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Final Report
Evaluation of the state of knowledge concerning discard practices in European fisheries

Portugal
September 2000

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Megapesca Lda.

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Preface

In 1999 the Directorate General for Fisheries of the European Commission contracted consultants Megapesca Lda of Portugal to undertake a study describing the current state of knowledge concerning the problem of discards in European fisheries.

The objective of the study was to collate and present the results of recent research on discarding practices in the European Union fishing industry. This is the Final Report of the study and it provides an overview of previous and current research on discards, covering both studies to quantify discards, and those studies designed to improve understanding of the reasons for and impact of discarding. The report finishes with a discussion on ways in which discarding can be reduced or eliminated, and considers both regulatory approaches, and the drive for more selective fishing methods.

In terms of the geographical scope of the report, we have focused mainly on EU fisheries. However, we have included in the text a number of examples drawn from the Norwegian experiences with discard management. This is not only because of their usefulness, but also because many EU vessels fish in Norwegian waters under reciprocal access arrangements, and are therefore subject to these policies. Discards experience in other regions is also addressed, with a brief summary provided in Annex 1.

Throughout the report we have used examples drawn from the research studies reviewed to illustrate some of the most important points. We have written the report in a way which is accessible to non-technical readers, and we have attempted to minimise the need for specialised terminology. Where this unavoidable, clear definitions are given.

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Glossary

Target Catch	The intended catch of fishing activity in terms of species or group of species
Incidental Catch	Retained catch of non-targeted species.
Discarded Catch	That portion of the catch returned to the sea as a result of economic, legal, or other considerations
By-catch	Discarded catch plus incidental catch.
Discard Rate	The proportion of total catch which is discarded
Fishing Effort	The amount of fishing activity measured by numbers of vessels, power, tonnage, hours fished and skill of fishers
Black fish	Fish which is retained on board in contravention of fisheries management regulations

1 Introduction

1.1 Background

Discarding is the practice of returning to the water fish which have been caught by a fishing operation. This report provides an overview of our current knowledge of discards, the extent to which they occur and why, and shows how a better understanding can help design new approaches to reducing or even eliminating their occurrence.

Many EU fisheries, particularly trawl fisheries, are characterised by high discard rates of unwanted fish, and of juvenile or undersized commercial species. Discards represent production and yield forgone, or future economic losses to the fisheries. There is also growing evidence that intensive fishing with poorly selective gears may alter the habitat, and affect bio-diversity, community structure, species composition and abundance, of both target species of fish, and of other species within the food web. For these reasons the practice of discarding in fisheries is generally perceived as a problem that should be eliminated or reduced.

The importance of the by-catch and discarding problem is reflected in international laws and agreements[1,2] that include relevant provisions and recommendations. The issue of discarding has been discussed in many international fora, including the UN General Assembly, which passed resolutions in 1994 calling for a more sustainable use of marine resources. The UN Commission on Sustainable Development again addressed the issue at its last session in April 1999, as have many other recent symposia[3].

Discarding is a significant problem in European fisheries. In 1992 the European Commission reported to the Council on the Discarding of Fish in Community Waters, (CEC(92)). The report concluded that:

> "*The problem of discards is of such importance and its repercussions of such gravity that drastic solutions must be sought now*"

and called for imagination in finding remedies, stating that:

> "*The search for solutions will only be possible if all forms of and reasons for discards are considered.*"

Reduction of the level of discards is expected to lead to lower environmental impacts of fishing, and improved profitability. However the search for policy and technical solutions to the discard problem is only possible with knowledge of the causes,

[1] United nations Agreement for the implementation of the provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 Relating to the Conservation and management of Straddling Fish Stocks and Highly Migratory Fish Stocks
[2] FAO Code for Responsible Fisheries, FAO, Rome 1995
[3] For example, Castro et al. 1996, University of Alaska Fairbanks, 1996, 1997, FAO 1997, Symposium on Ecosystem Effects of Fishing (Montpellier, France) 1999).

impacts and motivations of those involved, and this knowledge can only come from research.

1.2 EU funding for discards research

Research provides information on which to base better policies in the future. At present there is no single continuous EU-wide research programme on discards in operation. However discard-related research has featured prominently in projects selected for funding, and has focused on the following issues:

- quantification of discard volumes and rates to enable the dimensions of the problem to be defined
- quantification of discards of specific interest e.g marine mammals and sharks
- motivation and reasons for discarding in the major fisheries in the main EU fishing areas
- experimental studies to assess the impact of discard reduction measures

The European Commission currently operates two major research programmes which cover work in the areas of discards including by-catch, gear selectivity and multi-species interaction; the Biological Studies Programme and the 5th Framework Programme (replacing the successive FAIR, AIR and FAR Programmes).

The Biological Studies Programme (1994-98) has funded approximately 200 studies covering research into fisheries biology, economics and technical issues. Over this period around 50 of these studies have been aimed at or related to the issues of discards, by-catch and selectivity. Some of these studies have involved collaboration between a number of EU Member States, and have attempted to gain a quantitative and qualitative view of discards in entire fisheries, rather than the vessels of one particular member state.

