Workshop on Discard Sampling Methodology and Raising Procedures

Danish Institute for Fisheries Research,

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Final Report, 6/10/03

1; INTRODUCTION

1.1 Background and terms of reference

In the report of their 2003 meeting, the ICES Planning Group on Commercial Catch, Discards and Biological Sampling (PGCCDBS) noted that :

> "Many countries are about to start or have recently started discard-sampling programmes in order to fulfil the data requirements in the Data Directive, and some are encountering problems. In view of this, and the EU Commission's action plan on discards (COM (2002) 656), it is very important to review existing programmes and data series and evaluate procedures, in order to ensure that discard programmes are designed in a way to provide robust estimates which can be used in stock assessments."

> "Some institutes felt that the quality of their discard sampling programmes is good. However, only few had completed an evaluation of the quality of their sampling. The PG considered that there is a need to standardise and disseminate methods to enable institutes to complete such an evaluation."

As a result of the concerns, PGCCDBS recommended that a workshop on Discard sampling methodology and raising procedures be conducted. This workshop took place at DIFRES, Charlottenlund, Denmark on 2-4 September, 2003 with the following terms of reference :

a) Identify data requirements and appropriate discards sampling strategies and methods (e.g. stratification, mandatory and optional variables, selection of vessels, gears, etc.)) to collect fisheries data which fulfils requirements related to stock assessment.
b) Review the sampling strategy and methods in established discard sampling programmes and develop guidelines in order to minimise bias and maximise precision.
c) Identify raising procedures which minimise the bias and maximise the precision of estimates taking into account the sampling procedure and the use of the data.

1.2; Participants

The names and email addresses of the participants in the workshop are given below :

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1.3; Scope

Observers on board fishing vessels can potentially collect a wide range of different types of information. In the current context however, as noted in Term of Reference A, the main concern is with the collection of discard data for use in stock assessment. This tends to imply the collection of relatively detailed information for a relatively restricted number of species, i.e. those fish or shellfish species for which stock assessments may be required. It is noted that there is also increasing interest in the use of discard data in the evaluation of the wider, ecosystem effects of fishing. This requires information about all components of the catch, and may thus require a different sampling approach. The workshop also gave some consideration to this aspect of discard data collection, although it was treated as a lower priority than the stock assessment context.

1.4; Sources of information.

Many of the issues covered in this report have previously been discussed by the ICES Study Group on Discard and Bycatch Information (SGDBI), which met annually over 2000 to 2002. Reports are available at :

http://www.ices.dk/reports/acfm/2000/sgdbi/sgdbi00.pdf
http://www.ices.dk/reports/acfm/2001/sgdbi/sgdbi01.pdf
http://www.ices.dk/reports/acfm/2002/sgdbi/sgdbi02.pdf

The reports include

- inventory of ~35 projects on discard sampling and modelling in the ICES area (SGDBI, 2000, Section 2)
- methods for raising discard samples to the haul, trip and fleet level (SGDBI, 2000, Section 3)
- methods for sampling fishing trips or vessels (SGDBI, 2000, Section 3)
- compilation of discarding estimates in the ICES area (SGDBI, 2001, 2002)
- discussion of discarding in relation to stock recovery plans, stratification for discard sampling, problems associated with sampling national vessels fishing from ports in other countries (SGDBI, 2002)

In addition to these reports, other sources of information available to the group included working documents and presentations made at the workshop meeting, and the reports of EC-funded projects on discard sampling. Some of these sources of information have been compiled for circulation with this report. Another recent reference on the subject, which was not available for consideration by the Workshop is 'Guidelines for developing an at-sea fishery observer programme' by Davies & Reynolds (2003).

1.5; Structure of report

Section 2 of this report gives an introduction to the context for discard sampling as it summarises the causes and consequences of discarding, and discusses the use of discard data in stock assessment. Section 3 covers the statistical aspects of discard sampling and thus addresses terms of reference b and c. Section 4 covers the remaining, more practical aspects of sampling and thus addresses term of reference a. Many of the discard sampling schemes which currently exist in Europe have been described in the literature mentioned in Section 1.4, but there are also now other schemes in existence which have not previously been documented in this way, so Section 5 includes descriptions for some such schemes. Recommendations arising from the workshop are summarised in Section 6.

2; DISCARDING AND STOCK ASSESSMENT

2.1; Discarding

The following summary of discarding and its causes and consequences is adapted from FAO (1997) and Valdemarsen (2002).

Discarding is a global issue. The magnitude for the quantities of fish discarded was provided for the first time in an assessment published by FAO in 1994. Annual discards from the world's fisheries were estimated at that time to range from 17.9 million to 39.5 million tonnes. A subsequent re-evaluation of these estimates, together with adjustments allowing for subsequent reductions in discarding, indicates that current levels are lower. The most recent FAO estimate of 20 million tonnes, if correct, is however about 25 percent of the reported annual yield from marine fisheries.

Discarding and by-catches occur because most of fishing gears and fishing practices are not selective enough for the species and sizes being targeted and because target species inhabit also areas which are occupied by a wide range of other species.

The discarding of targeted species and bycatches have long been recognized as a problem. Usually discarding constitutes a reduction of future harvesting opportunities and it might have negative consequences for the environment and ecosystem.

2.1.1; Definitions of "discarding"

There are several practices in discarding:

a) Discarding of catch. Organisms, fish or other animals, which have been retained by a fishing gear, have been brought on board a fishing vessel or landed and have subsequently and voluntarily been returned to the sea or disposed of.

b) "Slipping" of fish. This almost always occurs with purse seines and hence with pelagic fish, usually mackerel and herring. On some occasions, a catch is made but prior to bringing the fish onto a ship it is discovered that the fish are too small or of poor quality. The whole or part of the catch is then released, dead or moribund, into the sea.

c) Escaping fish. As in slipping but also including organisms which escape from fishing gears (usually nets) when the gears are at the surface of the sea immediately prior to being hauled onto a fishing vessel. For example, when a demersal otter trawl is brought to the surface of the sea, the tension in the netting of the gear is reduced and many fish may escape at that time

The following definition might be useful when addressing discarding practices.

