Chapter 19
Monitoring the Implementation of the Landing Obligation: The Last Haul Programme

Miguel Nuevo, Cristina Morgado, and Antonello Sala

Abstract The collection of catch composition data during inspections at sea by EU Member States occurs under the framework of joint deployment plans (JDP). It is known as "the last haul" (LH) programme and has been a fundamental tool in allowing the estimation of discards and the derivation of indicators of compliance with the landing obligation (LO). During sea inspections, measures of quantities of fish below and above the minimum conservation reference size and grade categories of the legal-size catch are used to derive estimates of discards. The methods to estimate discards assume that the relative catch composition (discard ratios) obtained with the data collected during LH inspections reflects the true catch composition of the fleet segment operating with the same gear and mesh size and in that area. The comparison between these discard ratios and with what is reported in fishers' logbook is then used to estimate the discard component. The background of the LH programme, the methodologies for deriving discard ratios using LH data and the statistical analysis of the data are explained in this chapter.

Keywords Catch composition · Compliance · Inspections · Joint deployment plans · Risk assessment

19.1 Introduction

The landing obligation (LO) introduced under Article 15 of the latest reform of the EU's Common Fisheries Policy, adopted in 2013 (EU No 1380/2013), constituted a significant policy change and presented a number of challenges for control authorities working towards ensuring its uniform and effective implementation across all

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EU Member States (MS). With the obligation to land all catches of quota species being progressively implemented from 2015 to 2019, the whole approach of monitoring what was landed, for the purpose of fisheries control, had to change to monitoring catches at sea to detect possible illegal discards.

The European Fisheries Control Agency (EFCA) considered that a coordinated implementation of the landing obligation using common methodologies was a prerequisite to ensure efficiency, effectiveness and a level playing field for the fishing industry. EFCA, in accordance with its multiannual work programme, and in its role supporting MS and the European Commission in the implementation of the Common Fisheries Policy (CFP) requirements, carried out a technical reflection on the definition of procedures and systems for monitoring the implementation of discard plans. This reflection was driven by the goal of assisting MS and the European Commission to develop simple and cost-efficient methods for monitoring implementation and evaluating compliance with the obligation to land all catches.

Joint deployment plans (JDPs) are one of the EFCA main instruments to ensure effective enforcement and equal treatment for all those involved in a particular fishery. They are the vehicle through which the Agency organises the deployment of MS's human and material means of control and inspection pooled together. Two criteria have to be met before a JDP can be devised: the fish stock(s) concerned must be subject to a long-term recovery plan or a multiannual management plan, and a specific control and inspection programme, adopted by the European Commission, must be in place.

EFCA has no mandate to formulate fisheries policy, which is the responsibility of the European Commission. Nevertheless, it is within the Agency's mandate to make technical recommendations in the context of providing assistance to MS regarding the range of compliance tools which could be employed to help meet their obligations vis-a-vis both Article 15 of the CFP and existing control provisions.

Some key objectives of these recommendations were:

- To ensure compliance with the requirements for accurate recording of discards
- To assist MS in the development of practical control and monitoring tools for the enforcement of the landing obligation through the detection of discarding practices
- To support the development of specific discard plans with suggested guidelines to facilitate the controllability of the landing obligation

The controllability of the landing obligation is also complicated by exemptions built into the various regional discard plans (see Borges and Penas Lado, this volume; Rihan et al., this volume). These complexities give rise to a high level of risk of a non-uniform implementation of the LO, both within and across regions. It is for this reason that efforts to ensure a level playing field in terms of the implementation of the LO became imperative for EFCA. Compliance with the LO is likely to be improved if fishers observe a common approach to inspection in all the areas in which they operate. Indeed, a common point raised by the fishing industry, through fora such as the EU Advisory Councils, is the need for a level playing field in terms of control and enforcement. Experience with the phased implementation of the LO has already highlighted the importance of this issue.

Considering the EFCA recommendations and conclusions agreed during a stakeholder seminar in January 2014[1], the launching of a so-called “last haul” (LH) project was endorsed, an inspection programme coordinated by EFCA in the framework of the JDPs with the main aim to obtain estimates of discards for control and compliance purposes. It focused initially in the Baltic Sea, Western Waters (Pelagic) and Mediterranean Sea (Adriatic) JDP areas, as the species covered by these JDP areas were the first to be subject to the LO from 1 January 2015. This dedicated project was put in place in close cooperation with MS. The underlying driver for this initiative is the need to maintain a level playing field, which should be achieved by developing a harmonised and standardised approach to inspections focused on the LO. The LH programme is now being implemented throughout the main JDPs and integrated in routine sea inspection procedures.

The LH inspection programme as a specific monitoring scheme on the implementation of the LO was introduced following a timeline according to the active JDPs in each area and to the phased introduction of the LO:

- June 2014: Baltic Sea (cod, salmon, herring and sprat) and Adriatic Sea (anchovy and sardine)
- August 2014: Pelagic fisheries in Western Waters
- May 2015: Demersal fisheries for cod, sole and plaice in the North Sea
- May 2016: Demersal fisheries for other demersal species in the North Sea

To implement the LH programme in areas without a JDP, such as for other demersal species in the North Sea in addition to cod, sole and plaice, cooperation with regional bodies occurred through the EFCA PACT (Partnership, Accountability (compliance), Cooperation and Transparency) concept. This allowed assistance to be given by EFCA to the MS. EFCA cooperated with the control expert groups (CEGs) of the main regional bodies created in the framework of regionalisation, such as BALTFISH, Scheveningen, SWW and NWW CEGs, and enlarged its assistance in areas and for species where there is no legal mandate via the specific control and inspection programmes (SCIP) in place and thus not covered by the JDP framework (i.e. demersal fisheries in Western Waters).

The LH inspection work has now been encompassed within the JDPs routine control and inspection effort and target sea inspections by amending the respective JDPs and introducing this specific objective in some campaigns. These specific actions are planned according to the results of the regional risk assessment performed by EFCA in cooperation with relevant MS. A methodology was developed by EFCA to derive discard ratios from the LH data using different methods according to the discarding characteristics (see Sect. 19.4).

[1]https://www.efca.europa.eu/en/content/pressroom/efca-coordination-new-cfp-provisions

19.2 Conducting LH Inspections and Processing the Data

The LH inspection programme consists of inspections at sea with catch data being collected by MS inspectors. The catch composition of the last observed haul of the inspected vessel is recorded in terms of live weight per species and quantities above or below the minimum conservation reference size (MCRS). These data are recorded on a template form, which is then submitted to EFCA for compilation and analysis. The LH concept considers the differences between quantities of catches observed during the sea inspections and quantities of fish reported in the logbook. These differences are used to derive the true discard ratio. With the entry into force of the LO, the difference between the quantities of fish by species subject to the LO below the minimum size (BMS) observed during the LH inspections and the quantities reported in the logbook can be used as an indicator of illegal discarding practices. The LH data are considered as reference data and provide knowledge on the catch composition (number of fish above and below MCRS defined at EU level and ratio of different species) in the sampled hauls.