The EU FAIR Programme of Research and Technological Development (1994-98) had a total budget of €12.3 billion of which €130 million was available for fisheries research. A review of the Project Synopses Volume VI: Fisheries and Aquaculture (FAIR: 1994-98) shows that of the 106 projects listed, seven projects aimed to study discards related issues directly, and had a total budget of €7.0 million. A further seven projects conducted research into discard-related issues whilst having an alternative objective. The total budget cost for all of these studies is €11.2 million.

Furthermore, routine sampling programmes are undertaken by some Member States, to monitor discards. This happens in the UK, France, Netherlands and Ireland, but in other Member States discard data is only collected on an *ad hoc* basis.

1.3 Definition of by-catch and discards

The first comprehensive study of global by-catch and discard levels was published by the FAO in 1983[4]. It was estimated then that global discards of fish were about 6.7 million tonnes, but it was also apparent that at that time there was limited information available on discards and by-catch of fish, and virtually no data on discards of higher marine life forms, such as marine mammals, birds and turtles (FAO, 1994, pg.2).

In 1994 the FAO again evaluated the magnitude of discards, this time with considerably more information at their disposal, following the rash of studies and research report on the subject, when it was estimated that discards of fish ranged from 17.9 million to 39.5 million tonnes[5]. It was estimated that discards by weight in the North-east Atlantic and Mediterranean accounted for around 14% of the total global catch levels, equating to approximately 3.6 million tonnes. The most recent FAO estimate sets global discards at 20 million tonnes, which is equivalent to about 25% of reported annual production from capture fisheries[6].

'By-catch' was first defined in the 1983 FAO report as:

> *"that part of the gross catch which is captured incidentally to the species towards which there is directed effort"*.

Since then, there has been a proliferation not only in the number of studies and publications on these subjects, but also in the ways the terms "by-catch" and "discard" have been used.

For the purposes of this study discarded catch (or discards) is defined as:

> *"That portion of the catch returned to the sea as a result of economic, legal, or other considerations"*

1.4 Classification of different types of discard practice

Discards may be classified according to the type of impact on the ecosystem, or alternatively, based on the reasons or motivation for discarding.

A classification of by-catch impacts designed for Alaskan fisheries[7] has been adapted to a general discards classification system[8]. The resulting system produces

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4 Saila S B. Importance And Assessment Of Discards In Commercial Fisheries. FAO Fisheries Circular 765: FAO; (1983)

5 FAO Fisheries Technical Paper No. 339: 'A Global Assessment of Fisheries By-catch and Discards' FAO 1994

6 The State of World Fisheries and Aquaculture 1998, FAO, 1999

7 Hall, M. A. (1995) 'Strategic issues in managing fishery bycatches' in: Alaska Sea Grant College Program (Ed), *Solving bycatch: considerations for today and tomorrow*. Alaska Sea Grant College Program report No. 96-03, University of Alaska Fairbanks, 307-309

8 Pascoe, S. FAO Fisheries Technical Paper 339: '*A Global Assessment of Fisheries By-catch and Discards*' FAO 1994

classifications such as 'critical discards', where fish populations or species are in danger of extinction due to the level or discarding, through to 'sustainable levels of discarding' where stocks are not in danger of over-fishing or depletion as a result of the activity. The economic impact of discarding can be captured by the term 'inter-fishery discards' where discards in one fishery affect the catches of fishers in another fishery.

Discards may also be classified on the basis of the motivations of the fishers. The reasons for discarding are discussed in more detail in the next section.

2 Reasons for discarding

It is important for policy makers to understand the underlying reasons and motivations that can cause discarding. All policy measures for discard reduction will ultimately depend on fishers for their successful implementation, thus a better documented understanding of the economic and other behavioural motivations of fishers in relation to discards is required to ensure that the measures introduced are appropriate and have the desired effect.

There are many reasons why a fisher may not want to keep a fish on which he or she has spent money and effort to bring onboard. Very often there are economic reasons, but legal, technical and behavioural factors also play an important part.

2.1 Case studies on reasons for discarding

The following examples illustrate the diversity of reasons why discarding takes place. The case study fisheries in the Mediterranean and North-east Atlantic are very different in terms of scale, species and mechanisms, yet most causes of discarding fall into two main categories of reason; economic or regulatory.

In the **Mediterranean multi-species fishery** vessels are relatively small, (typically 10 to 20m in length) and fish mainly in the waters of Italy and Greece. Hundreds of medium-sized trawlers fish in depths of up to 300m and many more small vessels make day trips in coastal waters. A survey of discards in these trawl fisheries[9] found that an average of about 45% of the total catch volume is discarded; fishers were interviewed and observed in their work to identify the main reasons which are presented in Table 1.

9 "Analysis of Trawls discard operation in the Central & Eastern Mediterranean Sea", Institute of Marine Biology of Crete, Greece. (95/061) Draft Final October 1998

Explanation of discarding reason	**Type of reason**
• Fish species, or other marine life-forms, with no commercial value are discarded	Economic
• Catches of legally sized, but low value, species such as sardines and horse mackerel, may be discarded to save space and ice for more valuable target species.	Economic
• Minimum Landing Sizes (MLS) may result in discards of fish below the specified MLS; in some cases poor enforcement results in fish below MLS being landed illegally (instead of being discarded)	Regulatory

Table 1. Main reasons for discarding in the Mediterranean multi-species fishery

In the highly capitalised **North-east Atlantic Pelagic fishery** targeting mainly mackerel, herring and horse mackerel, fishing trips last around 3 to 4 weeks. The large trawl and purse-seine vessels (typically 100m in length with a crew of about 30 people) have huge storage capacity and freezing facilities. Two EU funded studies conducted in the North Sea[10,11] showed that average discards range from 16.3% (calculated from 142 hauls in the Dutch pelagic fishery) to 2.2% (calculated from 193 hauls in Scottish and Norwegian pelagic fisheries). Regulatory reasons appear to cause more discarding in northern European fisheries such as these, because quotas and TACs[12] are also in force, unlike in the Mediterranean where only MLS are imposed. Table 2 outlines the main causes of discarding.