"Discard" is the proportion of the catch, which has been taken onboard the catching vessel and which subsequently is thrown back to sea dying or dead. In addition, fish that during the capture process has been taken to the surface and handled in such a way that they are likely to die after release, including 'slipping', is also considered as discards.

2.1.2; Reasons for discarding

There are number of reasons for discarding. They are mainly legislative and/or economic or just belong to fishing practices. In many instances the individual reasons operate simultaneously. In a number of cases legislation make discarding compulsory affecting both juvenile and adult specimens. For example European Community legislation implicitly or explicitly requires discarding of fish, molluscs and crustaceans for specimens which are smaller than defined minimum landing sizes, catches in excess of defined percentage compositions of catches taken with of nets of a given mesh size and catches in excess of quotas.

National legislation may also imply or insist on discarding. In some countries national quotas of fish are allocated at national level into sectoral quotas or ITQs. In practice, when a vessel or sector of the fleet or has taken its quota, and if no further quota becomes available, catches in excess of a sectoral quota or ITQ may not be landed but should be discarded, even if a national quota is not exhausted.

Reasons for discarding may be listed as follows:

- **Fish of the wrong size**

  - Fish economically too small (no markets)
  - Under-sized fish (landing legally prohibited)

- **Fish of wrong species**

  - Species quota reached or vessel not licensed to land that species
  - Problem in mixed species fishery regulated by quotas (for example cod-haddock-whiting fishery in the North Sea)
  - Low-value species (e.g. in coastal mixed-species gillnet fishery)

- **Fish are damaged or spoiled**

  - Damages caused by gear or fishing operation
  - Fish are spoiled too fast because of too high temperature conditions
  - Damages caused by predation in gear (e.g. seal in a salmon trap-net)
  - Fish spoiled by waste substances and by other marine pollution
  - Fish are spoiled because of too long soaking time (e.g. in gillnet fishery)

- **High grading**

  - Less valuable fish are discarded to make space for more valuable catch
  - To preserve individual quotas for later use
  - Large fish are retained in preference to smaller size groups even though the latter may be greater than the minimum landing size.

- **Lack of space onboard**

  - Every fishing vessel has restricted storage space. In "mixed fisheries" where several species of fish are caught simultaneously by each operation of the fishing gear, the master of a vessel may prefer to keep the more valuable species in preference to the less valuable.

- **Species quota reached**

  - Capture of non target species prohibited by quota-regulations

- **Year-class variation**

  - A strong incoming year-class often attracts additional effort and causes additional discarding
  - Due to inadequate gear selectivity large numbers of small fish are captured

- **Season**

  - A fish specimen may or must be discarded if caught in a wrong season (e.g. a closed season)

2.1.3; Consequences of discarding

Discarded specimens are usually dead or moribund. Thus catching and then discarding practices have consequences, for example, in stock assessments and fishery management:

Firstly, the majority of specimens caught and then discarded are small and small specimens are sexually immature. That means reduction of future spawning stock biomass, which is at the moment one of the key parameters in fishery management.

Catching small fish reduces the growth potential of the stock and thus reduces the potential yield from a fishery with obvious economic consequences.

Discarding rates are often not very well estimated or they are totally unknown. In such cases discards may represent a major source of uncertainty about the real fishing mortality rates exerted on stock/stocks.

2.2; Use of discard data in stock assessment

The main objective of including discard data into stock assessment is to improve the estimates of removals from the population due to fishery. When discards form a substantial part of the catch for a given species, including accurate discard data is generally considered to improve the estimates of fishing mortality and recruitment. However, this is of prime importance when the discard patterns are variable over time due to e.g. yearclass effects, economic incentives or changes in the restrictiveness of TACs. When discard patterns do not vary over time, the inclusion of discards data would simply be a scaling parameter that does not affect the perception of the dynamics of the stock.

When discard data would be included into the data available for stock assessment, two distinct applications can be distinguished: (1) the estimation of the historic time series and biological reference points and (2) the short- and medium-term forecasts. When historic time series are to be re-estimated with newly available discards data, it is important to assess the extent of the discards data in time. A landings time series of e.g. 40 years and a discards time-series of e.g. 8 years could basically give rise to two different scenarios:

- estimate discards for the years prior to the discards collection program by use of modelling. The modelling of historic discard patterns should ideally take into account the effects of changes in mesh size, minimum landings size, economic incentives and TAC restrictions, but in the absence of such analysis a simpler approach such assuming a fixed discard rate for all past years may be appropriate. Additional modelling work is needed on these issues, preferably in conjunction with those datasets where relatively long series of discards data are available.
- only carry out the assessment for the years where discards data is available. This scenario would make it unlikely that a meaningful stock recruitment relationship or biological reference points can be estimated.

In cases where discard rates at age are found to vary substantially from year to year, an assessment without discards is likely to give a rather poor representation of actual trends in recruitment to the

stock. In such cases, using a simple approach, such as assuming fixed discard rates at age for the earlier, years for which no discard data are available, will not change the perception of recruitment during these earlier years, but it will allow discard data to be used for more recent years. If the discard data are of sufficient quality, this should improve the perception of recruitment for the recent period.

The importance of including discard data for a short term forecast does not necessarily depend on a long time series of discard data, particularly for stocks with relatively few age-classes present in the population. As long as an historic assessment of the total catch can be carried out over a certain number of years, the forecast can be based on that assessment. This is likely to give more realistic estimates of recruitment and (juvenile) fishing mortality.

The collation of discard and landings data to give total catch data would benefit from the levels of precision between the two sources being to a certain extent comparable. The addition of discard data with a very high variance to landings data which is relatively precise, could potentially make it difficult to trace year-class or length-class effects through the population.

The main species which suffer high discard rates (in temperate waters) are: haddock, whiting, plaice, *Nephrops*, and hake. Other species may include mackerel and cod (depending on the growth rate). For some stocks of these species, discard data have already been used historically.

Many stock assessment which are currently being carried out within e.g. ICES, are based on single stocks. Within that context the use of discards data would focus on delivering estimates of total number of discards by year. However, there appears to be a clear tendency towards more fishery-based assessments. This is mainly evident from the development of mixed fisheries models that try to model the short term effects of different management options on the developments of different fleets or fisheries and their implied effects on stocks (STECF 2002; Vinther *et a*l, 2003). Within a mixed fisheries framework, the use of discard data would be most useful when the data are available by stratum (e.g. gear/area) and when it includes discards on both target and non-target species.

