.g. PV021, week 19), only individuals >35cm were recorded. In that week there were 6 individuals of 35cm, 8 of 36cm, 5 of 37cm, etc. Because it is very unlikely just to catch cod above the MLS, this leads us to suspect that undersized individuals were caught, but not measured, in those cases. However, to provide a first estimate, we therefore (perhaps inappropriately) assume that in the absence of extra sized- and undersized individuals recorded, all individuals were measured. Using length-weight relations and the minimum landing size of 35 cm, it is possible to estimate the total weight *W* of under-sized (eq.1) and sized (eq. 2) individuals as follows

$$w_{l<35cm} = \sum_{l=1}^{34} n_l 0.0068 \cdot l^{3.101}, \qquad 1)$$

$$w_{l\geq 35cm} = \sum_{l=35}^{\infty} n_l \, 0.0068 \cdot l^{3.101} \quad , \qquad 2)$$

where n_l is the total number of individuals of length l in the sample. This can than be used to estimate a discard fraction $p_{discards}$ for that week as follows;

$$p_{discards} = 100 \frac{W_{l<35}}{W_{l<35} + W_{l\geq 35}} \quad . \qquad 3)$$

3.7 Estimating the precision of the observed discard percentage

Estimating standard errors is difficult due to large (most often positive) within trip auto-correlation. Simply estimating standard errors using the observed discard fraction (based on volume measurements) within each haul, in general will lead to an underestimation, since observations (i.e. hauls) within a trip are strongly correlated. In the extreme case where one would sample one vessel and measure a large number of trips, standard errors might be very small (i.e. the observations are very closely distributed around the mean), but the large variability between ships is not appropriately captured. Fitting a mixed-effect model (see e.g. Fox 2002, Pinheiro & Bates 2000) will capture both between and within vessel variability and will correctly estimate standard errors of the mean discard fraction. Discard fractions are multiplied by 100 to obtain percentages.

3.8 Explaining the variability in discard percentages; model fitting and variable selection

Regression methods relate a response variable to one or more explanatory variables. We defined the discards fraction as the response variable and use the total volume of plaice (in litres) as so-called model weights (McCullagh P. & Nelder 1989). The response variable is binomially distributed and modelled using a logit-link function ($g(\cdot)$ in eq. 4). We relate the linear predictor η (i.e. the logit of discard proportion p) as linear or smooth functions ($s(\cdot)$) of different explanatory variables (eq. 4). It is important to note that a linear function in the linear predictor η , leads to a S-shaped relationship between this variable and discard fraction. This allows for their non-linear effects on the response. The sub-index k refers to the kth data point.

$$\begin{aligned}
&\hat{d}_k \sim \text{Binomial}(n_k, p_k) \\
&p_k = g^{-1}(\eta_k) = \frac{e^{\eta_k}}{1+e^{\eta_k}} \\
&\eta_k = b_0 + s_1(\text{lat}_\text{k}, \text{lon}_k) + s_2(\text{date}_k) + s_3(\text{landings}_k) + \\
&\qquad \text{gear}_k + \text{chain mat}_k + \text{number of tickler chains from trawl head or shoe}_k + \\
&\qquad \text{number of tickler chains from the ground rope}_k + \text{meshsize}_k \\
&b_0 \sim Normal(\beta_0, \nu)
\end{aligned} \qquad 4)$$

‘Gear’ is treated as categorical variable and modelled as a factor. ‘chain mat’ is treated as a categorical variable (i.e. yes or no). The spatial position of the sample enters the model as a smooth interaction between latitude and longitude. b_0 is the so-called random effect intercepts which defines the between vessel variability (ν).

Model fitting is done using the Minimized Generalized Cross-Validation (mgcv) package in R. In summary, this procedure suggests a smooth function of a variable using all but one data point and validates that proposition by comparing its prediction with the true value of that data point. This procedure is repeated for all data points, and suggests a function that minimizes the sum of deviances for all comparisons.

Next we apply backward elimination of the explanatory variables. We start with a full model (see eq. 4) and remove that variable that leads to the biggest drop in the Akaike Information Criteria (AIC). AIC estimate the goodness-of-fit (i.e. a measure of how well the model fits the data) and penalizes for the number of parameters used, multiplied by the log of the number of data points (Burnham & Anderson 2002). For linear terms (e.g. 'number of tickler chains from trawl head or shoe') one parameter is used, but for smooth functions (e.g. a smooth function of 'date') more parameters are needed. Hence, AIC indicates how well the model fits the data and penalizes for complexity (i.e. the simpler the better). Variables are removed one-by-one, until no further decreases in AIC are observed.

3.9 Comparison of sampling methods

In Aarts & van Helmond, 2007 it was suggested that differences in discard estimates between the two programs is explained by the different sampling methods being used (appendix C and D). Wageningen IMARES only samples the discard section of the catch and the total catch is estimated (not measured) to determine the discard fraction. There is a risk that the estimate of the total catch is biased, leading to incorrect results. The Dutch Fish Product Board, on the other hand, uses a simple and direct method by measuring the ratio (in volume) of sized and undersized fish in a sample. Down side from this method is that is only useful for sampling one or two species at the time and very impracticable when all discarded species in a haul have to be measured, as in the observer programme of Wageningen IMARES. To investigate if the two methods inherently result in different discard estimations, a direct comparison was made between the two sampling protocols. First results were presented in Aarts & van Helmond (2007). However, these preliminary results were not considered to be a sufficient sample size to draw conclusion from. It was decided that the experiment had to continue in 2008. For 38 hauls on 7 commercial vessels both methods were used to estimate discard rates for plaice. The experiments were conducted by Wageningen IMARES research assistants.

During a discard monitoring trip on board a commercial beam trawler, Wageningen IMARES observers and researchers used both sampling methods to estimate discard rates for the same hauls. Accordingly a direct comparison between the discard estimates of both methods could be made.