Explanation of discarding reason	Type of reason
• Target species discarded for reasons of small size, damage, grading limitations and comparison to subsequent catches which may be valued more highly; note that small pelagic fish may also be illegally discarded after sorting by automatic grading machines used on pelagic freezers trawlers.	Economic
• By-catches of marine mammals discarded due to lack of commercial value	Economic
• Herring discarded by trawlers targeting mackerel (and vice versa) due to UK single species licences forbidding mixed species catches	Regulatory
• Horse mackerel discarded to save quota for later part of year	Regulatory

Table 2. Main reasons for discarding in the North-east Atlantic pelagic fishery

[10] Couperus, A. S., "*By-catch of marine mammals and discards in pelagic trawl fisheries (MAMDIS)*" Final Report August 1997 (94/018) DLO – Netherlands Institute for Fisheries Research

[11] North Atlantic Fisheries College "Investigation of the extent and nature of discarding from herring and mackerel Fisheries in ICES Sub-Areas IVa and VIa." Draft Final Report June 1999 (96/082)

[12] TAC: Total Allowable Catch

2.2 Economic motivation

In Europe, fishing is an economic activity: it has moved beyond being primarily a food gathering activity to being a means of generating income and profit. Fishers seek to maximise profits by generating the highest possible financial returns on a trip whilst aiming to keep the costs, particularly of processing and storage, to a minimum. Therefore, it may be argued that most decisions to discard are made based on economic considerations.

For example:

- Target species may be discarded because they are too small or below minimum landing size or damaged upon capture (perhaps as a result of being towed for too long), and so will either not be acceptable to the market, illegal or will command an uneconomic price.

- Target species which are acceptable to the market and lawfully caught may still be discarded in favour of better sized or quality individuals. This type of discarding occurs when individual quotas are allocated, and is commonly referred to as "high-grading" and results from the economic desire to land the highest value catch given the vessel's physical and legal constraints.

- Marketable non-target species which have a lower value than the target species may be discarded to reduce the workload on the crew or to preserve storage capacity required for higher priced target species.

- Non-marketable species will be discarded if there is no financial return to be generated once they are landed e.g. starfish have no commercial market value.

- At the beginning of a lengthy trip discards may occur of marketable species which do not keep well, such as shark.

Discards may therefore consist of marketable species (e.g. lower value catches) or of non-marketable fish (e.g. juveniles or species with no market). It should be noted that lack of acceptability or marketability may be a local or seasonal phenomenon; in other regions or at other times, the discarded species might be highly prized.

2.3 Discards caused by management measures

The Common Fisheries Policy (CFP) attempts to limit catches on species at conservation risk through the use of management measures such as minimum landing sizes, quotas and catch composition regulations. As fishing is a hunting activity it is often impossible to be completely certain that certain species will or will not be caught. The basic fisheries offence defined in EU regulations, is that of *retention onboard* of fish which does not comply with the regulations. Discarding is therefore an unfortunate and often unavoidable consequence of some of these management measures.

The following sections describe the circumstances in which regulatory measures can lead to significant discarding of fish.

2.3.1 Minimum landing sizes

The majority of managed fisheries include within their regulations a minimum landing size (MLS). Below this size fish may not be landed for sale and in EU waters, such undersized fish must be returned to the sea. In theory an enforced MLS will encourage fishers to concentrate their effort on adult populations of the target species, and to cease fishing if the proportion of small fish is too high. Thus the approach aims to discourage fishers from targeting concentrations of juvenile fish and from using small mesh nets.

However simple it is in theory to match a desired MLS to mesh size regulations, there are major problems with MLS as an effective management tool, especially in the case of mixed-species fisheries. There are both technical problems in linking gear selectivity to the MLS, and there is also an economic dimension. A MLS that is not well adjusted to the minimum mesh size (MMS) may result in significant discarding.

In the Irish Sea *Nephrops* fishery, for example, the MLS has been demonstrated to have little effect on fishers' behaviour, mainly due to the MLS being below the optimum size favoured by the market. The result being that the majority of small *Nephrops* caught are discarded even where they are above MLS; the smallest legal sizes are only retained when catches are poor.

It is certain that the establishment of MLS regulations for fish catches results in discards of undersized species in many fisheries, particularly in northern European waters. In areas like the Mediterranean where enforcement of MLS regulations are known to be less rigorous, and formal and informal markets for small fish exist, discards of this type occur less frequently.

In some countries active markets exist for illegally sized species, thus providing the economic incentive to retain the fish on board, rather than discard. In Portugal for example, small, juvenile horse mackerel actually demand a higher price than the large adult horse mackerel. Thus is not uncommon to find horse mackerel below the MLS of 15 cm being sold.