The survival rate of discards has been investigated by several authors (e.g. Jean, 1963; van Beek *et al*, 1998) and was generally found to be low. However, for species or stocks where the survival rate can be demonstrated to be relatively large, this should be incorporated into the estimation of the total catch.

The requirements for discards data for different types of assessment models can be summarized as follows:

- Age based assessment models: discards numbers at age and discards weight at age (e.g. plaice, haddock)
- Length based assessment models: discards numbers at length and discards weight at length (e.g. Nephrops)
- Biomass based assessment models: discards biomass (e.g. tuna).

Estimates of discards by fleet might also be used in estimating CPUE data for use in any of these methods.

In conclusion, the group notes that it is desirable that substantial analyses to be carried out before (short) data-series can be used in stock assessment. This work should focus on modelling of historic discard patterns and on estimating recent discard patterns by fishery (stratum). The latter is of prime importance for mixed fishery models which are become increasingly important for the biological advice to the different management authorities. Once this step has been taken, the group considers that progress will have been made towards a more realistic appraisal of developments in the North East Atlantic fisheries.

3 SAMPLING AND ANALYSIS GUIDELINES

A sub-group met to consider terms of reference:

b) Review the sampling strategy and methods in established discard sampling programmes and develop guidelines to minimise bias and maximise precision

c) Identify raising procedures that minimise the bias and maximise the precision of estimates taking into account the sampling procedure and the use of the data

The sub-group noted that most established discard sampling programmes are based on some form of stratified sampling. The bias and precision of the resulting discard estimates depends on things such as the

- number of strata
- sampling effort per stratum
- method of selecting samples (e.g. random, quasi-random, convenience)
- variability in the data (within and between strata)
- estimator used (including the choice of raising procedure)

The performance of a few sampling programmes have been evaluated in various reports (some of which are summarised in Section 3.1). However, these programmes are quite diverse, apply to different types of fisheries, and have reported their results in different ways. Although these evaluations can guide discussion on appropriate sampling strategies and methodologies, they are insufficient on their own to provide general guidelines.

The sub-group considered that the results from a wider range of discard programmes are necessary to provide generic advice. In particular, the discard data collected under the Data Collection Regulation could be used to provide variance estimates and other summary statistics to:

- assess current levels of precision
- compare alternative raising procedures
- identify logistic and methodological problems associated with current sampling strategies

In addition, the data would allow an exploration of alternative sampling strategies (e.g. different choice of strata, sampling allocations) that would demonstrate the levels of precision that might be achievable for different levels of sampling (and at different costs).

Section 3.1 summarises the experience from several established discard programmes. Section 3.2 describes the summary information that could usefully be estimated from the discard data obtained under the Data Collection Regulation. Section 3.3 describes ways of providing some quality control on the choice of samples (e.g. are trips sampled at random or ‘close to random’). Section 3.4 gives

a prototype Discard Sampling Review Form for collating the summary information described in Sections 3.2 and 3.3. The Review Form could initially be used as a tool to assess current sampling guidelines. However, a simplified Review Form might later be used as a standard reporting tool for ICES or the EU. Section 3.5 discusses the problem of unsampled strata.

3.1 Experience of established discard programmes

3.1.1 Scottish discard sampling programme

The Scottish Discard Sampling Programme is based on random stratified sampling by year, quarter, area and gear. However, the programme is over-stratified. For example, on the West of Scotland, there are ~ 20 trips per year to cover 180 strata (9 sampling areas, 5 gears and 4 quarters). This leads to problems in estimating total discards because unsampled strata need to be accounted for in some way. It also makes it difficult to estimate the precision of the programme because there is virtually no replication (i.e. more than one trip per stratum). Stratoudakis et al (1999) developed a method for collapsing the strata to estimate total discards and the precision of this estimate. For a subset of the data, they found the coefficient of variation of estimates of total species discards to be ~ 50% for the West of Scotland and ~ 25% for the North Sea (where ~ 60 trips are sampled each year). The whole time series is currently being analysed to re-estimate discards from 1978 onwards and to suggest a simplified stratification for future sampling.

3.1.2 Spanish discard sampling programmes (ICES area)

Spain has sampled discards on commercial vessels in 1987, 1988, 1993, 1994, 1997, 1999-present. Total discards have been estimated using the methods described by Trenkel (SGDBI, 2000) and Rochet et al. (2002). However, to date, levels of variability have only been assessed at the haul level. Numbers of fish discarded vary considerably from haul to haul. For example, numbers of hake discarded in the Spanish Baka Otter Trawl Mixed Fishery in ICES Divisions VIIIc and IXa had a between-haul CV of ~ 200%. Similarly, numbers of blue whiting discarded by Spanish Pair Trawl in the same area had a CV of ~ 210%. Changes in the sampling stratification had no effect on the CVs.

3.1.3 English discard sampling experiences

CEFAS Lowestoft have been sampling discards since 1994 using national and EU funds. Initially, 2 observers sampled a small set of co-operative NE coast roundfish and Nephrops trawlers. Next, observed trips were directed towards 4 gear-related strata to balance sampling better across the fleet. However, it was difficult to observe trips in every gear and quarter stratum with only 2 observers. As a result, coverage of the fleet was little better than before and variances could not be estimated. An EC project developed a sampling scheme with probability proportional to size (pps). The intention was to minimise bias by randomised sampling with large, active vessels thought to discard most given a larger probability of selection. CVs on estimates of the total numbers of fish of each species discarded or retained by the fleet varied between 25 and 50% (Cotter *et al*. 2002) The random sampling and lack of strata in this scheme were considered good because a wider range of vessels was sampled and the scheme was easy to implement. However, historic data on fishing effort used to assign sampling probabilities to vessels were not reliable. As a result, the pps scheme

was less statistically efficient than simple random sampling. Subsequently, random selection of trips without gear or area strata was used for the NE coast trawl fisheries. Since 2001, the EC Data Collection Regulation allowed extension of CEFAS sampling to fisheries around the English and Welsh coasts. Sampling is in line with the stratification scheme set out in the regulation.