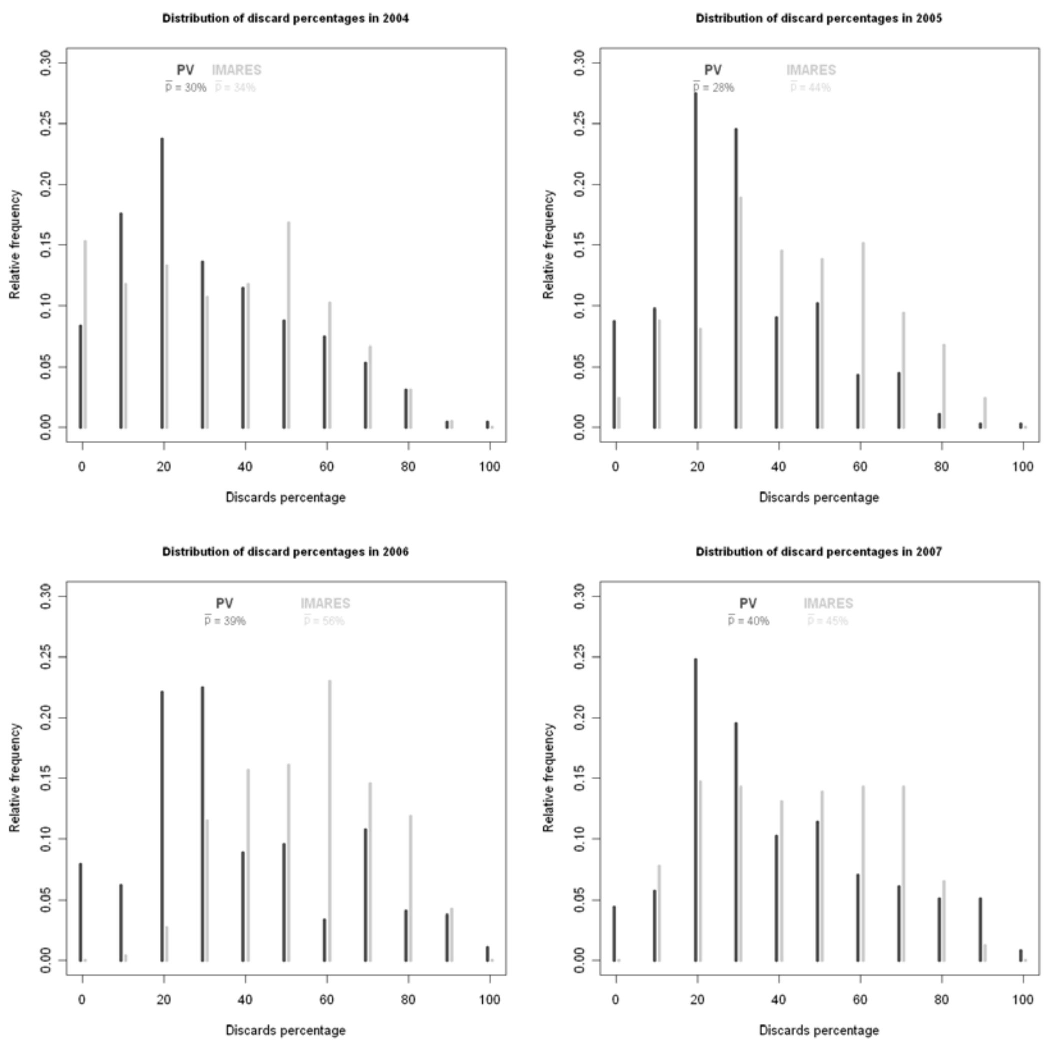
3.10 Discard meeting

On the 29th of March 2008 a meeting between the fishermen, participating in the self-sampling program, and the scientists, Aarts and van Helmond, was organised to discus the differences in discard rates between the two programs. Results and conclusions of the previous report, Discard sampling of Plaice an Cod in the North Sea by the Dutch Demersal Fleet from 2004 to 2006 (Aarts & van Helmond 2007), were presented in this meeting. The difference in discard rate estimates between the two sampling programs was an important discussion point. Outcomes of this meeting are used in the discussion of this report.

4 Results

4.1 Plaice discard percentage observed by PV and IMARES

Based on the maximum likelihood estimation, the estimated discards percentage (volume) based on the Product Board surveys for 2004 (last quarter only), 2005, 2006, 2007 and 2008 are 30%, 28%, 39%, 40%, and 50% . Estimates for the IMARES surveys in these years are 34% (also last quarter only), 44%, 56%, 45%, and 59%, respectively. The distribution of discards, percentage by haul, for both the Product Board and IMARES for the different years (Fig. 1). Statistical analysis (using 3 tests; t-test of normal and box-cox (Fox 1997) transformed discard fractions and binomial GLM) indicates a significant difference between the two estimates of mean discard fraction per year ($p<0.001$, t-test within GLM model). The PVis data shows an increasing trend in discards over the years.



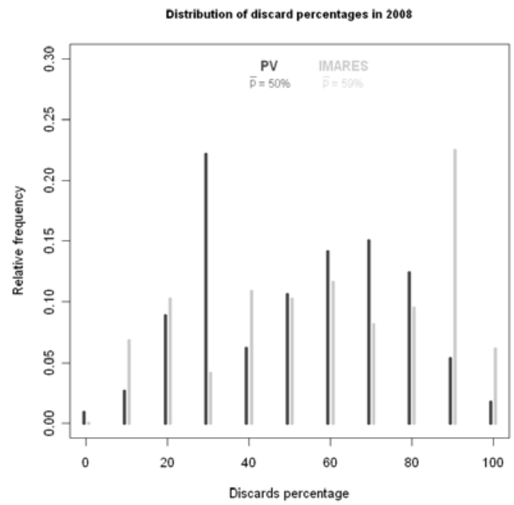


Figure 2. *Frequency distribution of discard percentages per year. Dutch Fish Product Board and IMARES data compared. Frequency is calculated at the haul level. (PVis= Dutch Fish Product Board).*

4.2 Precision of the observed discard percentages.

The standard errors and confidence intervals of the mean discard percentage and the variability between and within ships, are estimated using the procedure described in section 3.7. A generalized linear mixed effect model is used, with an intercept for the fixed-effects and treating the variability between vessels as a random effect (see §1.8)

Year	dataset	mean	se	lower	upper
2004	IMARES	34%	45%	17%	54%
	PV	30%	21%	21%	37%
2005	IMARES	44%	28%	34%	60%
	PV	28%	18%	25%	40%
2006	IMARES	56%	25%	47%	70%
	PV	39%	24%	26%	48%
2007	IMARES	45%	20%	37%	56%
	PV	40%	24%	24%	45%
2008	IMARES	59%	55%	34%	82%
	PV	50%	26%	41%	66%

Table 2. *Precision of mean discard percentage. Standard errors and the confidence intervals quantify the precision of the mean discard percentage estimates for each year. (PV= Product Board). The confidence intervals are based on the standard error estimates and quantify the variability of the mean discard percentage directly. In contrast, the standard error applies to log(discard percentage)/(1-log(discard percentage)). This is more difficult to interpret, but it does allow for a valid comparison between years and the data sources (i.e. IMARES and PV)*

The mean discard percentage estimated by the Product Board has smaller standard errors than the IMARES estimates in all years except 2007 (table 2). However, for 2007 the mean discard percentage of IMARES is more precise than the estimate made by the Product Board. Fitting a mixed-effect model using data from *all years* reveals that standard deviations (ν in equation 4) which express the variability *between vessels* are approximately equal. On the scale of the link function it is 0.88 for PVis and 0.93 for IMARES. So for Product Board-vessels, on average 95% of the vessels will have a mean discard percentage between 8 and 75%. This illustrates that there is large variation between vessels. However, the variability in the data *within vessels* is 1.0 for the Product Board and 0.55 for IMARES, and thus much larger for the Product Board. For the Product Board, 95% of the observations from a 'mean vessel' are between 6.4 and 79%, while for IMARES observations from mean vessel are between 24 and 74%.

4.3 Cod discard percentages observed by PVis

Based on the volume measurements (76 records), the mean discard percentage for cod is 21% (standard error = 3%). The mean discard percentage in volume, determined from weights measurements (volumes are calculated from a volume-weight relationship) (62 complete records), is 27% (se = 2.7%). The large number of missing data will probably lead to result in a non-representative sample of the entire fleet. For example catches with no or a low number of cod discards or landings may not be recorded. In some cases discards may not have been recorded at all (see methods section). Therefore we also calculate the cod discard percentages only based on the data on length measurements (fig. 3). This results in a mean discard percentage of 11% (se =0.9), which is much lower.