Additional data are also recorded during LH inspections by some MS on more detailed size compositions of legal-size catches (LSC), i.e. fish above the MCRS. In these cases, additional to the species catches quantities above and below the MCRS, the quantities of fish above the MCRS are recorded by commercial size grade (mainly for cod). The differences between the grades declared in the sales and the grades recorded during the LH inspections provide an indication of the discarding of LSC, also designated as high-grading (see Method D, described in Sect. 19.4.4).

To facilitate LH classification and the data analyses, the fisheries within a JDP were categorised in several fleet segments according to gear, mesh size, area and species caught (see example in Annex 19.2). This categorisation by fleet segment was developed by EFCA in close cooperation with MS, within the JDP steering groups (SGs) and the regional control expert groups (CEGs) constituted in the framework of the CFP regionalisation. The analysis of the LH data and subsequent estimation of discards are conducted at fleet segment level.

Categorising the fisheries within a JDP area into fleet segments assumes implicitly that the catch profile of the fishing trips using the same gear and mesh size and operating in the same areas, i.e. belonging to the same fleet segment, is similar. However, there are variations in the proportion of undersized fish depending on the areas, the type of gear and time of year. In order to have a qualified knowledge of these variations and their interdependencies, it is necessary to obtain a large number of samples to have representative reference data.

19.3 Data and Analysis

The data are collected through the LH inspections together with the declared catches by category (i.e. discards, landed catches below and above the minimum conservation reference size, BMS and LSC, respectively). EFCA compiles these data provided by the MS concerned, which allows completing and updating a matrix of discard ratios by segment and by period, which serves as a baseline for future analysis.

In combination with the LH data collected during inspections, the datasets from each fleet segment are compiled based on information on annual quantities reported in logbooks provided by MS and aggregated by:

(a) Month: from January to December.
(b) Fleet segment: fleet defined based on the gear, mesh size and area of fishing activity. In some case the target species is an additional component to define the fleet segment.
(c) Areas: area of fishing activity.
(d) Species: the species caught.

19.3.1 Weighted Mean and Standard Deviation of the BMS Ratios

In the LH inspections, the following quantities are collected by species:

BMS_{RET}^{LH}: quantity (in kg) of the fish retained below MCRS

LSC_{RET}^{LH}: quantity (in kg) of the fish retained above MCRS

Considering the BMS ratio derived from the LH, $rBMS_{RET}^{LH}$, the percentage of fish below MCRS in relation to the total catch (*BMS* + *LSC*), for each LH, the ratio *rBMS* is:

$$rBMS^{LH} = \frac{BMS_{RET}^{LH}}{BMS_{RET}^{LH} + LSC_{RET}^{LH}} \tag{19.1}$$

The LH *rBMS mean*, *weighted by the catch of the respective haul*, is then calculated. Whereas weighted means generally behave in a similar way to arithmetic means, they do have a few counter instinctive properties.

Considering the weight (w_i) for each *ith* observation (or LH) the total catch (*BMS* + *LSC*), the LHs with higher catches contribute more than the LHs with lower catch quantities:

$$\overline{rBMS}_{RET}^{LH} f, s = \frac{\sum_{i=1}^{n} \left(w_{f,s,i} \times rBMS_{RET}^{LH} f, s, i \right)}{\sum_{i=1}^{n} w_{f,s,i}} \tag{19.2}$$

$$\forall f, s \;\; i = \{1, \ldots, n\}; \quad n \in \mathrm{N}_0$$

where *f* and *s* define a specific *fleet segment* and *species*, respectively, and *n* is the number of LHs for that specific segment.

The weighted standard deviation (sd_w) of the mean $\overline{rBMS}$ is therefore:

$$sd_{w}{}^{LH}_{RET}f,s = \sqrt{\frac{\sum_{i=1}^{n}\left[w_{f,s,i} \times \left(rBMS^{LH}_{RET}f,s,i - \overline{rBMS}^{LH}_{RET}f,s\right)^2\right]}{\frac{\left(n' - 1\right) \times \sum_{i=1}^{n} w_{f,s,i}}{n'}}} \quad (19.3)$$

$$\forall f,s \quad i = \{1,\ldots,n\}; \qquad n \in \mathrm{N}_0$$

where *n'* is the number of non-zero weights and $\overline{rBMS}$ is the weighted mean of the LH observations for a specific *fleet segment (f)* and *species (s).*

19.3.2 Standard Error and Confidence Limits of the Mean

One of the best ways to assess the reliability of the precision of a measurement is to repeat the measurement several times and examine the different values obtained. Without variation, all the repeating measurements should give the same value, but in reality the results deviate from each other. Statistics treats each result of a measurement as an item or individual (i.e. each LH) and all the measurements as the sample. All possible measurements, including those which were not done, are called the population. The basic parameters that characterise a population are the **mean**, μ, and the **standard deviation**, σ. The latter indicates the variation or dispersion of the values around the mean. In order to determine the true μ and σ, the entire population should be measured, which is usually impossible to do. In practice, measurement of several items is done, which constitutes a sample. Estimates of the mean and the standard deviation are calculated based on data from sampling and are denoted by $\bar{x}$ and s, respectively. The values of $\bar{x}$ and s are used to calculate the **confidence interval** (*CI*), which is a range of values which is likely to contain the population parameter of interest. The formula for a confidence interval for a population with unknown standard deviation is therefore given by the formula:

$$CI = \bar{x} \pm t^*_{n-1} \times s/\sqrt{n} \quad (19.4)$$

where t^*_{n-1} is the critical t^*-value from the *t*-distribution with *n-1* degrees of freedom (where *n* is the sample size). The plus-or-minus figure usually is called **margin of error** and expresses the *statistical uncertainty* or the maximum expected difference between the true population parameter and a sample estimate of that parameter. To be meaningful, the margin of error should be qualified by a probability statement (often expressed in the form of a **confidence level**). The confidence level informs how sure the value is. It is expressed as a percentage and represents how often the true percentage of the population lies within the confidence interval. For example, the 95% confidence level (which is usually used) means the population parameter will be within that range with 95% certainty. The 95% confidence interval for the mean is calculated as:

$$Lower\ limit: \quad LL = \bar{x} - t_{.95} \times s_M \quad Upper\ limit: \quad UL = \bar{x} + t_{.95} \times s_M$$

The standard error of the mean is designated as σ_M. It is the standard deviation of the sampling distribution of the mean, which is $\sigma_M = \sigma/\sqrt{N}$ where σ is the standard deviation of the original distribution and N is the sample size (the number of scores each mean is based upon). When s is used as an estimate of σ, the estimated standard error of the mean is $s_M = s/\sqrt{N}$. The larger the sample size, the smaller the standard error of the mean. More specifically, the size of the standard error of the mean is inversely proportional to the square root of the sample size (Fig. 19.1).