Similarly, a recent study on the Mediterranean swordfish fishery, showed that significant numbers of swordfish below the MLS of 120 cm were being caught and landed for sale (Regulatory discard of swordfish[13], see Box 1).

[13] De Metrio, G. (co-ordinator). 1999. Regulatory discard of swordfish (*Xiphias gladius* L.): effectiveness of the EU regulation regarding the catch minimum size of swordfish in the Mediterranean. Interim Report, Commission of the European Communities, DG XIV-C-1, Contract Nº 97/0074.

A study is currently investigating the impact of the MLS for swordfish in the Mediterranean. Preliminary findings show that nearly 75% of the sample of swordfish caught in the South Adriatic Sea were undersized. Regulation 1626/94 stipulates that the lower jaw fork length must be a minimum of 120 cm in length.

In the North Ionian Sea long-line and drift-net fishing targeting swordfish, made catches with 84% and 83% of swordfish being below the MLS respectively, whilst 100% of swordfish by-catches in the long-line fishery targeting albacore tuna were undersized.

The health status of undersized fish varied depending on the fishing area and gear used. For example, 77% of the catch of undersized swordfish fish in the South Adriatic Sea and 35% in the North Ionian Sea, Tyrrhenian Sea and Strait of Sicily, caught by long-line targeting swordfish, were found to be in a poor condition or dead when hauled onboard. Even if alive at the time of discarding, these undersized fish would be unlikely to survive. Catches were landed for sale, unless the fish were damaged.

Box 1. Regulatory discards resulting from MLS:
The Mediterranean swordfish fishery

2.3.2 Quotas

Quota arrangements and Total Allowable Catches (TACs) are the other major regulatory management measures of the Common Fisheries Policy (CFP) of the European Union. TACs are adopted annually by the Council of Ministers, and then distributed as national quotas amongst Member States, with shares being based upon the principle of relative stability. In some states quotas are then allocated to individual Producer Organisations or vessels. As with fishing, setting quota levels is not an exact science and 'quota discarding' can occur for the following reasons:

- when more target quota species is caught than a vessel has quota for;
- target quota species may be discarded for example when prices are low, to 'save' quota for later on in the year;
- when quota species are caught but not in the appropriate area;
- marketable fish are caught, but for which quota is not held.

Although the presence of over-quota fish is regularly cited by fishers as being the principal reason for discarding fish that is suitable for human consumption, there is evidence that most fishers prefer to retain and sell marketable fish, even if this practice is illegal (so-called 'black fish').

In addition, some EU fishers have also been caught attempting to land fish illegally, by recording catches in their logbooks only when it looks as though they will be checked. This permits them to make their scarce quota last for the entire fishing period, without discarding a single marketable fish.

If quotas and reporting requirements were more strictly enforced, discard rates would certainly increase, at least in the short-term. However, in the long-term, stocks levels would be expected to improve, and profits could increase.

2.3.3 Catch composition regulations

In addition to minimum size limits and quotas for particular species, fisheries managers have also applied controls on landed catch composition, by specifying limits on the percentage of target and non-target species.

The catch composition regulation is designed to prevent fishers from targeting concentrations of small fish of certain species, on the pretext that they are fishing for other species. The regulation has been updated from initial proposals, and requires catch compositions to be recorded on a daily basis in the standard EU logbook.

In the EU, percentage composition requirements are specified in Council Regulation (EC) Nº 850/98 for mesh sizes below the largest regulatory mesh size. The rules specify the minimum percentages of target species that can be landed (as a proportion of quota species) thus attempting to limit catches of non-target quota species. The minimum percentages tend to decrease with increasing mesh size, and are highest for single species fisheries such as the industrial fisheries for sand eels. Thus for example the minimum percentage catch composition for sand eels with mesh sizes of less than 16 mm is 95% whereas for 32 to 54 mm mesh size it is only 30%.

In theory minimum percentages should also discourage the use of smaller, but legal, mesh sizes of both static and active gears. However, in the case of fisheries for valuable but small species such as deep water shrimps and Norway lobster where small mesh sizes are used, this regulation may result in significant discarding of by-catch species of commercial value and size.

Minimum mesh size regulations have been set largely on a regional basis, and not a fishery or species basis. This has lead to confusion in their application, particularly in the multi-species context. However, in conjunction with other technical measures such as the use of grids and square mesh panels, enforcing minimum percentages of target species appears to be an effective way of reducing by-catch and discards in many fisheries.

Although modern fish finding devices may help vessels to target adult fish of the desired species and size characteristics, they are not 100% reliable. Large hauls of a single species of shoaling fish such as herring or mackerel may contain juvenile fish, or a mixture of, for example, mackerel and horse mackerel. Such mixed hauls are worth less and it is common procedure in such cases to ‘slip’ the unwanted catch by emptying the net overboard rather than into the boat. These ‘slipped’ discards rarely survive.

Blame for this type of discarding can only partly be placed on quota restrictions; low market value also plays a role in these discards. In some cases fish may be ‘slipped’ in the absence of any quota regime at all, due to limits to on-board storage capacity, as well as low market values.