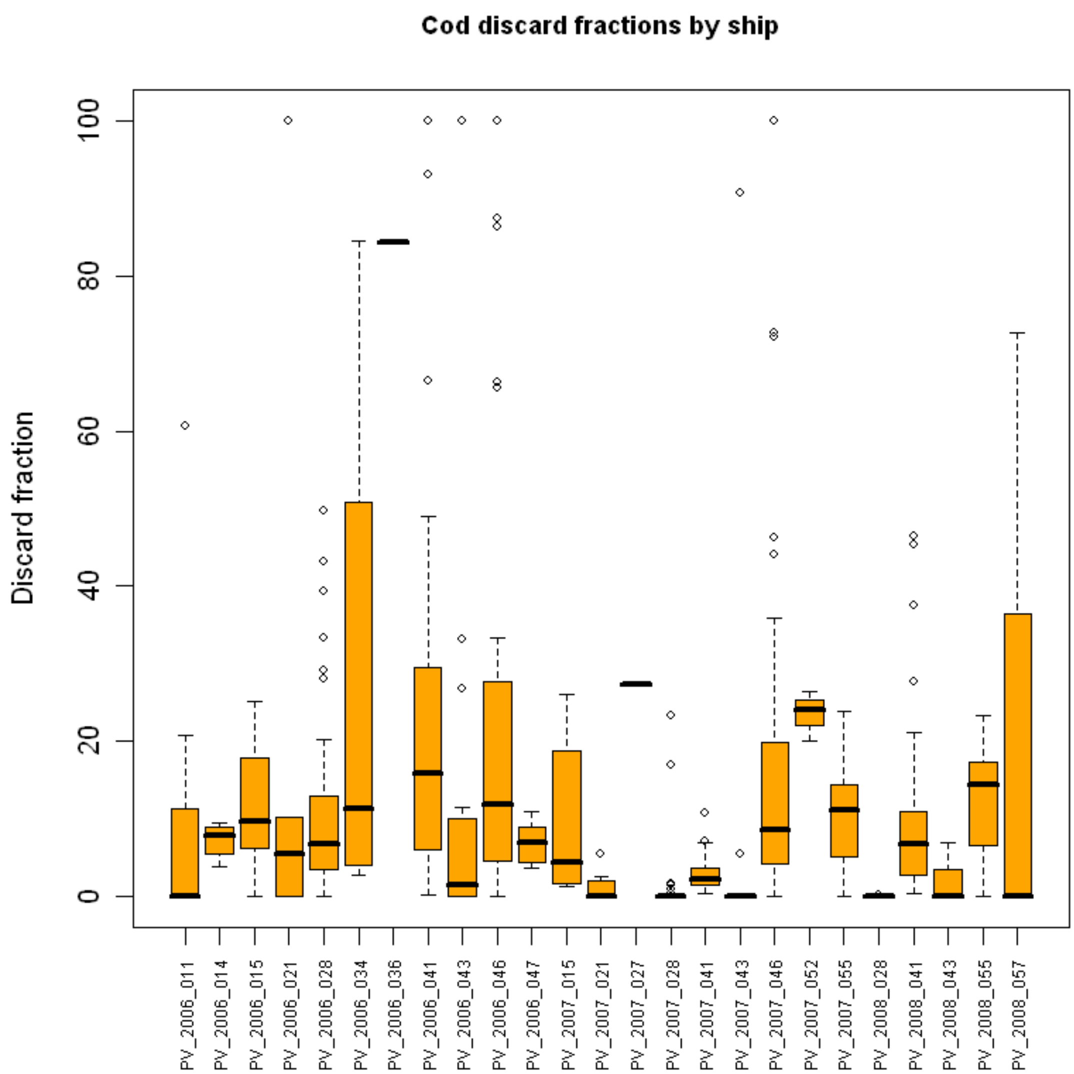


Figure 3. *Box plots of cod discard percentage by vessel based on length measurements. The minimum (lower bar), 25% quantile (lower end of box), median (bold bar), 75% quantile (upper end of box), maximum excluding outliers (upper bar) and outliers (dots) are shown.*

These estimates only give a rough idea of the discard percentage of cod in this fishery. The large number of missing observations makes it difficult to quantify how accurate these discard estimates really are. Furthermore, the three estimates, based on volume (21%), volume computed with volume-weight relation (27%) or just based on length measurements (11%), differ substantially. Especially the estimate based on length measurements is much lower.

4.4 Explaining the variability in discard fractions; model fitting and variable selection

Using the methods described in section 3.8, the effect of the explanatory variables on the discard fraction (PVis) can be revealed. We start with the full model containing the variables presented in eq. (4). We remove terms one-by-one on the basis of changes in the Akaike Information Criteria (table 3).

Deleted term	dAIC	Cum. % deviance explained
all terms	NA	55.16
Mesh size	6.97	55.16
gear	6.28	55.02
No. chains from trawl head or shoe (‘wekkers’)	1.11	54.61
No. tickler chains from ground rope (‘kietelaars’)	-12.52	51.51
chain mat	-8.02	50.51
s(date)	-299.88	43.74
s(lon,lat)	-2095.52	0

Table 3. *Results of backward model selection. dAIC represents the change in AIC. Negative values mean that removing the variable in question leads to a lower AIC, and thus a better model. Cum. % represents the cumulative percentage of explained deviance.*

The variables removed first are ‘mesh size’, ‘gear’ and ‘number of tickler chains from trawl head or shoe’ (‘wekkers’). This leads to a drop in the explained deviance, which quantifies the goodness of the model fit to the data, of only 0.6%. Removing any other term leads to a lower quality model. It is important to note that the spatial component alone (the smooth interaction between latitude and longitude (s(lon,lat))), explains 43.7% of the variability. The best model (see section 3.8) is a model containing a linear relationship with ‘number of tickler chains from ground rope’ (‘kietelaars’), the presence of a chain mat (0 or 1), a smooth term for the day of the year and a smooth interaction between latitude and longitude. This model (table 3) will be used for further analysis. One may argue that the effect of the number of tickler chains is not linear. First of all, the relationship with the response is not linear, but s-shaped, because a logit-link is used. Furthermore, we also investigated non-linear effects using a smooth of the number of tickler chain, but a linear term (based on Minimized Generalized Cross Validation) was most appropriate.

One important thing to note is that application of backwards model selection necessitates using a dataset *without missing data for any of the variables*. After model selection, some variables with missing observations are excluded. So those observations with missing information for the excluded variables, but that have complete records for the variables in the model, can now be included in the final model (presented in table 4). Consequently, using more data leads to different parameter estimates, p-values and % explained deviance.