19.3.3 Evaluating the Effect of the Number of LH Samples

The mean of a sample of measurements, $\bar{x}$, provides an estimate of the true value, μ, of the quantity we are trying to measure. However, it is quite unlikely that $\bar{x}$ is exactly equal to μ, and an important question is to find a range of values in which we are certain that the value lies. This range depends on the number of measurements done and on the question of *how certain we want to be*. The more certain we want to be, the larger the range we have to take.

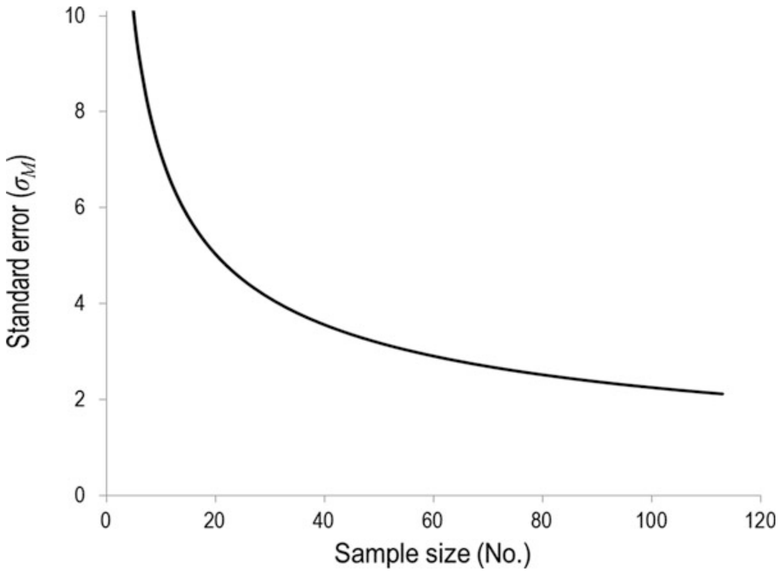

Fig. 19.1 Example of an effect of the sample size on the standard error for a standard deviation

The larger the number of experiments done, the closer $\bar{x}$ is to μ, and a smaller range has to be taken for the same percentage of certainty. The error in the estimate of the mean is proportional to the standard deviation of the sample, *s*, and the sample size, *n*. It can be visualised by plotting the mean and its 95% confidence interval (*CI95*). To calculate the sample mean $(\bar{x})$ is likely to be anywhere in the shaded region of the graph in Figure 19.2a, which shows the variation of the confidence interval around the mean $\overline{rBMS}$ or $(\bar{x})$ for different sample size (*n*).

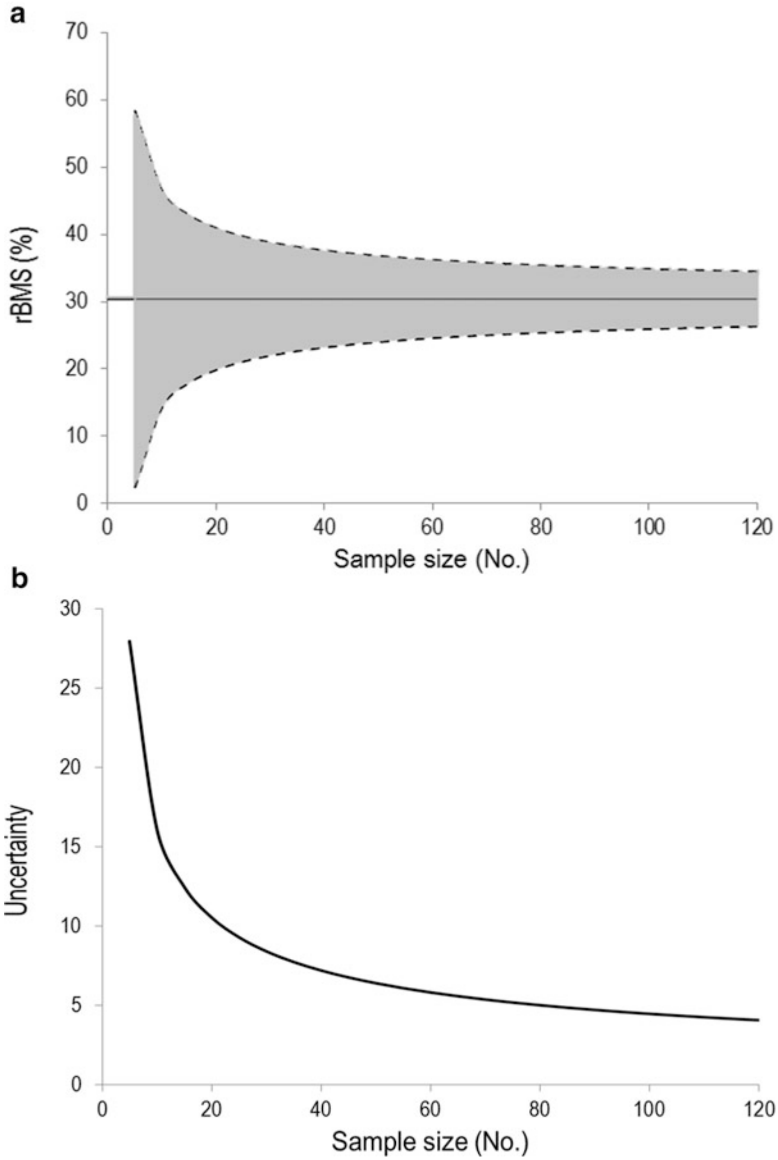

Fig. 19.2 Representation of the 95% confidence region (**a**) around a mean rBMS of 30.4% (bold line) contrasted with sample size (number of observations). Effect of the sample size (**b**) on the margin of error, e.g. statistical uncertainty of the mean

For sufficiently large number of samples, n, both the curve of the Uncertainty (Fig. 19.2b) and of the Standard Error (see Fig. 19.1) level off. To know the mean with a required certainty, there is a need to choose the right size of sample, i.e. the right number of repeated experiments, n.