Research into the extent of discarding in the Scottish and Norwegian pelagic trawl and purse-seine fisheries for herring and mackerel shows that despite discarding rates being relatively low (an average discard rate of 2.2%, with the rate from trawlers being nearly twice as great as that from purse-seiners) there is a significant amount of discarding by trawlers in the mackerel fishery resulted from the 'wrong' species being caught (i.e. herring). Conversely, it is reported that fishers have been unable to target large shoals of herring due to the high mackerel by-catch (around 20%), unless fishing is being undertaken by factory trawlers which can use on-board mechanical graders to separate the unwanted portion of catch.

The reason that catches of these species have to be separated is that UK single species licences are required, forbidding the landing of mixed catches. Multi-species licences would greatly reduce discarding in this fishery and at the same time increase the vessel's efficiency and hence profitability. They would however encourage an overall higher rate of exploitation.

Source: North Atlantic Fisheries College, "Investigation of the Extent and Nature of Discarding from Herring and Mackerel Fisheries in ICES Sub-Areas IVa and Via" Draft Final Report, June 1999 (96/082)

Box 2. Discarding from Herring and Mackerel Fisheries

2.4 Overview of reasons for discarding

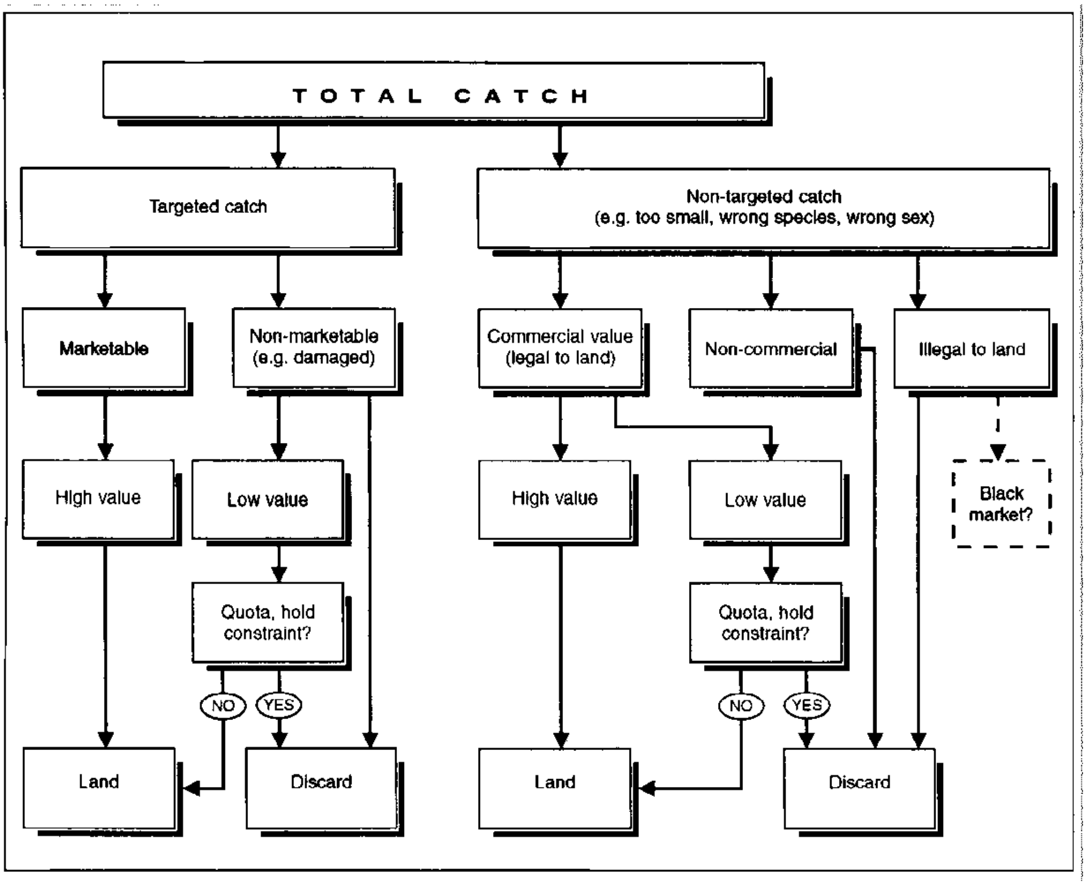
The discard decision making process has been illustrated by FAO in a flow chart as shown in Box 3.

Even when discards occur as a result of regulatory measures, it can be argued that the underlying motivation to discard is ultimately based on economic considerations, i.e. the skipper weighs up probability, costs and benefits of being caught acting illegally and acts accordingly. One should also remember that two skippers in the same fishery may act differently in the same situation, depending on their attitude to the management regime.

A recent EU funded-research study is currently underway entitled "Economic Aspects of Discarding"[14]. It will identify the economic causes of discarding, the role of regulations and evaluation of possible solutions in three EU fisheries with significant discarding problems. These are the Dutch North Sea beam trawl for flatfish, the UK whitefish and French *Nephrops* fisheries. The fisher's decision making process is to

[14] Buisman, E., J Willem de Wilde, R. Cappell, B. Caillart and G. Borel. 1997. Economic Aspects of Discarding. Interim Progress Report, June 1999-February 2000. Contract 97/SE/018 CEE DG XIV. Lead Contractor: LEI

be examined in detail to determine the most important regulatory or economic reasons bringing about discarding in each fishery.