3.1.4 Irish discard sampling programme

Optimum sampling levels in the Irish discard sampling programme were obtained by Borges et al. (submitted) considering cost and precision objectives simultaneously. Multistage analysis established the precision achieved in the past (1993 to 2002), and a cost function estimated the cost of the programme based on the time spent by observers in different tasks. Gear, fishing ground, targeted species and ICES Division were the main factors affecting discarding. Discarding also varied between haul, trip and vessel. The optimum sampling levels indicated that the current sampling scheme should be redesigned to sample a greater number of vessels. The analysis by fleet components, as described by the gear used, fishing ground and target species, shows high CV's (24 to 69%) in the total number of fish discarded per hour and suggests a marked increase in sampling levels. Reductions in the present budget will only imply marginal decreases in precision, although changes in cost variables can have an impact on sampling levels. On the other hand, halving the CV will imply a considerable increase in sampling and associated cost.

The results above showed that the precision levels specified in the Data Collection Regulation would not be achieved by the Irish discard sampling programme, since variability is expected to be higher for less aggregated data (e.g. species numbers at age). This highlighted the need to restructure the sampling programme and increase sampling effort. The nature of the fishing activity in Ireland and the results of Borges et al. (submitted) have changed the sampling focus of the Irish discard programme in 2003 to a fleet based approach. Twelve demersal fleets were identified in the Irish fishery for discard sampling regarding the DCR specifications, the state of the stocks and stock importance (national share of the quota). Due to other considerations, such as human resource constraints and sampling precision achieved in the past, three fleets were eliminated from the 2003 sampling effort allocation. This decision will improve the discard estimations of the remaining fleets, although increases the number of un-sampled fleets (strata) with all its data analysis implications (see Section 3.5).

3.2 Summary statistics from Data Collection Regulation discard data

Although the performance of discard sampling programmes described above can guide discussion on appropriate sampling strategies and methodologies, the data from a wider range of discard programmes are necessary to provide general guidelines. In particular, summary information about stratification, sampling levels and variability from the discard data collected under the Data Collection Regulation could be used to:

- assess current levels of precision
- compare alternative raising procedures
- identify logistical and methodological problems associated with current sampling strategies
- explore alternative sampling strategies

This Section describes the summary information that should be collated across discard programmes. In particular, summary information should be collated for two alternative raising variables: number of trips and total landings (across species). These raising variables have been selected because they have been widely used in the past and because they should be available in all discard programmes. Their performance can therefore be compared over a range of programmes. However, the sub-group noted that other raising variables might perform better and would welcome the submission of corresponding summary information.

The summary information is described for programmes based on stratified random sampling (e.g., Thompson SK, 1992, Sampling, John Wiley & Sons). Note that:

- Summary information should be provided for each stratum. A top level of stratification is specified by the Data Collection Regulation, but in practice a greater level of stratification might be used. Results should be reported at the most stratified level.
- Sampling levels should relate to the *primary sampling unit*. In random sampling, the 'fishing activity' within a stratum is divided into a number of primary sampling units, each of which has an equal probability of being observed. Usually, the primary sampling unit is the fishing trip but other possibilities include the fishing vessel or the deployment of a gill net. The definition of the primary sampling unit is necessary to avoid confusion with *secondary* sampling units such as hauls within-trips (which are not sampled at random). For simplicity, we shall talk about trips and hauls, rather than primary and secondary sampling units.
- Even though sampling is rarely truly random, the summary information should still be supplied. However, interpreting the information becomes harder as sampling becomes less random. Section 3.3 considers reasons for non-random sampling, its possible effect, and quality control checks on the selection of trips.
- Sometimes, trips have an unequal, but known, probability of selection. For example, sampling might be 'probability proportional to size'. The appropriate formulae for the summary information can be found in Thompson (1992).

Information on sampling levels

For each stratum s, we require

- the number of primary sampling units (trips) sampled
- the total number of primary sampling units (trips)

Variance information for raising by number of trips

The following information should be supplied for

- total biomass discarded across species
- total biomass discarded of each commercial species
- numbers at age discarded of each commercial species (for some age range).

For stratum s, suppose we sample n_s trips and let N_s be the total number of trips. Let d_{st} be the observed discarded quantity on trip t, $t = 1 \ldots n_s$. For example, d_{st} might be the total biomass of haddock discarded on the trip. Note that the quantities d_{st} have been raised to trip level and thus have averaged out, to a certain extent, the haul-to-haul variation in discarding within-trips.

Let

$$\bar{d}_s = \frac{1}{n_s}\sum_{t=1}^{n_s} d_{st}$$

be the sample mean discards in the stratum. Further, let

$$\sigma_s^2 = \frac{1}{n_s - 1}\sum_{t=1}^{n_s} (d_{st} - \bar{d}_s)^2$$

be the sample variance. Raising by the number of trips (assumed known), discards in stratum *s* is estimated to be

$$\hat{D}_s = N_s \bar{d}_s$$

with variance

$$\mathrm{Var}(\hat{D}_s) = \left(1 - \frac{n_s}{N_s}\right) N_s^2 \frac{\sigma_s^2}{n_s}$$

The estimate of discards across strata is then:

$$\hat{D} = \sum_s \hat{D}_s$$

with variance

$$\mathrm{Var}(\hat{D}) = \sum_s \mathrm{Var}(\hat{D}_s)$$

The appropriate summary statistics to record for each stratum would then be n_s, N_s, $\bar{d}_s$, σ_s^2.

Variance information for raising by total landings (across species)

The following information should be supplied for

- total biomass discarded across species
- total biomass discarded of each commercial species
- numbers at age discarded of each commercial species (for some age range).