After a critical analysis of the LH data, it was decided to look at the rate of variation of the Statistical Uncertainty (e.g. variation of the Margin of Error), hereby named as dMoE and set an arbitrary reference or threshold of $dMoE = 2.5\ \%$ (see the green line in Fig. 19.3) to identify the most appropriate number of samples (or LH), n, limit beyond which it would not be convenient to increase the sample size (e.g. number of LH).

Mathematically, the tax of variation of a certain variable is called **derivative,** and the official definition is:

$$f'(x) = \lim_{h \to 0} \frac{f(x+h) - f(x)}{h} \tag{19.5}$$

Thus, for the example reported in Fig. 19.3, the experiment would have had at least 92 samples to achieve the threshold of $dMoE = 2.5\ \%$, noteworthy additionally LHs would not have brought further “Certainty” (or less uncertainty) to the mean estimation of rBMS.

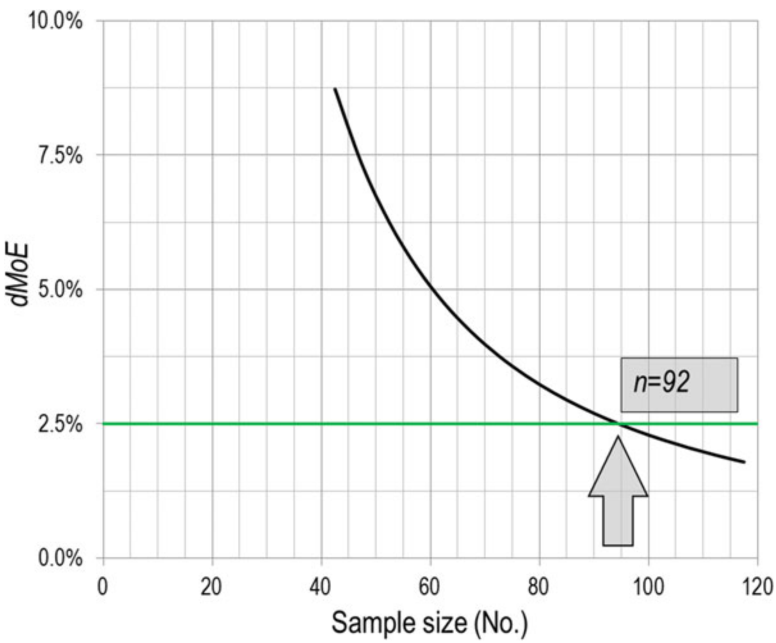

Fig. 19.3 **Example** of the variation of the margin of error (dMoE) contrasted with the sample size (number of observations). The arrow shows the appropriate number of samples (e.g. n = 92 LH) based on the reference threshold of dMoE = 2.5%

19.4 Discarding and Methods to Derive Discard Ratios

There are several reasons for discarding, and usually discarding is a combination of several factors, either legal or economic (Pascoe 1997; Hall et al. 2000; Catchpole et al. 2015; Damalas et al. 2015). To estimate discards there is a need to understand the reasons why discarding takes place, so that it becomes possible to identify more appropriate data and methodologies to be used. The decision tree below identifies the methodology to be used according to the main reason for discarding (Fig. 19.4).

Method A: Discards of fish below minimum conservation reference size (MCRS) not subject to the landing obligation (LO).
Method B: Discards of fish below MCRS subject to the LO.
Method C: Discard of fish species subject to the LO below and above the MCRS, but without reference data on fish size structure. The proportion of the species composition in the catch is used as reference information.
Method D: Discard of fish species subject to the LO below and above the MCRS, with reference data on fish size structure. This method is a combination of Method B, to estimate the discard of the catches below the MCRS, and the estimation of high-grading, i.e. discarding of fish of legal size (legal-size catch, LSC).
Method E: Discard of species subject to the LO with quota limitation (choke species). This method is similar to Method C but should take into account a component of temporal variability, since discarding could be higher when close to quota exhaustion.
Method F: Discard of species subject to the LO with exemption cases. This method provides discard estimates based on either Method B or C (depending on the main discarding motive).

In Sect. 19.4.1, the calculations used in each method to estimate the discard ratio are described (see also Annex 19.1 for an overview of these methods). Method A is applied for species not subject to the LO, while all the other methods concern species subject to the LO. Further details are provided here on when the use of each method is appropriate. The quality of the discard estimates depends on the quality and representativeness of the reference data used and the validity of the assumptions.

Note that in some cases in the literature, the term "discard rate" is used instead of "discard ratio". The latter is the appropriate terminology because a "ratio" represents the proportion of two quantities measured using the same units (e.g. weight in tonnes), while "rate" represents the proportion of two quantities measured in different units (e.g. speed in km/hr is a rate). Nevertheless, the term "rate" is very often used to denote the proportion of discarded fish in relation to the total catch.

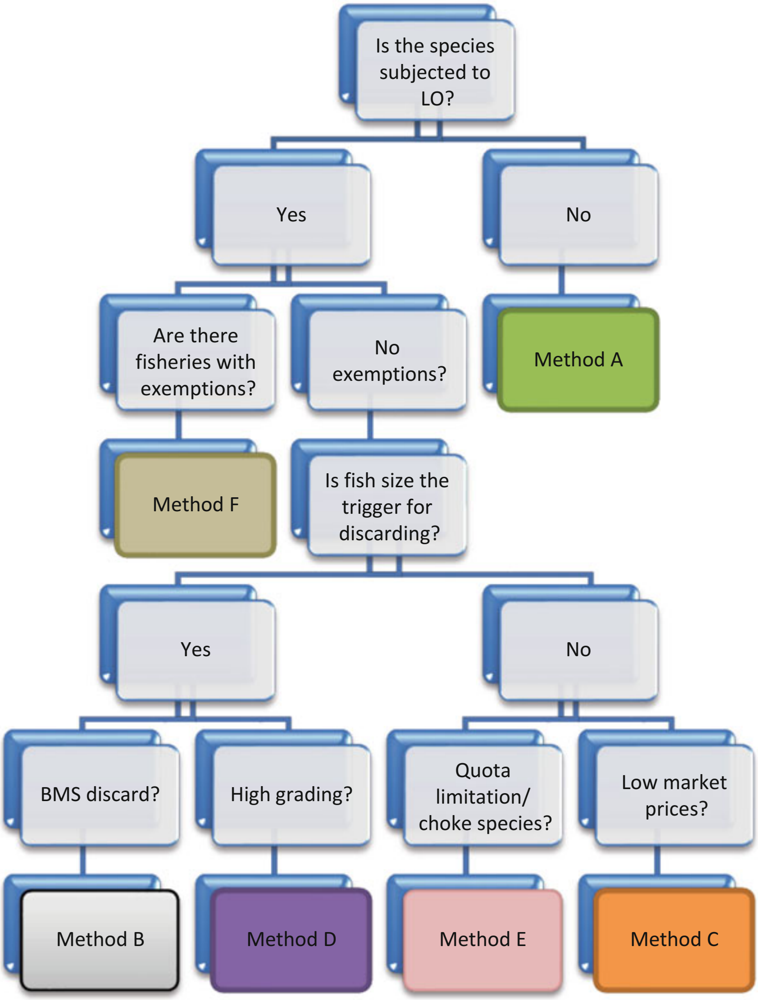

Fig. 19.4 Decision tree of the several methodologies used to estimate the discard ratio using reference data

19.4.1 Method A: Discard of BMS Catches for Species Not Subjected to the Landing Obligation

This method is applicable to estimate the discard ratio for species not subjected to the LO. To apply this method, reference data are needed on the catch size composition of the species being analysed. These data are obtained during detailed inspections on board (LH).