Source: Pascoe, S. FAO Fisheries Technical Paper 339: '*A Global Assessment of Fisheries By-catch and Discards*' FAO 1994; Reproduced by permission of FAO

Box 3. Flow chart illustrating decision tree for discarding fish at sea.

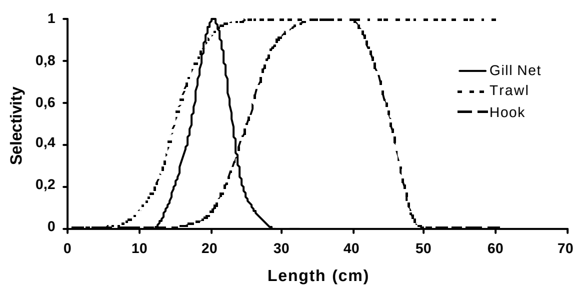
3 Discard practices in European waters

3.1 Why discards occur

The types and quantities of discards in fishing operations will depend on the species and size selectivity characteristics of the gear used in relation to the target species. Other relevant factors include the fishing grounds, the time of the year, and the fishing tactics. Because the same gear used under different circumstances may result in very different catches and thus discards, the term "métier" is often used to distinguish particular fishing operations on the basis of the above combination of factors.

Although some métiers catch a wide range of species, others can be extremely selective, with most of the catch dominated by one or a few species. For example, for all practical purposes, only one species is caught in octopus pots, and thus there is no discarding of other species. However, gears such as trawls are relatively non-selective with regards to species and consequently will catch many non-target species which may or may not be discarded.

All fishing gears are to some degree selective in terms of the sizes of a particular species which are caught. In other words the probability of capture will vary with characteristics of the fish, because of selection processes associated with the gear. Probabilities of capture of fish of different sizes with a certain gear and mesh size are obtained from selectivity curves. Selectivity curves are widely used to evaluate the impact of different gears and mesh sizes and to establish minimum landing sizes (MLS), and examples are shown in Box 4. Selectivity curves are generally bell-shaped for gears such as gill nets where a relatively narrow size range of fish are caught. Probabilities of capture decrease on either side of the optimum size, with small fish passing through the mesh and larger fish escaping after making contact with the net. For bag-type gears (trawls, dredges and seines), the probability of capture increases with size until all fish above a certain size are retained. To date there is no clear consensus on the size selectivity of hook and line gear. However, most studies have shown that hooks generally catch a wide size range, with a decrease in probability of capture at the upper end of the size spectrum. Thus hook selectivity curves are probably intermediate between the bell-shaped and logistic curves. Examples of the three types of curves are given in Box 4 and a hypothetical example showing how the size distribution of the catch is determined by the selectivity of the gear being used is shown in Box 5.



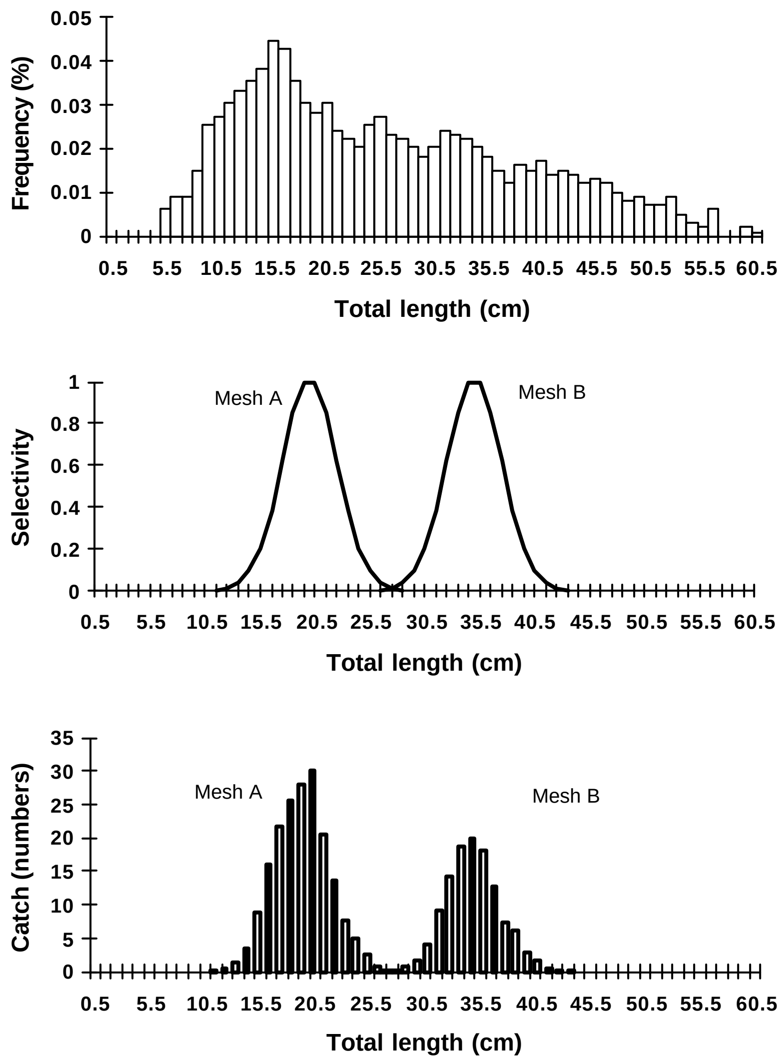
Selectivity for a given fishing gear is a factor relating catch of fish of a given size to the number of fish of that size in the population

Box 4. Example of three types of selectivity curves.