Let l_{st} be the total landings (across species) on trip *t*, let $\bar{l}_s$ be the sample mean total landings and let L_s be the stratum total landings. The sample ratio is then

$$r_s = \frac{\bar{d}_s}{\bar{l}_s}$$

Discards in stratum *s* are estimated to be

$$\hat{D}_s = L_s r_s$$

and discards across strata are estimated to be

$$\hat{D} = \sum_s \hat{D}_s$$

To estimate variance, we need the quantity

$$\tau_s^2 = \frac{1}{n_s - 1}\sum_{t=1}^{n_s} (d_{st} - r_s l_{st})^2$$

Then

$$\mathrm{Var}(\hat{D}_s) = \left(1 - \frac{n_s}{N_s}\right) N_s^2 \frac{\tau_s^2}{n_s}$$

although sometimes an alternative estimator

$$\mathrm{Var}(\hat{D}_s) = \left(1 - \frac{n_s}{N_s}\right) \frac{L_s^2}{\bar{l}_s^2} \frac{\tau_s^2}{n_s}$$

is used (Thompson, 1992). The variance of $\hat{D}$ is then

$$\mathrm{Var}(\hat{D}) = \sum_s \mathrm{Var}(\hat{D}_s)$$

as before. The appropriate summary statistics to record for each stratum are now n_s, N_s, $\bar{l}_s$, L_s, r_s and τ_s^2.

Comments

The discard data could also be used to estimate species landings (at age). These estimates could be compared to those based on official reported landings and market sampling data. Such a comparison might help assess the selection of trips in the discard programme (see Section 3.3).

The formulae for estimating discards using total landings can be generalised to any raising variable.

The sub-group also made the following general observations about raising procedures:

- Raising by number of trips should give an approximately unbiased estimate of total discards
- Simulation studies by Stratoudakis et al (1999) suggest that raising by total landings will give approximately unbiased estimates of total discards provided that there are at least five samples per stratum. However, the results might not apply to fisheries markedly different to those simulated. It is also unclear what will happen when there are fewer samples per stratum.
- Raising by total landings will give biased estimates of total discards if the fleet landings are biased (e.g. due to misreporting). However, at least landings-at-age and discards-at-age will be biased in the same way.

3.3 Quality control of trip sampling procedures

Ideally, a sampling programme will give all primary sampling units (trips) a known probability of being observed. Stratified random sampling (usually) gives all sampling units within a stratum the same probability of being observed. However, other schemes such as sampling proportional to size (pps) are possible. Randomisation allows means and variances to be estimated with well-known statistical properties. In particular, stratified random and pps sampling schemes can give unbiased estimates of total discards.

However, true random sampling is rare in discard programmes. Many countries attempt random sampling but cannot observe all trips in every stratum due to lack of co-operation by the fishing industry, the small size or poor safety of vessels, or for other practical reasons. Other countries do not attempt random sampling, possibly because they see it as difficult to implement or because they deliberately target a subset of vessels for logistical reasons. Lack of randomisation produces a sample with unknown bias and statistical properties. There is therefore a need to know how closely

the actual sample of trips approximates a random sample from the stratum; i.e. is the sample 'close to random'.

In the following paragraphs, we recommend
1. a simple, standard way of obtaining a nearly-random sample of fishing trips within a stratum so far as practical constraints on sampling will permit
2. simple ways of assessing whether the actual sample of trips is substantially different from a typical random sample

Sampling proposal
All the vessels in a stratum to be sampled are listed just prior to the sampling period (quarter, year, 3-year period, etc.). It is important that the list is up-to-date since many fleets change rapidly. Vessels are drawn (selected) at random and listed in the order of drawing. The drawing is 'with-replacement'. That is, a vessel can be drawn more than once, in which case more than one trip may be observed during the sampling period. Observers then contact the owners of each selected vessel in the order of listing and try to arrange to sail on the next fishing trip. If necessary, the list may be extended with more vessels drawn using the same method. A note is kept of all vessels unavailable for sampling and the reasons for this. This method gives a random sample of all fishing trips available for observation and provides an estimate of the fractions of the fleet that are unavailable for the different reasons. The fraction unavailable should be reported on the Discard Sampling Review Form (Section 3.4) and monitored by the appropriate authorities.

Some countries may not be able to implement this proposal because they do not maintain up-to-date lists of vessels in a fleet. Priority should be given to rectifying this situation. Poorly defined stratum membership compromises the performance of discard estimators. Strata should be designed so that their definitions are expected to be stable over the proposed sampling period.

Discard sampling assessment proposal
The sample of trips observed during a sampling period may be compared with (1) the sample of trips drawn but unavailable for observation, and (2) with the population of vessels in the stratum. The comparisons should be easily achievable and use readily available data. For example, comparisons could be made using histograms or descriptive statistics of fishing hours, days at sea per trip, and/or vessel lengths. The results could usefully appear on the Discards Sampling Review Form (Section 3.4). Notable differences should be carefully considered to assess whether bias might have been caused either by the sampling method, or by the nature of the unavailable fraction of the population. Testing for statistically significant differences between the sample trips, the unavailable trips, and the population is not recommended.

3.4 Discard Sampling Review Form

This section presents a prototype form for collating:
- general information about each discard programme
- summary information on stratification, sampling levels and variability (Section 3.2)
- quality control information about the choice of trips and the proportion of trips unavailable for sampling (Section 3.3)

The form builds on that developed by SGDBI. In its current form, it would be suitable as a tool to assess current sampling guidelines. Subsequently, it could be developed into a standard reporting tool for ICES or the EU.

NB The form has been constructed quickly and it should be refined and tested before being used.

Discard Sampling Review Form

General information on the sampling program

Geographic coverage (EC 2002/1639 areas)	
Participating countries/institutes	
Fleets and fisheries covered	EC 2002/1639 gear categories
Objectives	pilot, regular
Funding	Data Collection Regulation, other
Coordinator(s)	
Year	2002
Method of selecting vessels	random, quasi random, co-operative vessels only
Types of data collected	
Documentation of data (reports, publications)	
Products/dissemination	which data sent to e.g. WG
Lowest (effective) stratum level	e.g. gear (3), vessel class (2), quarter (4) Total strata sampled : 11
Potential auxiliary raising variables	Effort (trip duration, duration of hauls, soaking time, length of gear (set nets), number hooks), total landings, landings by species. Only useful if the variable is also available for the whole fleet!