During LH inspections, catch data on unwanted and wanted catch quantities are collected. If a given *Species A* is not subjected to the LO, the unwanted catch component is discarded (DIS), and the wanted component is retained (LSC).

The method assumes that there are no high-grading practices, i.e. all the LSC are landed. The method, as all the other methods, also assumes that the LH data of a given fleet segment is a representative of that fleet segment. Therefore, the catch composition *Species A* of the LHs is the same as all the other fishing trips within a given fleet segment. The information of "other fishing trips" is obtained in the declared discards and landings in logbooks. Note that there are two components of the discards: declared $\left(DIS_A^{LB}\right)$ and undeclared discard$\left(DIS_A^{LB*}\right)$. The aim of this method is to calculate the latter quantity, which is unknown and not reported in the logbook.

$$rDIS_A^{LH} = \frac{DIS_A^{LH}}{DIS_A^{LH} + LSC_A^{LH}} \tag{19.6}$$

$$rDIS_A^{LB} = \frac{DIS_A^{LB} + DIS_A^{LB*}}{DIS_A^{LB} + DIS_A^{LB*} + LSC_A^{LB}} \tag{19.7}$$

By equating the discard ratio of the LH $\left(rDIS_A^{LH}\right)$ of *Species A* to the logbook discard ratio $\left(rDIS_A^{LB}\right)$, the discard ratio of *Species A* in a given fleet segment is:

$$rDIS_A^{LH} = \frac{DIS_A^{LB} + DIS_A^{LB*}}{DIS_A^{LB} + DIS_A^{LB*} + LSC_A^{LB}} \tag{19.8}$$

This corresponds to:

$$DIS_A^{LB*} = \frac{rDIS_A^{LH} \times LSC_A^{LB}}{1 - rDIS_A^{LH}} - DIS_A^{LB} \tag{19.9}$$

Using Eq. 19.9, we can calculate the unreported discard ratio $rDIS_A$ for *Species A*:

$$rDIS_A = \frac{DIS_A^{LB*}}{DIS_A^{LB} + DIS_A^{LB*} + LSC_A^{LB}} \tag{19.10}$$

Replacing $\left(DIS_A^{LB*}\right)$ of Eq. 19.9 in Eq. 19.10, we end with:

$$rDIS_A = \frac{rDIS_A^{LH} \times \left(LSC_A^{LB} + DIS_A^{LB}\right) - DIS_A^{LB}}{LSC_A^{LB}} \tag{19.11}$$

If high-grading (discarding of legal size catch) occurs, the estimation resulting from Method A does not take that into account and should be considered an underestimate. This is because the high-grading component is not recorded in the LH data (e.g. it is not expected that fishermen are high-grading during a LH inspection).

19.4.2 Method B: Discard of BMS Catches for Species Subjected to the Landing Obligation

This method is very similar to Method A but should be used when the species of interest is subjected to the LO. The non-reference data continues to consist of two catch components: the wanted and unwanted catch, as in Method A. However, in Method B there is an additional catch component to be considered in the non-reference data – the unwanted catch component that is now landed. This method is appropriate when the discarded catch consists only of fish below the minimum conservation reference size (MCRS), designated as below minimum size (BMS).

Similar to Method A, this method requires reference data of the size catch composition of the species being analysed, such as data collected during detailed inspections on board (LH). If the species is subjected to the LO, when conducting a LH inspection, the unwanted (BMS) and wanted catch (legal-size catch, LSC) quantities are recorded separately. The estimation of the discards of non-reference data is based on the proportion of unwanted catch of the species in the reference data, which is the BMS ratio $\left(rBMS_B^{LH}\right)$. For a given fleet segment, the BMS catch ratio of ***Species B*** in the LH data $\left(rBMS_B^{LH}\right)$ is compared to the BMS catch ratio in the logbook $rBMS_B^{LB}$.

From the LH data, the available information is the quantity of the fish retained below MCRS $\left(BMS_B^{LH}\right)$ and above MCRS $\left(LSC_B^{LH}\right)$. Therefore, the BMS ratio from LH of *Species B* $\left(rBMS_B^{LH}\right)$ is:

$$rBMS_B^{LH} = \frac{BMS_B^{LH}}{BMS_B^{LH} + LSC_B^{LH}} \tag{19.12}$$

However, the non- reference data $\left(rBMS_B^{LB}\right)$ might have an additional illegal and unreported component of fish below MCRS that is discarded, DIS_B^{LB*}. This component is not recorded in the LH data because it is not expected that fishers discard a species subjected to the LO in the presence of an inspector.

$$rBMS_B^{LB} = \frac{BMS_B^{LB} + DIS_B^{LB*}}{BMS_B^{LB} + DIS_B^{LB*} + LSC_B^{LB}} \tag{19.13}$$

Method B calculates the quantity of illegal discards, DIS_B^{LB*}, which is unknown and not reported in the logbook.

Assuming that $rBMS_B^{LH} = rBMS_B^{LB}$, the total BMS ratio of non-reference data is:

$$rBMS_B^{LH} = \frac{BMS_B^{LB} + DIS_B^{LB*}}{BMS_B^{LB} + DIS_B^{LB*} + LSC_B^{LB}} \tag{19.14}$$

which corresponds to:

$$DIS_B^{LB*} = \frac{rBMS_B^{LH} \times LSC_B^{LB}}{1 - rBMS_B^{LH}} - BMS_B^{LB} \tag{19.15}$$

Using the Eq. 19.15, the discard ratio $rDIS_B$ for a given *Species B* subjected to the LO is:

$$rDIS_B = \frac{DIS_B^{LB*}}{BMS_B^{LB} + DIS_B^{LB*} + LSC_B^{LB}} \tag{19.16}$$

Replacing $\left(DIS_A^{LB*}\right)$ of Eq. 19.15 in Eq. 19.16:

$$rDIS_B = \frac{rBMS_B^{LH} \times \left(LSC_B^{LB} + BMS_B^{LB}\right) - BMS_B^{LB}}{LSC_B^{LB}} \tag{19.17}$$

19.4.3 Method C: Discards of Low-Market Species Subjected to the LO Regardless of Size

In this method, discards of a certain *Species C* might occur because of its low market value, and the part DIS_C^{LB} is made of both the BMS and the LSC component. For such *Species C*, subjected to the LO, the recorded BMS from the reference data (LH) is not indicative of the usual discarding fishers' behaviour, as it is not expected that fishers discard either BMS or LSC components during an inspection.