3.2 Types of fishing gear and their effect on discards

In general, fishing gears can be classified as active or static. Active gears are those which involve motion and include trawls and dredges which are towed and purse seines which surround the school of fish. Static (also known as fixed) gears are those which are anchored or fixed, and depend on the movements of the fish to come into contact with the gear. Such gears include longlines, gill nets, trammel nets, pots, and traps. Hook and line gear and traps usually require the use of natural bait as an attractant.

The following sections give a brief review of the main fishing gears and their selectivity.



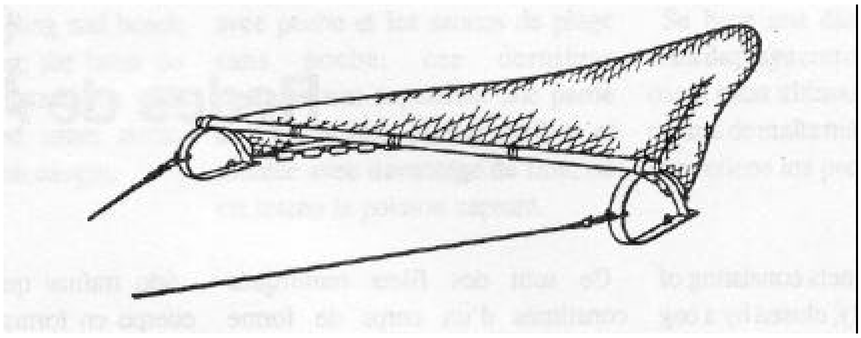
Upper: a hypothetical fish size distribution, middle: selectivity curves for two mesh sizes of gill nets, lower: the resulting catch size distributions of the two mesh sizes.

Box 5. Illustration of size selectivity.

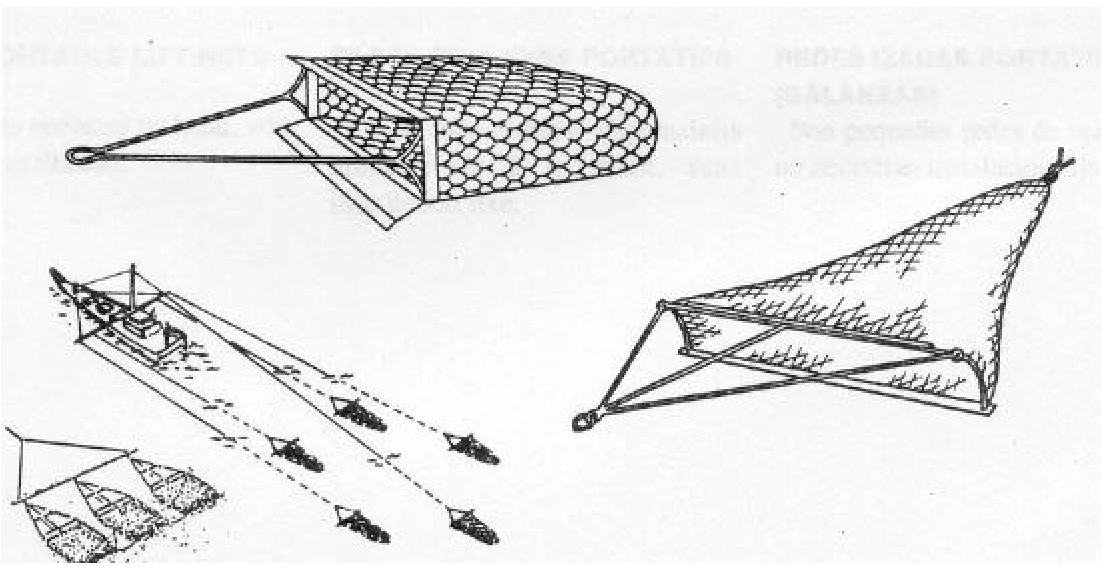
3.2.1 Trawls and dredges

Trawls and dredges are active gears towed by one or a pair of fishing vessels. Trawls are sac-like nets that are towed by one or a pair of fishing vessels along the bottom or in the water column. The otter trawl is kept open by a pair of heavy metal doors in front of the net that also herd fish towards the opening and into the net where they fall back into the cod-end after tiring. In contrast, beam trawls rely on a heavy (10 mt or more) metal structure to keep the net open as it is towed fast over the bottom. Both types of trawls use chains and other devices at the front of the net to force the fish off the bottom and over the edge of the net at the opening. Vertical opening of the net is achieved by means of floats.

Various types of trawls are used to target demersal[15] species from relatively shallow inshore waters to depths of more than 1000 m, as well as schooling or pelagic species in the water column. Towing speed and the height and width of the opening of the trawl are important factors affecting catch composition and discards. Size selectivity is also a function of the mesh size used in the cod-end, which is regulated by law in all EU fisheries. However, because of their nature, trawls and dredges have low selectivity for demersal species.



Box 6. Example of a trawl (otter or beam).