In the previous analysis (Aarts & van Helmond 2007) show that the best model is one containing a smooth interaction between latitude and longitude (s(lat,lon)), a smooth of the date and the number of tickler chains from the trawl head or shoe (# ‘wekkers’). Both studies show that geographical position and date are very important, but the studies differ in how they quantify the importance of the fishing vessel characteristics. One major problem of the analysis is that almost all explanatory variables are highly correlated. For example, the 100mm mesh size is only used in areas further North. Consequently it is not possible to differentiate between the effect of mesh size and area on the level of discards. So if one variable is excluded from the model, this does not mean it does not have an effect on discards, it just means that given the other covariates it does not contribute significantly to the model. To illustrate this point. If we only fit a model using mesh size (table 5), mesh size becomes significant, explaining 6.2 % of the deviance (Table 5).

```
Model:
Discard fraction ~ # tickler chains from ground rope + chain mat + s(date) +
    s(lon,lat)

Parametric coefficients:
                                  Estimate Std. Error z value Pr(>|z|)
Intercept                         -1.40443    0.12532 -11.207  < 2e-16 ***
# tickler chains from ground rope -0.03832    0.00659  -5.815 6.07e-09 ***
chain mat                          1.35513    0.13827   9.800  < 2e-16 ***

Approximate significance of smooth terms:
                 edf Est.rank Chi.sq p-value
s(date)        8.921        9  367.4  <2e-16 ***
s(lon,lat)    26.325       29 1616.8  <2e-16 ***

R-sq.(adj) =  0.787   Deviance explained = 54.6%
UBRE score = 0.1126  Scale est. = 1         n = 2018
```

Table 4. *Final model used for further analysis. Significance codes used in the table: :'***' < 0.001, '**' < 0.01, and '*' < 0.05. Edf =effective degrees of freedom which reflects the effect number of parameters used for each term. Chi.sq = the value of the Chi^2 test statistics used. P-value reflects the significance of the term.*

```
Formula:
Discard fraction ~ mesh size

Parametric coefficients:
             Estimate Std. Error z value Pr(>|z|)
Intercept    2.240484   0.178012   12.59   <2e-16 ***
Mesh size   -0.034681   0.002154  -16.10   <2e-16 ***

R-sq.(adj) =  0.477   Deviance explained = 6.18%
UBRE score = 1.1491  Scale est. = 1         n = 2211
```

Table 5. *Results of model using mesh size as only covariate. These results illustrate the effect of collinearity between covariates. For more details see the legend of Table 4.*

4.5 The effect of variables on the discard fractions

The final model includes 'use of chain mat', 'number of tickler chains from ground rope', day of the year and spatial position. The latter is most important, explaining 43.7% of the observed variability in the data. For a given day (1st of June 2008 in this case) and a vessel with an average number of tickler chains (9 in this case) from the ground rope, it is possible to plot how the discard fractions vary spatially (Fig. 4). It is important to note that discard fractions not only vary spatially, but also change seasonally and vary with the number of tickler chains. Consequently, the absolute discard values in Fig. 4 only apply to this arbitrarily chosen time (1st of June 2008) and vessel with 9 tickler chains. Nevertheless, the relative regional differences in discards captured by the model are the same under different conditions.

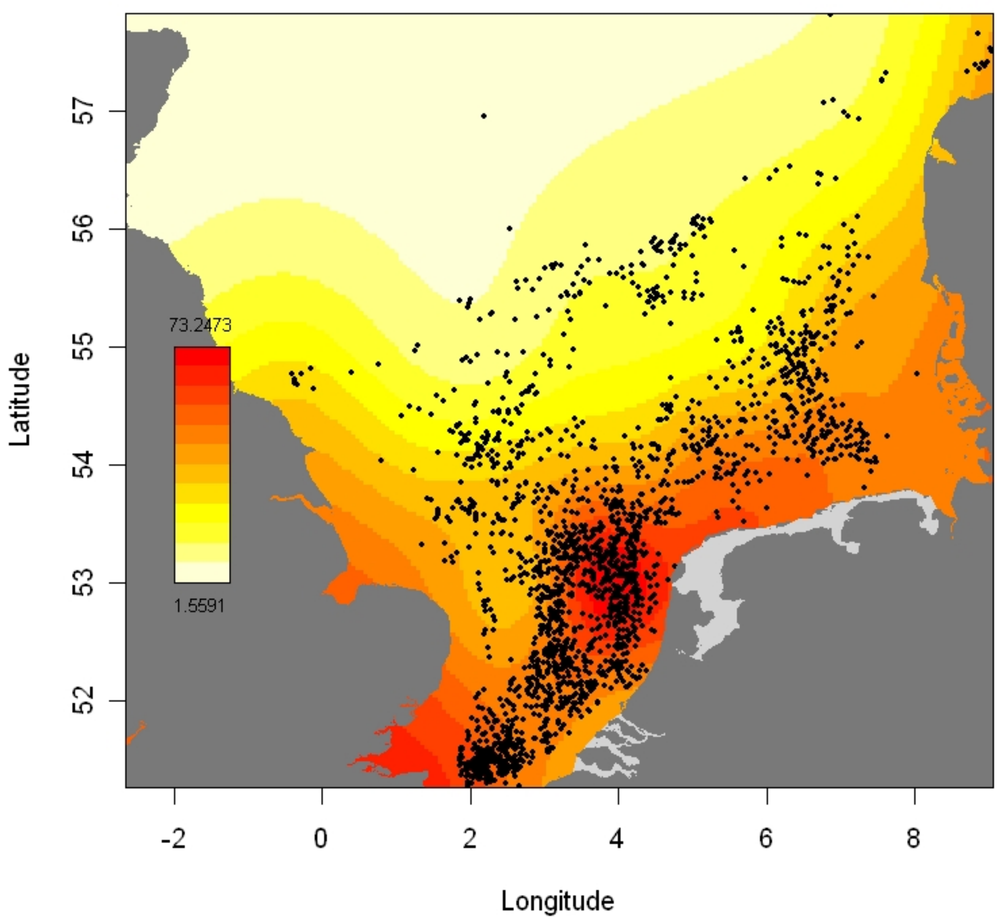


Figure 4. *Model predictions of plaice discard percentages and distribution of the Product Board data plotted on top. Predictions are made for the beginning of June 2008 (one month before the most recent data point) for a vessel with 9 tickler chains from the ground rope (and no chain mat) and the absolute discard levels only apply to those conditions. Colours represent the gradient in discard fractions in space (Lon, Lat) from 73.2 % (red) to 1.6 % (white).*

The discard fraction decreases away from the Dutch coast, as shown in Figure 4. Close to shore, in the northern part of the Netherlands, discard percentages can exceed 70%, while in the most northern regions of the North Sea, discard percentages are only a few percent. Especially the area just West of the Wadden Sea is characterized by very high discard estimates. Another interesting feature is that further south, south-west of the province 'Zeeland', discard percentages are also lower (around 30 %), which is indeed also observed by fishermen, sharing their experiences during meetings with IMARES. Spatial predictions along the UK coast and the coast of Denmark are based on almost no data points and thus very unreliable.

Similarly, the temporal changes in discard fractions can be plotted (Fig. 5). Again, it is not possible to derive absolute trends in discards, but it can only be predicted for fixed values of the other variables in the model; spatial location (54° latitude, 4° longitude) and 'number of tickler chains from the ground rope = 9. Similarly to Fig. 4, the absolute discard fractions apply to these conditions only, but the relative trends in discard will be similar under different conditions (e.g. in different regions or for vessels with a different number of ticklers).