Deployed sampling effort

Primary sampling unit: e.g. trip

Stratum	Number of units sampled	Total number of sampling units	Number of failures to get onboard for sampling[1)]
Stratum 1			
Stratum 2			

1) due to e.g. lack of co-operation or safety concerns

Total discard biomass[2)] estimates and achieved precision per stratum

	Raising by trip		Raising by landings[3)]			
Stratum	Average discards in stratum $\bar{d}$	Discards sample variance σ^2	Estimated ratio *r*	Variance of ratio τ^2	Average landings in sample $\bar{l}$	Total landings in stratum *L*
Stratum 1						
Stratum …						

2) total discards biomass can refer to fish + benthos or to all fish discards or to all commercial fish from the sampled trips.
3) total landings or landings for set of species used for raising

Discard biomass estimates and achieved precision per stratum for species A

	Raising by trip		Raising by landings[3)]			
Stratum	Average discards in stratum $\bar{d}$	Discards sample variance σ^2	Estimated ratio *r*	Variance of ratio τ^2	Average landings[3)] in sample $\bar{l}$	Total landings in stratum *L*
Stratum 1						
Stratum …						

Discard biomass estimates and achieved precision per stratum for species B…
Same for all species of interest

Discard numbers at age estimates and achieved precision per stratum for species A
Estimates should be provided for most important age
Age :

	Raising by trip		Raising by landings[3)]			
Stratum	Average discards in stratum $\bar{d}$	Discards sample variance σ^2	Estimated ratio *r*	Variance of ratio τ_2	Average landings[3)] in sample $\bar{l}$	Total landings in stratum *L*
Stratum 1						
Stratum …						

Discard numbers at age estimates and achieved precision per stratum for species B…
Same for all species of interest

Summary discards estimates and achieved precision per year for the given area (all strata combined)

	Raising by trip		Raising by total landings[3)]	
Quantity	Total discards	CV on total discards	Total discards	CV on total discards

Total biomass				
Biomass species A				
Biomass species B…				
Numbers age x species A				
Numbers age x species B…				

Total landings in sampled strata, national and international by species in a given year[4)]

Species	Total landings in sampled strata	National landings	International landings
Species A			
Species B…			

4) The landings covered by the sampling programme are compared to the national and international landings to assess the 'relevance' of the sampling programme

SUMMARY STATISTICS REGARDING THE QUALITY CONTROL OF THE DATA (SEE SECTION 3.3)

Sample populations and strata populations can be investigated using the following:

- Average duration of hauls or comparison of histograms
- Fishing location (maps, average location, proportion of trips per subarea, …)
- Landings composition
- Comparing raised landings from discards trips to total landings reported in national databases
- Date of trips (e.g. proportion of trips per month or quarter)

3.5 Unsampled strata

In the data regulation 1639/2001 the stratification scheme with four different vessel length groups and 10 different fishing techniques gives 40 strata, and most countries have several areas and fisheries defined according to target species potential giving a lot of strata to collect. Given the small number of observers and the number of trips that they can cover there is a high risk of empty cells in the sampling scheme.

There can be several reasons why strata are not sampled. There might be a mismatch between the number of strata and the resources available. In this case it is vital to either increase resources or revise the stratification (i.e. reduce the number of strata). Sometimes, reducing strata will mean

combining ‘similar’ strata. Alternatively, pilot studies and expert knowledge might identify fisheries with little or no discards that can be excluded from the sampling scheme.

Empty strata might also arise when skippers, or groups of skippers, refuse access to observers, when groups of vessels cannot be sampled for safety reasons, or when there are problems with sampling very long trips (i.e. Dutch freezer trawlers).

If the sampling scheme includes empty cells, decisions must be made on how to include these strata in the total discard estimate. One way is to ‘borrow’ estimates from similar strata or use a mean of all other strata. Another way would be to record the data as missing and add nothing to the total.

It is recommended that

- decisions on how to deal with missing strata are left to assessment working groups,
- discard estimates are reported to assessment groups on a stratum basis with supporting data on sampling levels etc

4; PRACTICAL ASPECTS OF SAMPLING

Section 3 is primarily concerned with the statistical aspects of discard sampling, and as such included some consideration of issues such as stratification of sampling and selection of vessels. There are also more practical, logistical issues concerned with discard sampling, and these are considered below.

4.1; Selection of strata for sampling

There are two broad reasons for stratifying sampling; for statistical and for practical reasons. Statistically, using strata which represent, e.g. groups of vessels which are similar with regard to their discard practices should result in estimates of discards which are of higher precision. From a practical perspective, it is necessary to allocate sampling effort in some way, and stratification represents a useful way of doing this.

How strata are defined depends on the objective of the sampling scheme, e.g. whether the requirement is to obtain estimates of the total discards, or discards for specific species or fisheries. It is here assumed that the primary use of the data will be for stock-assessment purposes, in which case what would be required would be annual estimates of the total discards by species, usually expressed as numbers at age. Further, reflecting both practical considerations and likely future developments towards a more fleet- or fishery-based approach to stock assessment, it is also assumed that discards will be collected to obtain estimates at a fleet or fishery level, which can then be aggregated to stock level. This requires that all fisheries with discards of the relevant stock are sampled.

Decisions about stratification will also require consideration of the amount of observer effort which is available. In general it is better to have relatively few strata so that more than one sample can be obtained from each stratum, than to have large numbers of strata, many of which are only sampled once, or not at all. Analysis of the long-running Scottish discard sampling scheme (Stratoudakis *et al,* 1999) has indicated that this scheme is over-stratified in this manner – see Section 3.1.1. It

should be noted that any stratification should also be reflected in the quantities used to raise the data to total estimates, e.g. effort or total landings.

Defining strata will typically require specific local knowledge about the fisheries in the area of interest. Co-operation with local fisher's organisations can provide a very useful source of such local knowledge. With respect to stratification by gear, the nature of the fleet will often provide a natural stratification. For instance, if half of the vessels in a particular fishery are trawlers, and the other half are gill-netters or artisanal vessels, then it would be sensible to treat these two vessel groups as separate strata. However, not all fisheries are so easy to classify in this way. In particular, vessels fishing in more northern fisheries are often trawlers which may fish with a wide range of different mesh sizes and net configurations even in the same fishery. To give one example, sampling of otter trawlers off the North East coast of England found more than 100 different net and twine configurations in 275 observed trips (Cotter, in prep). In cases such as this, further subdivision may be both difficult and inadvisable.