Since the discards also occur in the LSC component, Method B is not appropriate. Method C to estimate of the discard ratio ($rDIS_C$), for a given *Species C* subjected to LO, is based on the catch profile similarity between the two species. As in the other methods, LH data are used as references and compared with the data recorded in the logbooks. The model assumes that within each fleet segment, the catch proportion of *Species C*, named r_C in the following equations, in relation to the total catch, is similar. Considering two species both subjected to the landing obligation, *Species B* and *Species C*, but with *Species C* discarded regardless of fish size, it is assumed that $r_C^{LH} = r_C^{LB}$. Therefore,

$$r_C^{LH} = \frac{t_C^{LH}}{t_C^{LH} + t_B^{LH}} \tag{19.18}$$

$$r_C^{LB} = \frac{t_C^{LB}}{t_C^{LB} + t_B^{LB}} \tag{19.19}$$

where t_B and t_C correspond to the total catch of *Species B* and *Species C*, respectively, in the LH and logbook (LB). The total catches for each species in the logbook are:

$$t_C^{LB} = DIS_C^{LB*} + BMS_C^{LB} + LSC_C^{LB} \tag{19.20}$$

$$t_B^{LB} = DIS_B^{LB*} + BMS_B^{LB} + LSC_B^{LB} \tag{19.21}$$

where DIS_C^{LB*} is the unknown discarded quantity of *Species C*. The discard component of *Species B*,DIS_B^{LB*}, also unknown, is estimated by applying Method B by Eq. 19.15.

Based on the above-mentioned assumption $r_C^{LH} = r_C^{LB}$, the ratio of *Species C* is:

$$r_C^{LH} = \frac{t_C^{LB}}{t_C^{LB} + t_B^{LB}} \Rightarrow t_C^{LB}\left(1 - r_C^{LH}\right) = r_C^{LH} \times t_B^{LB} \tag{19.22}$$

Replacing t_B^{LB} in Eq. 19.23 with $DIS_B^{LB*} + BMS_B^{LB} + LSC_B^{LB}$ from Eq. 19.20, the total catch of *Species C* is:

$$t_C^{LB} = \frac{r_C^{LH}}{1 - r_C^{LH}} \times \left(DIS_B^{LB*} + BMS_B^{LB} + LSC_B^{LB}\right) \tag{19.23}$$

Substituting the resulting t_C^{LB} from Eq. 19.23 into Eq. 19.20, the DIS_C^{LB} can be calculated, and discard ratio, $rDIS_C$, of *Species C* is (Eq. 19.28):

$$DIS_C^{LB*} = t_C^{LB} - \left(BMS_C^{LB} + LSC_C^{LB}\right) \tag{19.24}$$

$$rDIS_C = \frac{DIS_C^{LB*}}{t_C^{LB}} \tag{19.25}$$

$$rDIS_C = \frac{t_C^{LB} - \left(BMS_C^{LB} + LSC_C^{LB}\right)}{t_C^{LB}} \tag{19.26}$$

$$rDIS_C = 1 - \frac{BMS_C^{LB} + LSC_C^{LB}}{\frac{r_C^{LH}}{1 - r_C^{LH}} \times \left(DIS_B^{LB*} + BMS_B^{LB} + LSC_B^{LB}\right)} \tag{19.27}$$

$$rDIS_C = 1 - \frac{\left(1 - r_C^{LH}\right) \times \left(BMS_C^{LB} + LSC_C^{LB}\right)}{r_C^{LH} \times \left(DIS_B^{LB*} + BMS_B^{LB} + LSC_B^{LB}\right)} \tag{19.28}$$

19.4.4 Method D: High-Grading Discards

Method D should be used in similar cases as Method C, i.e. when discarding also involves the legal-size component of the catch. However, Method D should be applied when there are data available on the size structure of the catch for both reference and non-reference data sets. The size structure considered here is the grade size information, information which is easily collected. Other size structure information, such as the length frequency distribution of the catches, could be used but are more difficult to collect and therefore are not addressed here.

To estimate total discards, there is a need to consider two components: one to estimate the high-grading (discarding of LSC) and another to estimate the discarding of BMS, using Method 1 or 2, depending if the species is subjected to the LO or not, which should only be applied if the LSC are corrected with the estimates of LSC discards.

Method D assumes that high-grading practices are similar within a fleet segment or within the unit used for the analysis. Also, it assumes that high-grading does not occur for larger fish.

Considering the catch proportion of each grade size x, denoted as P_x, as:

$$\boldsymbol{P_x = \frac{C_x}{C_{TOTAL}}} \tag{19.29}$$

Being C_x, the catch of grade x and the total catch of all grades, as:

$$\boldsymbol{C_{TOTAL} = \sum_{x=1}^{5} C_x = C_1 + C_2 + C_3 + C_4 + C_5} \tag{19.30}$$

In Eq. 19.30, five grade sizes are considered, but a different grade size number could be adopted as a different stratification, such as considering a group of combined grades (e.g. grade size equal or smaller than grade 3).

If the catch proportion of the non-reference data to be assessed ($P_{n,x}$) of grade size x is lower than the catch proportion of the same grade size x of the reference data ($P_{f,x}$), then there is an indication of discarding, because the method assumes similar size structures between reference (f) and non-reference data (n).