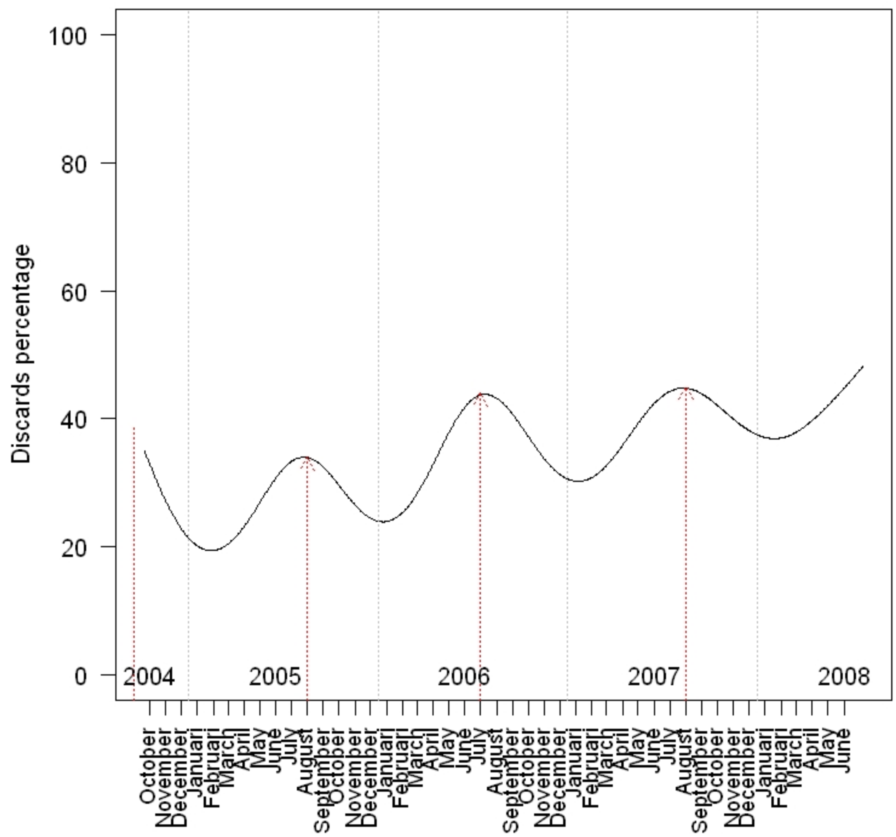


Figure 5. *Model predictions of plaice discard percentage for at 54°latitude and 4°longitude for a vessel with 9 tickler chains (see table 4 for parameter estimates).*

4.6 Comparison between Dutch Fish Product Board and IMARES sampling methods

There are no significant differences between the discard percentages estimated using both sampling methods (t=1.27, df=70, p-value=0.20, Figure 6). The methods used by Wageningen IMARES and The Dutch Fish Product Board, does not lead to significant different or biased discard estimates, as has been suggested previously.

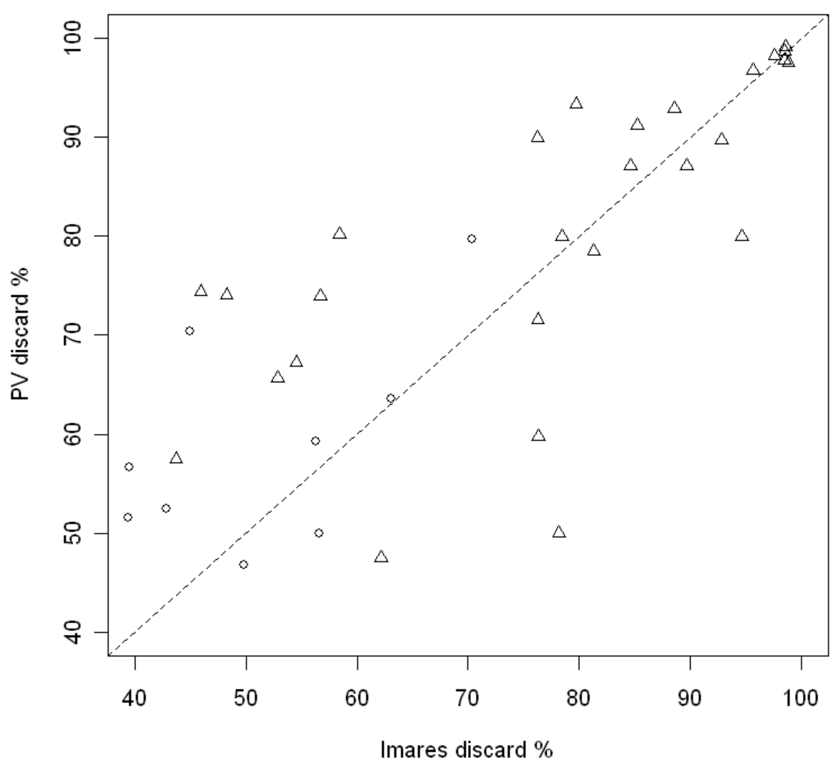


Figure 6. *Comparison of the data collection methods implemented by Wageningen IMARES and The Dutch Fish Product Board (PV) on a haul-by-haul basis for the years 2007 (circles) and 2008 (triangles). Data are presented as discard percentages of the total catch per haul.*

5 Discussion

From 2004 onwards the annual mean discard percentage for plaice has been increasing up to 50% in 2008 based on the self-sampling program. The IMARES discard estimate is higher (59% vs. 50%) and have also been increasing. The most likely explanation for this increase is the increasing fishing effort close to shore, driven by high fuel prices. These coastal areas are characterized by high numbers of juvenile plaice. This is particularly so for areas west of the Wadden Sea (figure 4). The Wadden Sea is an important nursing ground for plaice, and consequently more smaller individuals will be present in the vicinity. Similar to the results of 2007 (Aarts & van Helmond, 2007) a clear spatial distribution pattern of discarded plaice was observed. Discard percentages are higher close to shore (figure 4). The observed pattern closely matches the actual distribution of the beam trawl fisheries. This increase in fishing activity in areas where juvenile plaice is more abundant results in higher discard percentages.

The discard estimates of the self-sampling program provided clear temporal trends in previous studies. To a lesser extent the temporal trends, are also present in the Wageningen IMARES discard sampling program. Although, the trend in this study is again evident, high discard percentage during summer (July-August) and low percentage in winter (December), some dissimilarities with previous analysis do exist. Highest discard percentage are expected in July and August in the analysis in 2008. In the analysis of 2007 discard percentage is highest in September. The summer growth of young individuals (1 and 2 year old) leads to sizes that increase the capture probability. In autumn and winter, mortality or redistribution (e.g. juveniles migrating to offshore areas) might set in, reducing discards again. Not only seasonal variability is present (Fig. 5), the discard percentages also varies between years, with a gradually increasing percentage discards from 2004 up to 2008.

The number of tickler chains or the use of chain mats are of significant importance for the amount of discarding. It is therefore advisable to register this information for each participating vessel. In addition, an opportunity for fishermen to inform researchers of Wageningen IMARES of incidents or factors that influence discard rates during a fishing trip will be a valuable tool to interpret discard estimates of a particular trip. Although this may be difficult to organize from a logistic point of view due to the number of vessels sampled simultaneously throughout the year, a random selection of hauls to be sampled on a trip is desirable. This way a possible bias in discard estimates, caused by spatial or temporal factors, can be avoided.