Any stratification by season which may be required will also depend on the nature of the fishery. If there are large changes in discarding on a relatively short time scale it may be appropriate to use a short time step (e.g. month) to reflect this. Again, this decision would require expert local knowledge on the fishery. In cases where there is little or no prior knowledge of discarding practices, results from short-term, exploratory discard sampling may be useful in determining which fisheries are most important for discarding.

There is a discussion of this issue in section 6.4 of ICES (2002; SGDBI, report ICES CM 2002/ACFM:09)

4.2; Selection of vessels

Section 3.4.1 of ICES (2000, SGDBI report, CM 2000/ACFM:11) gives a list of the possible approaches to selection of vessels for sampling, together with their advantages and disadvantages. As outlined above, we here assume that some strata have been predefined, so we are thus concerned with selecting vessels from within these strata for sampling. Section 3.3 of this report proposes an approach to selecting vessels for sampling. In practice it will normally only be possible to sample a subset of the vessels in a given stratum, due e.g. to lack of space on the vessel, or unwillingness to accept an observer. Some sampling schemes use a small subset of the vessels, so that a small number of vessels are sampled regularly (the "co-operative sampling" of ICES, 2000). However, this approach has potential problems with bias if the sampled vessels are not representative of the overall fishery. It would be possible to sample a wider range of vessels if observers were given the legal right to board vessels. The alternative approach would be to work in close co-operation with the fishing industry in order to develop trust so that more vessels becoming willing to accept an observer and the list of vessels to be sampled becomes less restricted.

4.3; Information collected at sea

There is potentially a very long list of different piece of information which could be collected by an observer on a commercial fishing trip. However, for practical reasons it is necessary to identify

which are the most important. The definition of importance will be determined by the purpose of the sampling scheme, hence here we are concerned with estimation of discards.

Many parameters are of interest concerning discard data and it is not possible to give a definitive list of variables, which should be mandatory for all discard sampling strategies. At the same time, there are parameters, which as a minimum have to be recorded so that the data are sufficient to serve as input data for assessment. For this reason the table below gives a list of variables grouped into mandatory (M) and optional (O). The definition of mandatory variables is that they are either part of the stratification (S) or that they are input data for the stock assessment (A). The assessment method may vary and this means that the list of mandatory variables will change accordingly.

The list is subdivided into trip-, haul- and gear related information in order to indicate the hierarchical grouping of the data.

The table is based on an update of the list given in the final report from the EC Project: 95/094 "On-board sampling of fish landed and discarded by commercial vessels".

TRIP			
Variable	Explanatory notes	Status (**M**andatory or **O**ptional)	Justification (**S**tratification. or **A**ssessment)
Trip code	Unique trip id (by country and year).	M	S
Stratum code	Identifies which stratum the trip belongs to	M	S
Vessel code	Unique vessel id (by country).	M	S
Type of vessel	E.g. beamer, trawler, long liner gill-netter.	M	S
Engine power	Horse power or Kwats.	M	S
Vessel length	Overall length of the fishing vessel.	M	S
Capacity of fish basket or box	If necessary in order to be able to estimate total weight of catch.	O	(A)
Port, date & time of departure		M	S
Port, date & time of arrival		M	S
Port of discharge	If catch not unloaded at port of arrival.	O	(S)
Target species and sizes	Intended catch and sizes.	O	S
Other notes	General trip objectives and restrictions on fishing (e.g. filled catch quotas, poor market values and other factors affecting outcome of trip).	O	
Usual number of hauls per day		O	
Usual haul duration		O	
Fishing grounds	The name of the ground actually fished	O	S

	(Exact position is recorded for each haul/set).			
	HAUL/SET			
Date			M	S
Haul number	Unique haul id (by trip).		M	S
Gear code	Gear id. Key parameters for gear description.		M	S
Shooting time			M	S
Shooting depth			M	S
Shooting position			M	S
Hauling time			M	S
Hauling depth			M	S
Hauling position			M	S
Fishing duration	The time between the gear has start and stopped fishing.		M	A
Gear damage	Indication of any deviation from normal.		M	A
Crew shift (if not always the same)	Recording of change in discard pattern.		O	
Sea state, wind speed and direction			O	
Quantities of catch, discard, and retained fish on all sample levels relevant for estimation of total catch by species.	All weight information by species for each set of sub-samples necessary for raising from sub-sample level to total catch.		M	A
Total quantities of benthos ,weed, rubbish etc			O	A
Length information	Length distribution of all relevant species with indication of measuring units.		M	A
Mean weight	Information on mean weight by length group. At least for assessment relevant species.		O	A
Age information	Age determination of otoliths or scales etc. for all assessment relevant species.		M	A
Factors affecting stowage of fish	E.g. quota restrictions, fish-hold full, low value etc.		O	
Other notes			O	
	GEAR			
Gear code	Gear id. Key parameter to the haul/set description.		M	S
Gear characteristics	Type of gear (demersal trawl, mid water trawl, gill net, trammel net etc.) mesh sizes in codend/netting, indication of selection panel.		M	S
Additional gear characteristics	E.g. tickler chains, mean and s.d. of measured mesh sizes, codend rig, as appropriate for each gear type.		O	

Many of the parameters given in the above table may be important in some sampling schemes but not others, and hence are described as optional. It is also useful to distinguish between those parameters which are essential for their use, e.g. in defining strata or estimating total quantities, and other parameters which may be useful in interpreting or analysing data but are less important for the primary purpose of estimating totals discarded.

For stock assessment purposes what is required is relatively detailed information (e.g. length and age information) for those species subject to routine assessments, and this requirement is reflected in the above table. For studies of the broader ecosystem effects of fishing, information would also be required on the other components of the catch/discards, both of non-commercial fish species and other fauna. This is also reflected in the above table to a certain extent although the collection of information on benthos etc. is suggested as an optional, rather than mandatory parameter. As a general point it is desirable to obtain as detailed information as possible for a subset of the hauls during a trip, than to obtain incomplete information for all hauls. If some hauls are not sampled, it will of course also be necessary to record this in order that the data from the sampled hauls can be raised to the trip total.