Based on Eq.19.29, the catch proportion of reference data could be calculated as:

$$\boldsymbol{P_{f,x} = \frac{C_{f,x}}{C_{f,TOTAL}}} \tag{19.31}$$

To estimate the high-grading of non-reference data, it is necessary to identify the grade sizes for which high-grading is not perceived to be an issue, i.e. grades with similar catch proportion in reference and non-reference data.

$$\boldsymbol{P_{n,x} \sim P_{f,x}} \tag{19.32}$$

Assuming that the grade size with no discarding (high-grading) are grade size 1 and 2, then Eq. 19.31 for reference data would be:

$$P_{f,1-2} = \frac{C_{f,1+}C_{f,2}}{C_{f,TOTAL}} \tag{19.33}$$

There is a need to verify that the catch proportion of reference and non-reference data is similar for those grade sizes (Eq. 19.32). After identifying the grades with no discards (100% retained), it is then possible to estimate the total catch of non-reference data, $C_{n,TOTAL}$, using Eq. 19.29. Considering that the grades with no discarding are grades 1 and 2, the catch proportion of reference data of non-discarded grades defined in Eq. 19.33 can be written as:

$$C_{n,TOTAL} = \frac{rC_{n,1} + rC_{n,2}}{P_{f,1-2}} \tag{19.34}$$

where $rC_{n,1}$ and $rC_{n,2}$ are the declared landings of grade sizes 1 and 2 of non-reference data, respectively, which are assumed to be grades with no high-grading.

The total weight of high-grading, H, is:

$$H_{TOTAL} = C_{n,TOTAL} - \sum_{x=1}^{5} C_{n,x} \tag{19.35}$$

ETo calculate the high-grading weight of a given grade size, x, the proportion of the reference data of that grade size is applied to the total catch of non-reference data (from Eq. 19.34), to obtain the total catch of each grade, which is then subtracted from the reported catch of that grade, as:

$$H_x = \left(P_{f,x} \cdot C_{n,TOTAL}\right) - rC_x \tag{19.36}$$

The estimation of the total high-grading ratio, HR, is:

$$HR = \frac{H_{TOTAL}}{C_{n,TOTAL}} \tag{19.37}$$

Note that the high-grading ratio is a discard ratio only for the legal-size component of the catch and does not consider the discards of fish below the MCRS.

19.4.5 Method E: Discard of Species with Quota Limitations (Choke Species) and Subjected to the Landing Obligation

Method E should not be considered as a method but a combination of different methods based on available information of discard practices. Discards in this case originates due to quota limitations. The more appropriate method to estimate the discard ratios is the application of Method C, but data analysis should be conducted regularly throughout the year as the discard pattern might change depending on the quota availability throughout the year.

19.4.6 Method F: Discard of Species Subjected to the Landing Obligation with Exemption Cases

Method F is a combination of methods according to the main discard reasons and should only be applied to the catch proportion that is not exempted. Therefore, there is a need to estimate the catch proportion that is subjected to the LO and the exempted component.

19.5 Outcome and Way Forward

The results from the LH programme are an important input into the annual risk assessment workshops, for the evaluation of the likelihood of non-compliance with the landing obligation. The outcome of the risk assessment is then used as a key input for the planning of the JDP for the upcoming year control activities. It should be noted that the objective of the collection of LH data is not to obtain precise discard ratios but to identify where problems are present, and in which magnitude, to focus monitoring and control efforts. The information collected by MS under their scientific discard observers' programmes is also taken into account when evaluating compliance. This information is compiled in a public database available at https://stecf.jrc.ec.europa.eu/web/stecf/reports. The Joint Research Centre is assembling fishery data collected under the EU Data Collection Framework (DCF)[2,3] and acting as secretariat of the Scientific, Technical and Economic Committee for Fisheries (STECF).

During the EFCA JDP risk assessment workshops, the main threats, including non-compliance with the LO and associated misreporting, are identified at fleet segment level, and the spatial and temporal distributions of fisheries are assessed, allowing for the planning of future JDPs. A set of possible risk treatment measures is then developed, and, on this basis, a series of "specific actions" addressing the main threats are implemented in the JDPs. In addition to the risk assessment workshops,

[2]Council Regulation (EC) No 199/2008 of 25 February 2008 concerning the establishment of a community framework for the collection, management and use of data in the fisheries sector and support for scientific advice regarding the Common Fisheries Policy.

[3]Regulation (EU) 2017/1004 of the European Parliament and of the Council of 17 May 2017 on the establishment of a union framework for the collection, management and use of data in the fisheries sector and support for scientific advice regarding the Common Fisheries Policy and repealing Council Regulation (EC) No 199/2008.

the CEGs formally requested the assistance of EFCA to facilitate a joint compliance evaluation with the provisions of the LO. In this context, EFCA is using the methods described in this chapter to derive indicators that can be used in the evaluation of compliance with the LO, one of which being based on the comparison of reference fishing activity information (inspected activity using LH, with information coming from electronic monitoring (EM) with video or observers) versus non-inspected activity. Differences could be measured and utilised in the form of a compliance indicator. This approach has been followed in the context of the LO and assisted in deriving the characterisation of the nature of possible non-compliance behaviours.

Regarding standardisation of how LH inspections are conducted, EFCA developed basic guidelines, produced in cooperation with MS in 2015. The standardised sampling procedure differs by region and type of fishery (segment) and includes observing the whole catch or taking a determined minimum sample size for large hauls (i.e. 300 kg). For these larger hauls, it is recommended that three sets are taking at the beginning, middle and end of the haul. A good approach to standardisation is also the exchange of experiences and best practices among MS in dedicated workshops, exchanges of inspectors and participation of EFCA coordinators. The issue of last haul standardisation was also raised in other meetings, specific LH and discard workshops organised by EFCA, in which relevant scientists, MS authorities and other stakeholders' feedback on the LH programme was acknowledged. The current guidelines provide a common basis for promoting standardisation and harmonisation, and more detailed guidelines to further improve LH data quality are being developed between EFCA and MS.

Additionally, reference data on catch composition could be observed through fully documented fisheries (FDF), including EM with video. These observed data could then be systematically compared with catch composition data from the reported landings of vessels of the same fleet segment that have operated in the same area at the same time.

Incentives may continue to exist for discarding, for example, of specimens below MCRS, smaller market categories [high-grading], species that threaten to choke the fishery, species of low market value, etc. If such specimens are being discarded due to non-compliance with the LO, it is expected that these will be found in smaller proportions of the reported landed catch than in the observed catch. One limitation of the LH programme could be that discrepancy between the observed and the reported catch composition cannot be used as evidence of discarding in any individual case (because catch compositions can vary by chance or due to differences in the skills of skippers), but trends in the magnitude of these discrepancies at aggregate level are being considered by EFCA and the MS as an indicator to evaluate compliance with the LO (see, e.g. Valentinsson et al., this volume). At the same time, declining trends in the proportions of unwanted catch (below MCRS or of the choke stock) in the inspected catch could be an indicator of progression in avoidance behaviour. These trends could be interpreted by looking at changes in selective gear uptake or changes in spatiotemporal effort allocation.