To improve the current discard estimates used in stock assessment for plaice there is a possibility to include the self-sampled discard estimates as an explanatory variable for explaining the Wageningen IMARES estimates. In other words, using the spatial and temporal patterns found in this study to improve the discard estimates of the observer programme. For a direct input of the self-sampled data in the stock assessment, however, a negative advise is given by Wageningen IMARES, since there is a significant difference with discard estimation of self-sampling program of the industry and the observer program of Wageningen IMARES.

On the 29th of March, the preliminary results (only ten hauls) of direct comparison of both sampling methods, were presented. The discussions during this meeting made clear that the moment and the actual handling of taking a sample of the catch on board, can lead to different discard estimates. Wageningen IMARES observers sample repeatedly different sections from the sorter conveyor belt of the entire haul, where most fishermen take the complete sample at once straight from the hopper (unsorted catch), just prior to processing the haul. Probably the catch is not uniformly mixed in regard to species and length composition. This will lead to different discard estimates depending on which section of the catch is sampled (Heales et al., 2002). We believe this can be the most important reason why the self-sampling and Wageningen IMARES estimates differ. After we were able to analyse the complete dataset in 2008 (figure 8), it was evident that the methods themselves do not inherently result in different discard estimates.

Based on this study we can conclude that a clear description of the sampling procedure and a thorough training of the crewmembers of the selected vessels will be of great importance for a good implementation of a self-sampling program. The sampling procedure used by the Wageningen IMARES researchers during this study, repeatedly sampling sections from the sorter conveyor belt of the entire catch, did not lead to significant different results than the sampling method used in the self-sampling research. We therefore believe that this technique of sample taking is the best option of getting a representative sample of discards on board commercial trawlers. Different methods, e.g. sampling only the first or the last part of a haul (Heales et al., 2002) or taking the sample straight from the hopper (see section 5.3) can result in different discard estimates. Accurate and unbiased discard estimates are essential for future research and management. For example, the study of Haugh & Wilson, 2009, proved that biased discard estimates, both over or under estimated, have a significant effects on stock assessment outcomes.

Cod discard estimates were based on three data sources: volume, weight and length measurements. The estimates based on the weight and volume were relatively close; 27 and 21% respectively. However the estimate based on length measurements was much lower, 11%. There could be many explanations for this. From Figure 3 it is evident that there are very large differences between vessels, which increases the risk that the data from the few vessels that take length measurements is not representative for the entire fleet. Another explanation is that not all smaller individuals have been measured. For example, in week 20, 2007, one vessel (PV028) measured 29 individuals from 35 cm (MLS) up to 41, but no smaller individuals. For many other vessels (see Figure 3), this pattern is not evident, which suggest that the data still provides a first guess on the level of cod discards.

The self-sampling program has given insight into the spatial and temporal trends in plaice discards. In addition, the program itself has lead to fruitful discussions and a critical review of the current DCR discard sampling program. In 2009 Wageningen IMARES started a new DCR sampling program. The most remarkable difference with the previous program is the integration of self-sampling next to a less intensive observer program. This will lead to an increase of discard data available over space and time, which will be of great value, but we strongly recommend clarity of sampling procedures, thorough training and intensive communication with fishermen. Hence, inaccurate data on discards will have a significant impact on future management strategies.

6 Quality Assurance

IMARES utilises an ISO 9001:2000 certified quality management system (certificate number: 08602-2004-AQ-ROT-RvA). This certificate is valid until 15 December 2009. The organisation has been certified since 27 February 2001. The certification was issued by DNV Certification B.V. Furthermore, the chemical laboratory of the Environmental Division has NEN-AND-ISO/IEC 17025:2005 accreditation for test laboratories with number L097. This accreditation is valid until 27 March 2013 and was first issued on 27 March 1997. Accreditation was granted by the Council for Accreditation.

References

Aarts, G. M. and A.T.M. van Helmond. 2007. Discard sampling of Plaice (*Pleuronectes platessa*) and Cod (*Gadus morhua*) in the North Sea by the Dutch demersal fleet from 2004 to 2006. IJmuiden, Report number C120/07: 42 p.

Hauge, K.H. and D.C.Wilson (Eds). 2009. Comparative Evaluations of Innovative Fisheries Management: Global Experiences and European Prospects Dordrecht The Netherlands: Springer Publishing forthcoming. Chapter 6.

Burnham, K. P., and Anderson, D. 2002. Model selection and Multi-Model Inference: A practical-theoretic approach. Springer-Verlag, New York

Dekker, W., and van Keeken, O. 2005. Bemonstering van scholdiscards door de visserijsector in 2004 en 2005.IJmuiden. IMARES Rapport C039/06.

Dekker, W., and van Keeken, O. 2004. Statistische betrouwbaarheid van de bemonstering van de scholdiscards door de visserijsector. IMARES Rapport C011/05.

Fox, J. 2002. Linear Mixed Models. Appendix to 'an R and S-PLUS companion to Applied Regression'. Sage publications

Hauge, K.H. and D.C.Wilson (Eds). 2009. Comparative Evaluations of Innovative Fisheries Management: Global Experiences and European Prospects Dordrecht The Netherlands: Springer Publishing forthcoming. Chapter 6.

McCullagh P. and Nelder, J. A. 1989. Generalized Linear Models. London: Chapman and Hall.

Pinheiro, J.C., and Bates, D.M. 2000. Mixed-Effects Models in S and S-PLUS. Springer.

Quirijjns, F.J. Het vangstsucces als maat voor de visstand. Wageningen IMARES, IJmuiden, 4p., 2006.

Van Beek, F. A. 2001. Offerte voor het verzamelen en beheren van gegevens die essentieel zijn voor het gemeenschappelijk visserij beleid. RIVO offerte 01.063. IJmuiden, RIVO: 38 p.

Van Helmond, A.T.M. and H.M.J. van Overzee, 2008. Discard sampling of the Dutch beam trawl fleet in 2007. CVO report 08.008: 44 p.

Wood, S. 2006. Generalized Additive Models: An Introduction with R. Chapman & Hall/CRC, London.

Justification

Rapport C094/09
Project Number: 4391103601

The scientific quality of this report has been peer reviewed by the a colleague scientist and the head of the department of Wageningen IMARES.

Approved: Ir. Niels Hintzen
Researcher

Signature:

Date: 14-09-2009

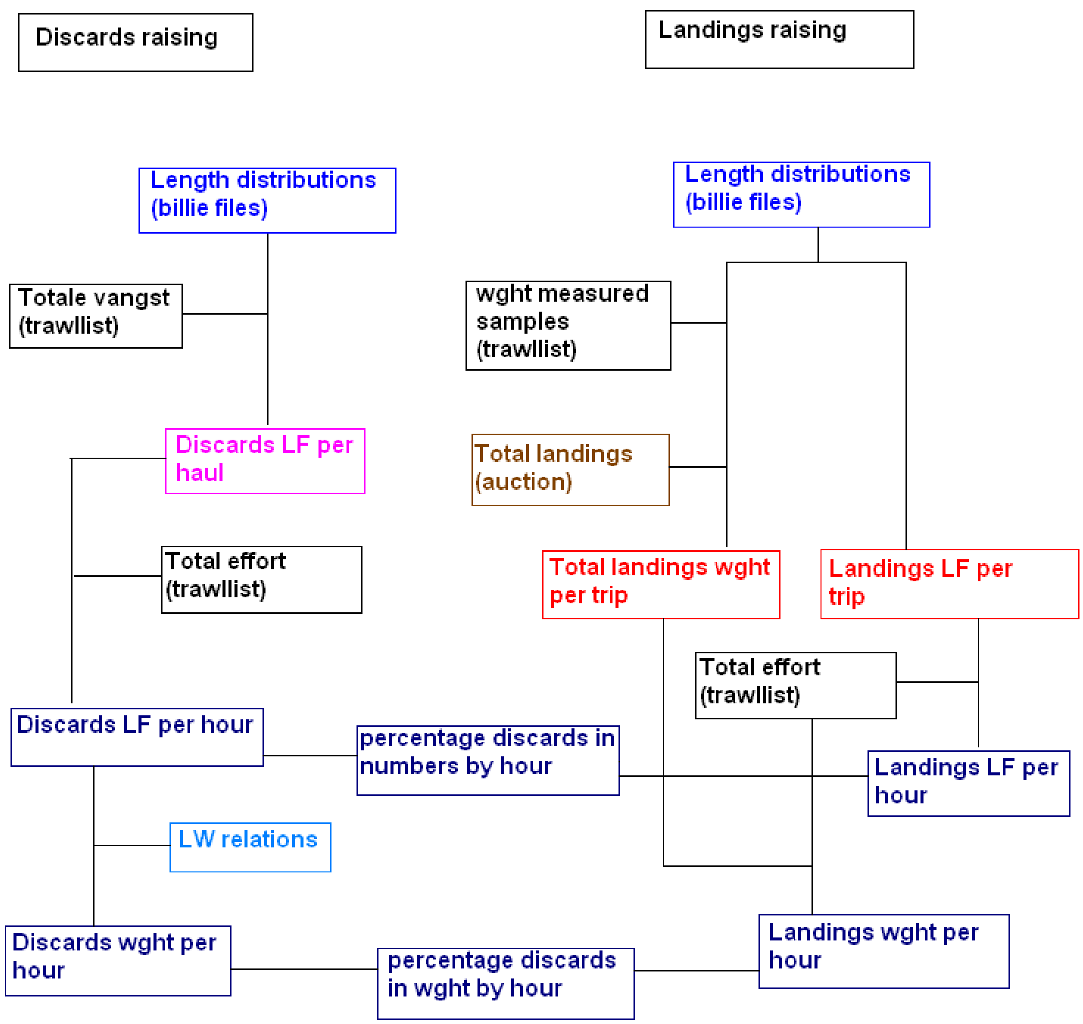
Approved: Drs. F.C. Groenendijk
Head of Department Ecology

Signature:

Date: 14-09-2009

Appendix A.

Schematic overview of procedures raising discard data by Wageningen IMARES



Appendix B

Detailed description of the IMARES procedure to estimate discard fractions

Wageningen IMARES takes samples of the total catch (*C*) in one haul after fishermen remove all commercially valuable individuals (*L*). These landings were recorded and verified with the auction data. The remaining section (referred to as *W*) contains non-commercial species (e.g. sea stars, urchins) and undersized individuals (e.g. undersized plaice). From this, a sample *S* is taken. The sample *S* contains one basket of 40 liters. In some cases the length of all individual fish in that sample are measured. However, often (especially for the abundant species) a fraction *f* (e.g. $\frac{1}{8}th$) is taken. Using known length-weight relations, we can estimate the weight $w_{i,l}$ (in kg) of an individual from species *i* and length *l* (in centimeters). For plaice, the formula to calculate the weight is as follows:

$$w_{plaice,l} = 0.0082 \cdot (l)^{3.026} / 1000 . \qquad \text{B1)}$$

We can also estimate the total number of individuals *N* from species *i* of length-class *l* in the catch C in volume of one haul.

$$N_{plaice,l} = n_{plaice,l} \cdot \frac{W}{S} \cdot \frac{1}{f},$$
$$where \qquad \text{B2)}$$
$$W = C - \sum_{\text{all species}} L.$$

where $n_{plaice,l}$ is the total number of individuals from length-class *l* in the sample (S) or sub-sample (S·f), *W* is the total volume discarded (including non-commercial species) and $\sum_{\text{all species}} L$ is the total volume of landings of all commercial species.

Finally, the total discards per haul of one species, e.g. plaice can be calculate as follows

$$D_{plaice} = \sum_{all\_lengths} \left(N_{plaice,l} \cdot w_{plaice,l} \right) . \qquad \text{B3)}$$

So *W* is the total volume of discards including all species, both commercial and non-commercial. *D* is a species-specific amount of discards, expressed as a weight. To conform to the data collected by the PV, total weight of plaice discards and landings, D_{plaice} and $L_{landings}$ respectively, are transformed into volumes by multiplying each by 0.89 and 0.83 respectively. Finally discard fractions are calculated as

$$p_{discards} = \frac{D_{plaice}}{(D_{plaice} + L_{plaice})} . \qquad \text{B4)}$$

As an example: if the total catch is 18 baskets, 7 of which are commercially valuable species, *W* equals 11 baskets (440 liter). From this, 1 basket (*S*=40 liter) is taken and for plaice a fraction of $f = \frac{1}{8}$ is measured. We observe 12 plaice of 22cm in our sub- sample. The average weight of a plaice of 22cm is

$$w_{plaice,l} = 0.0082 \cdot (l)^{3.026} \cdot 1000 = 0.0082 \cdot 22^{3.026} / 1000 = 0.094 \text{ kilogram} \qquad \text{B5)}$$

The total number of 22cm plaice in the catch ($N_{plaice,\ 22cm}$) is

$$N_{plaice,22cm} = n_{plaice,22cm} \cdot \frac{W}{S} \cdot \frac{1}{f} = 12 \cdot \frac{11}{1} \cdot \frac{1}{\frac{1}{8}} = 1632 \qquad \text{B6)}$$

Consequently, the total weight of 22cm plaice is 0.094kg·1632 = 153.408kg. This calculation is repeated for all length classes and summed over all lengths (B3). Finally, weights are transformed into volumes and a discard fraction (B4) is estimated.

Appendix C

Sampling method on board commercial vessels (IMARES).

Bemonsteringsprocedure Discards Demersaal IMARES

1) Het schatten van de totale vangst (hoops).

2) Het verzamelen van een discardmonster.
    i) Een discardmonster bestaat uit 1 standaard mand die in delen wordt genomen uit het begin, midden en einde van de verwerking van de trek.

3) Het meten van het discardmonster.
    i) Alle vissoorten worden uit het discardmonster gesorteerd, gemeten, geteld en genoteerd op lengteklasse.
    ii) Alle benthos wordt op soort gesorteerd, geteld en genoteerd.
    iii) Noteer de subsampling factor ten opzichte van de standaard mand.

4) Het meten van een landingsmonster.
    i) Bemonster van de maatse doelsoorten (schol, tong, schar) tussen 10-15 kg. Vaststellen gewicht monster. Alle individuen meten en noteren op lengteklasse.
    ii) Bemonster (wanneer mogelijk) van de bijsoorten (kabeljauw, wijting, tarbot, griet, bot, nephrops) tussen 10-15 kg. Vaststellen gewicht monster. Alle individuen meten en noteren op lengteklasse.