4.4; Self-sampling

'Self-sampling' refers to discard sampling programmes in which the fishers take samples of their own catches. Such programmes have been used in France, England, and elsewhere. Potential problems with this method concern whether fishers may take a representative sample of the catch. For this reason it is desirable to cross-check data obtained using this method with observer data. There may also be legal problems associated with retaining discards on board. Nevertheless, self-sampling provides the only method of sampling certain vessels, e.g. very small boats, unsafe vessels. It may also be useful for small-scale fisheries which are not sufficiently important to justify sending an observer to sea, e.g. potters, small scale net fisheries, etc.

5; ADDITIONAL INFORMATION ON SAMPLING SCHEMES

Many of the existing discard sampling schemes in Europe have been previously described in the Reports listed in Section 1.4, notable in SGDBI 2000. This is not true of all existing discard schemes however, so some additional schemes are described in this Section.

5.1; Recent discard sampling programs carried out in the Italian seas

Small pelagic fishery. Within the framework of the EU project 97/065 “Discards from the Adriatic small pelagic fishery” the occurrence of discarding at sea of sardines caught by the Italian fleet in the Adriatic Sea was investigated, using data and samples collected by an observer on board of the fishing vessels. Data were analysed by regression tree models and estimated discards were added to the landings. Discards were calculated for the period 1987-1999, as their values were thought negligible before 1987. Stock assessment on the time series 1975-1999, with and without discard correction, was carried out by means of the population dynamics method VPA.

Rapido trawl fishery. Within the EU Study contract n. 99/051 "Study on the mixed-species catches of the *rapido* trawl fishery along the Italian coasts" (2000-02) data on fishing areas, landings, fishing effort, fishing yields and composition of the retained and discarded catch, as well as the size composition of the target *(S. vulgaris*) and the most relevant commercial species were collected in northern Adriatic, eastern Ligurian Sea and central Tyrrhenian Sea. Data collection plan included sampling of landings and fishing effort and observations on board of commercial vessels at 20-day intervals. Catch of each haul was analysed according to the commercial categories adopted by the fishermen of each area: target species, "kept" by-catch and discarded by-catch; this last fraction was further subdivided in "commercial" and "non commercial" species. Occurrence and composition of debris (dead shells, stones, etc.) was also registered. Number and total weight were recorded for each species as well as the individual size of *S. vulgaris* and of the most relevant commercial species. Abundance and biomass were standardised as number of individuals/km^2 and kg/km^2. Ecological Use Efficiency, Stock Use Efficiency indices and discard (kg) produced for one kg of retained biomass were calculated as different approaches to evaluate the ecological impact produced by rapido trawling.

Small-scale fisheries. Data on discards of small-scale fisheries were collected in the framework of a 2-year project funded by the Italian Government (1999-2000) and carried out in northern Adriatic and eastern Ligurian Sea. Weekly sampling was performed at the main mooring sites to record amounts and composition of landings, technical features of gears, fishing time, grounds and effort. At the same time, periodic observations aboard of commercial vessels were carried out to investigate composition of retained and discarded catch, as well as demography and biological parameters of target species. The catch was subdivided in target species, kept by-catch, discard of commercial species (discard C) and non commercial species (discard NC). Catch data were standardised as number of individuals and biomass caught in 1 hour and by 5000 m of gear. The importance of discard on catches was assessed using the Ecological Use Efficiency (EUE) and the Stock Use Efficiency (SUE) indexes.

Bottom trawling. Many projects specifically addressed to discard of bottom trawling were carried out in the last decade, in collaboration with other countries institutes; most were funded by EU.

All the projects collected data by direct observations of researchers during habitual fishing trips. Data collection included sampling on board commercial trawlers, examination of the discard samples in the laboratory, and data on the trawl fleets and landings in the study ports.
Trawl discards can include non-commercial species, but also marketed species, depending on size.
The results showed that discards were fairly relevant, with high variability, values ranging, on average, from 25% to 35% of the total biomass caught. In general, about half or more of the discard is made by no-marketable species. Gear, depth, season and fishing grounds were the main factors affecting discarding, but variations could depend on market demand and commercialisation as well.
The results of some of these projects were presented to the FAO-GFCM (General Fisheries Commission for the Mediterranean), Sub-Committee of Stock Assessment. Based on these results GFCM recommended the inclusion of discards in the assessments submitted to the SCSA.
During 2003 two national pilot projects are being carried out along the Italian seas according to the EC regulations 1543/00 and 1639/01 to assess discard of the target species by management unit. Expected results are:

- total estimated weight discard by fishery management and year
- discard length distribution by fishery management and year
- discarding size by target species

6; RECOMMENDATIONS

The Workshop recommends that
a) the Discard Sampling Review Form should be tested and refined
b) the Discard Sampling Review Form should be completed for as many discard sampling programmes as possible
c) the information in the Discard Sampling Review Forms should be collated and used to:

- assess current levels of precision of discard estimates
- compare alternative raising procedures, particularly number of trips and total landings
- identify logistic and methodological problems associated with current sampling strategies
- explore the effect of alternative stratifications, sampling levels, etc on the precision of discard estimates and the corresponding cost of obtaining them
- produce guidelines for sampling and raising that might be generally applicable across a wide range of programmes.

7; WORKING DOCUMENTS AND PRESENTATIONS

The following material was available to the Workshop in the form of Working Documents or Presentations

L. Borges; Optimum sampling levels in discard sampling programmes.

A. Carbonnell; Spanish Mediterranean sampling discard programs trawl fleets.

N Cingolani, G Kirkwood, G Arneri, A Santojanni, A Belardinelli, A Giannetti, G Colella, S Donato & C Barry; Discards from the Adriatic small pelagic fishery (EU Project 97/065)

J Cotter; Analysis and modelling of the trawl fisheries off the NE coast of England

B Couperus & M Pastoors; Dutch discards sampling; pelagic freezer trawlers

G Fabi & F Grati; Monitoring of discarding and retention by common sole gillnet fishery in the Adriatic sea.

G Fabi & F Grati; Monitoring of discarding and retention by Rapido trawl fishery in the Adriatic sea.

R. Fryer; The Scottish discard sampling scheme

P. Martin; Estimation of trawl discards in the western Mediterranean. European hake (*Merluccius merluccius*) as case study.

N Pérez & J Bellido; Summary of discard sampling, Spanish protocol (ICES area, IEO) to meet requirements from EU sampling fishery program.

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