Annexes

Table Annex.19.1 Overview of different methodologies used by EFCA to estimate discards and the discard ratio

	Subject to LO	Discarded component	Type of reference data needed	Assumptions	Discard ratio
Method A	No	BMS	Reference catch data discriminated as retained and discarded	No high-grading in the retained component Uniform catch size composition within the fleet segment	$uDR_n = \frac{uDIS_n}{uDIS_n + rDIS_n + RET_n}$
Method B	Yes	BMS	Reference catch data discriminated as BMS and LSC	No high-grading in the LSC component Uniform catch size composition within the fleet segment	$uDR_n = \left(\frac{DR_f \cdot LSC_n}{1 - DR_f} - rBMS\right) \cdot \left(\frac{1 - DR_f}{LSC_n}\right)$
Method C	Yes	BMS and LSC	Reference catch data of two species discriminated as BMS and LSC	Uniform catch size and species composition within the fleet segment	$uDR_{A,n} = \frac{uA_n}{A_{n,TOTAL}}$
Method D	Yes	BMS and LSC	Reference data with size structure information (i.e. grade size)	Uniform catch size composition within the fleet segment No high-grading of the grade size classes of larger fish and similar retained proportion of reference and non-reference data	$DR_n = \frac{uBMS_n + H_{TOTAL}}{uBMS_n + rBMS_n + C_{n,TOTAL}}$
Method E	Yes	BMS and LSC	Similar to Method C	Similar to Method C	Similar to Method C
Method F	Yes, partially	See other methods[a]	See other methods[a]	See other methods[a]	See other methods[a]

[a]Dependent on the discarding practices in the nonexempted component

Annex 19.2 Baltic Sea JDP fleet segments

Fishery	Gear	Segment	Area	Segment code
Demersal fisheries, active gears all vessels lengths	Demersal active	OT[a] (≥105)	22–24	BS01
		SX[b] (≥105)	22–24	BS02
		OT[a] (≥105)	25–27	BS03
Pelagic fishery for sprat and herring, active gears and all lengths	Pelagic active	OT[a], PT[c] (≥16 and <32)	22–27	BS04
		OT[a], PT[c] (≥32and <90)	22–27	BS05
		OT[a], PT[c] (≥16 and <105)	28–32	BS06
Salmon South	Pelagic passive	GN[d] (≥157)	22–29	BS07[f]
		LL[e]	22–29	BS08[f]
Salmon North	Pelagic passive	FIX (national rules)	22–32	BS09[f]
Passive gear fishery	Demersal passive	GN[d] (≥110), LL[e]	22–24	BS10
		GN[d] (≥110), LL[e]	25–27	BS11
	Pelagic passive	GN[e] (≥32 and <110), FIX (national rules)	22–32	BS12
Other	Other	Other non-reported in segments 1–12	22–32	BS13

Notes:
[a]*OT* includes the following gear codes according to Annex XI of Regulation (EU) No 404/2011: OTB, TBN, TBS, TB, OTT, OTM
[b]*SX* includes the following gear codes according to Annex XI of Regulation (EU) No 404/2011: SDN, SSC, SPR, SX, SV
[c]*PT* includes the following gear codes according to Annex XI of Regulation (EU) No 404/2011: PTB, PTM
[d]*GN* includes the following gear codes according to Annex XI of Regulation (EU) No 404/2011: GN, GNS, GNC, GTN, GTR
[e]*LL* includes the following gear codes according to Annex XI of Regulation (EU) No 404/2011: LHP, LHM, LLS, LLD, LL, LTL, LX
[f]Direct fishing for salmon (i.e., when salmon catches are > 50% of total catches per fishing trip)

Glossary of Terms and Symbols Used in the Equations

Glossary of Terms

Below minimum size (BMS) Marine organism with size below the minimum conservation reference size (MCRS).

Discard(s) Catch component that is not retained (discarded) and not landed. Abbreviated in this document as DIS. Discarding is the practice of returning unwanted catches to the sea, either dead or alive, because they are undersized, due to market demand or due to specific regulations such as quota exhaustion or catch composition rules.

Discard rate See discard ratio definition.

Discard ratio Proportion of discard quantities in relation to the total catch. Usually expressed in percentage (%) and often also designated as "discard rate".

Grade size Size category determined according to weight or number of fishes in 1 kg. The EU grade definition is laid down in Council Regulation (EC) No 2406/96.

High-grading Discarding of legal-size catch (see LSC definition below).

Landing Obligation EU term for the obligation to land all catches of regulated commercial species on board and to count those catches against quota. As defined in Article 15 of Regulation (EU) No 1380/2013, the LO applies to all catches of species subject to catch limits or, in the Mediterranean, species which are subject to minimum sizes. The LO includes some exemptions: de minimis (that allows the discarding of a small percentage of catches), high survivability (defined in the discard plans and that allows the discarding of specimens with a high chance of surviving) or for catch damaged by predators, disease or contaminated and therefore unfit for human consumption.

Last haul (LH) Hauls in which fisheries inspectors have recorded the amounts of the different components of the catch (i.e. BMS, LSC, etc.) per species. Data collected at those hauls are considered reference data to estimate discards.

Legal-size catch (LSC) The catch of marine organisms of size above the minimum conservation reference size (MCRS).

Non-reference data In this document, it refers to data recorded in logbooks or landing declarations, where the discarding component has not been fully verified.

PACT Partnership, Accountability (compliance), Cooperation and Transparency. This concept allowed assistance to be given by EFCA to the MS in accordance with provisions of Articles 7 and 15 of EFCA's founding regulation. EFCA cooperated with control expert groups from the main regional bodies created in the framework of regionalisation and enlarged the assistance in areas and for species where there is no SCIP in place and thus not covered by the JDP framework.

Reference data Data assumed to be representative of the true catch composition. In opposition to non-reference data, in reference data, the discarding component is likely to have been fully verified.

REM Remote electronic monitoring. Vessels which are equipped with video cameras and a system of sensors and vessel monitoring tools, to record fishing and fish sorting operations. Very often fishing data from these vessels are considered reference data.

Retained catch Catch component that is retained (not discarded) and landed. Abbreviated in this document as RET.

Unwanted catch Designates the catch that was, usually, discarded prior to the coming into force of the LO. Very often, associated with undersized or low market demand fish or cases of catches for which the quota had been exhausted or in contradiction with catch composition rules.

Wanted catch Is used to designate the quantity of fish that would be landed in the absence of the LO.

Symbols Used in the Equations

BMS Catch below minimum size
rBMS Ratio of catch below minimum size
t *Total catch*
DIS Discards
rDIS Discard ratio, also designated as discard rate
H High-grading weight
HR High-grading ratio
LSC Legal-size catch
r *Catch proportion of a certain species in relation to the total catch*
P Proportion (e.g. of grade sizes in relation to the total catch)

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