5) Het verzamelen van discards voor leeftijdsanalyses op het lab.
    i) Voorgeschreven soorten: Schol, Tong, Schar.
    ii) Andere soorten (wanneer mogelijk): Kabeljauw, Wijting, Schelvis.
    iii) De monsters voor leeftijdsanalyses hoeven uitsluitend te bestaan uit ondermaatse vis. Indien de visserij zich beperkt tot een enkel gebied, dan volstaat 1 monster van 3 vissen per cm-groep. Indien de visserij in duidelijk verschillende gebieden plaatsvindt, dan dienen discardsmonsters te worden verzameld per gebied.

6) Het schatten van de aanvoer per trek.
    i) De aanvoer per trek van de hoofdsoorten en bijsoorten wordt geschat door de bemanning (eventueel op navraag van de opstappers). De schipper wordt verzocht om de aanvoergegevens per trek per soort bij te houden in het door IMARES verstrekte logboek.

Minimaal moet per reis 60% van de trekken worden bemonsterd. Van belang is dat de bemonsterde trekken worden gespreid over dag en nacht.

Appendix D

Sampling method PV

Instructies voor het discardsonderzoek naar schol en kabeljauw door de visserijsector

Schol

1. Iedere week bemonstert u de eerste trek na dinsdag- en donderdagmiddag 16.00 u. Dit is een gewone trek (geen speciale vistijd o.i.d.) zoals bij u aan boord wordt uitgevoerd om een zo goed mogelijk beeld te krijgen van het normale vispatroon. Op dinsdag bemonstert u de stuurboord vangst en op donderdag bemonstert u de bakboord vangst. Als u hier van afwijkt (bijv. omdat u op donderdag al binnen bent), meldt u dit op het registratieformulier.

2a. Na het legen van het net in de opvangbak neemt u een monster door de gestandaardiseerde vismand vol te scheppen tot en met de bovenste rand met gaatjes. U probeert hierbij een zo representatief mogelijk monster te nemen. Het is dus niet de bedoeling dat u een speciaal deel van de vangst selecteert dat bijvoorbeeld alleen uit schol bestaat.

2b. Wanneer er maar weinig (ondermaatse) schol en / of zeer grote hoeveelheden benthos (bodemdieren en andere “rommel”) aanwezig zijn in het monster (u bepaalt dit op basis van uw eigen inzicht), neemt u de dubbele hoeveelheid van een monster. Het is belangrijk dat twee keer dezelfde hoeveelheid (dus 2 keer een vismand) bemonstert. Omdat u maar 1 gestandaardiseerde vismand heeft, moet u de eerste mand leeg gooien en deze inhoud tijdelijk in bijv. een viskist bewaren. In de lege mand kunt u uw tweede monster scheppen. U verwerkt de beide monsters verder samen als 1 groot monster. Wanneer u een tweede mand bemonstert, is het belangrijk dat u dit duidelijk op het registratieformulier aangeeft!

3. De vismand (en evt. de viskist als u een dubbele hoeveelheid bemonstert) zet u apart en u verwerkt de rest van uw vangst op de voor u gebruikelijke wijze.

4. Vervolgens wordt het monster uitgezocht. U zoekt de schol en kabeljauw uit de vismand (en evt. viskist). De rest, de overige (commerciële) vis en bodemdieren kunt u naar believen verwerken. De kabeljauw verwerkt u volgens de instructies op de ommezijde .

5. De schol uit de vismand (en evt. viskist) wordt verdeeld over twee emmers. Eéntje met de maatse schol en de andere emmer met ondermaatse schol.

6. Op de standaard emmers staat een schaalverdeling. U leest de hoeveelheid (=volume) maatse en ondermaatse schol af van de schaalverdeling. Dit noteert u op het registratieformulier.

7. U meet de lengte* van 50 maatse schollen en 50 ondermaatse schollen met behulp van het meetplankje (grens ligt op 27 cm). De resultaten turft u op de turflijst. Heeft u meer schollen gevangen, dan hoeft u deze niet te meten. Bij minder vissen, meet u ze allemaal.

8. De maatse schol kunt u daarna verder verwerken. De ondermaatse schol moet u weer overboord zetten.

9. U noteert een aantal gegevens van de visreis en de bemonsterde trek op het registratieformulier.

10. Van uw afslagbrief neemt u de hoeveelheid maatse schol in kilogrammen per categorie over op uw registratieformulier.

Kabeljauw

1. Gedurende de hele reis verzamelt u uit alle trekken alle kabeljauw, dus zowel de maatse als de ondermaatse. U bewaart de ondermaatse kabeljauw apart van de maatse kabeljauw in viskisten. De ondermaatse vis moet in een viskist en in een doorzichtige plastic zak komen.
2. De ondermaatse kabeljauw blijft ongestript. De maatse vis kunt u verwerken zoals u gewend bent.
3. Na de laatste trek meet u de lengte* met behulp van het meetplankje. Hiervoor neemt u willekeurig 50 maatse kabeljauwen uit de vangst. Heeft u er minder dan 50 gevangen, dan meet u ze allemaal. De lengtes noteert u op de turflijst.
4. U meet ook de lengte* van 50 willekeurig gekozen ondermaatse (kleiner dan 35 cm) kabeljauwen met behulp van het meetplankje. Heeft u er minder dan 50 gevangen, dan meet u ze allemaal. De lengtes noteert u op de turflijst.
5. Na de laatste trek noteert u het aantal kisten met ondermaatse kabeljauw. Op de terugreis naar de haven/afslag meldt u dit aantal bij de AID en de afslag waar u gaat verkopen. Ook geeft u de te verwachten aankomsttijd door.
6. Zowel de maatse als de ondermaatse kabeljauw levert u af bij de afslag. De ondermaatse kabeljauw moet u aanbieden in normale viskisten maar moet u verpakken in doorzichtige plastic zakken die voordat ze worden aangevoerd, dichtgebonden moeten worden met tie-raps. Elke zak moet u voorzien van een goed leesbaar vaartuigbriefje.
7. Bij aflevering bij de afslag wordt de ondermaatse kabeljauw apart gehouden en gewogen door de visafslag onder toezicht van de buitendienstmedewerker van het Productschap Vis. De buitendienstmedewerker noteert de hoeveelheid en geeft dit door aan u. De maatse kabeljauw wordt volgens het normale traject gewogen.
9. U noteert deze gegevens van de afslag samen met nog een aantal gegevens over de visreis op het registratieformulier.
10. De buitendienstmedewerker zorgt er verder voor dat uw ondermaatse kabeljauw gedenatureerd (ongeschikt gemaakt voor menselijk gebruik) en afgevoerd wordt.

Verzamelde gegevens

Iedere maand stuurt u de verzamelde gegevens naar het Productschap Vis. Dit kan per post (postzegel is niet nodig) t.a.v. discardsonderzoek, Antwoordnummer 10387, 2280 WB Rijswijk, maar bij voorkeur per e-mail aan discards@pvis.nl.

Vragen?

Als u vragen heeft, kunt u contact opnemen met uw visserijorganisatie of met Fenneke Brocken van het Productschap Vis, tel: 070-3369606 / 06-10938639 of e-mail: fbrocken@pvis.nl

* Lengte meten

De lengte wordt gemeten van snuit tot en met staart en in hele centimeters genoteerd. Een vis van 27,8 cm noteert u als 28 cm en een vis van 35,3 cm noteert u als 35 cm.

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