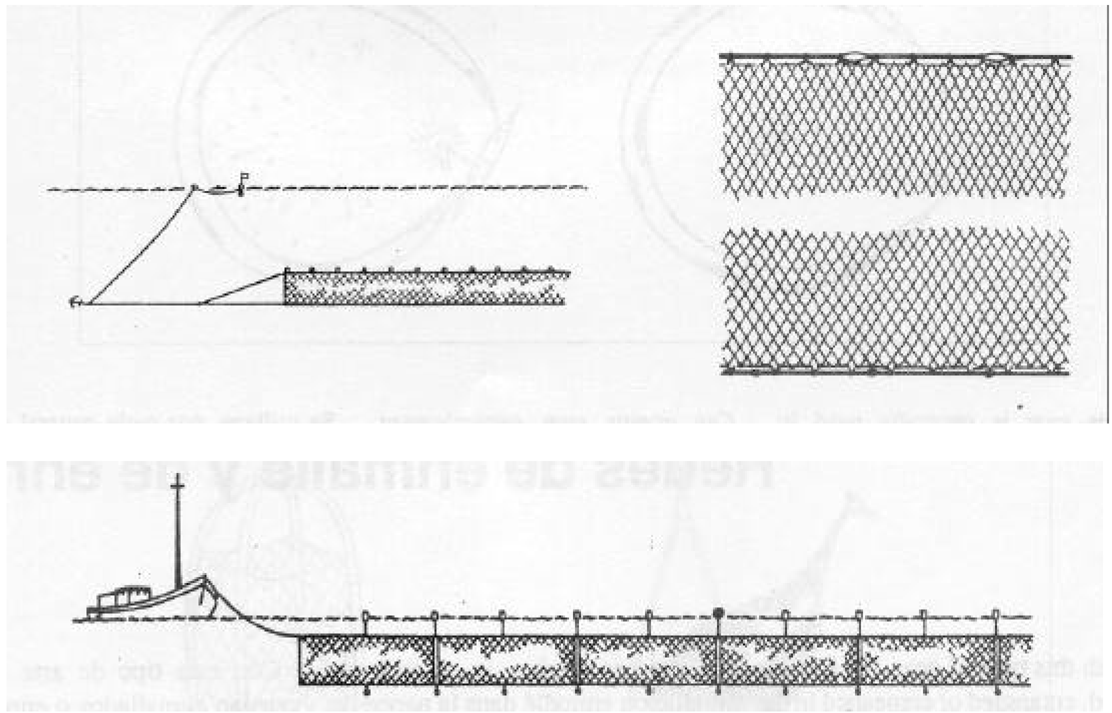


Box 7. Examples of dredges.

[15] bottom dwelling

3.2.2 Gill nets

Gill nets are single sheets of netting, usually mono-filament, with a weighted footrope and a headrope with floats. The net is usually anchored on the bottom to catch demersal and benthic fish. However, many variations exist, including pelagic or drift gill nets which fish at the surface, and encircling or 'run-around' gill nets which are set around schools of fish and act partly in the manner of purse seines. Gill nets are generally considered to be highly selective in that, depending on the mesh size and the tautness of the netting, a very precisely defined size range of target species is caught. They may, however, catch or entangle other fish and animals. Some gillnets are capable of incidentally entangling large numbers of crustaceans such as crabs. These are often destroyed, as this is the only practicable way of removing them from the nets. Regulations exist to prevent the misuse of these nets in targeting crustaceans, limiting the by-catch that can be landed, or prohibiting the landing of, for example, crab claws.



Box 8. Example of a gill net.

3.2.3 Trammel nets

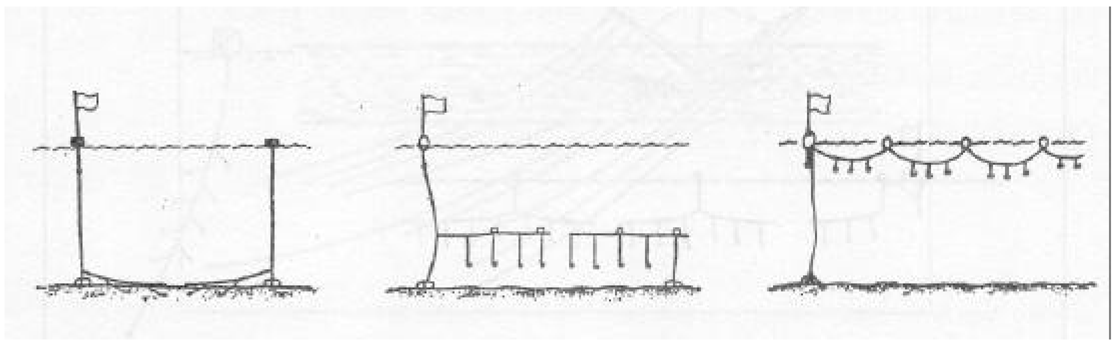
Trammel nets consists of three sheets of netting: an inner small mesh panel (e.g. 80 mm stretched mesh) between two large mesh outer panels (e.g. 140 mm stretched mesh). Whilst some fish may be gilled or wedged in the smaller mesh netting, larger fish will push the small mesh netting through the larger mesh, forming a pocket in which they are tangled. Trammel nets are widely used for species of flatfishes, sea breams and cuttlefish. In comparison with gill nets, trammel nets are considered less selective because of the different ways that fish are caught (wedged, gilled or entangled).

3.2.4 Tangle nets

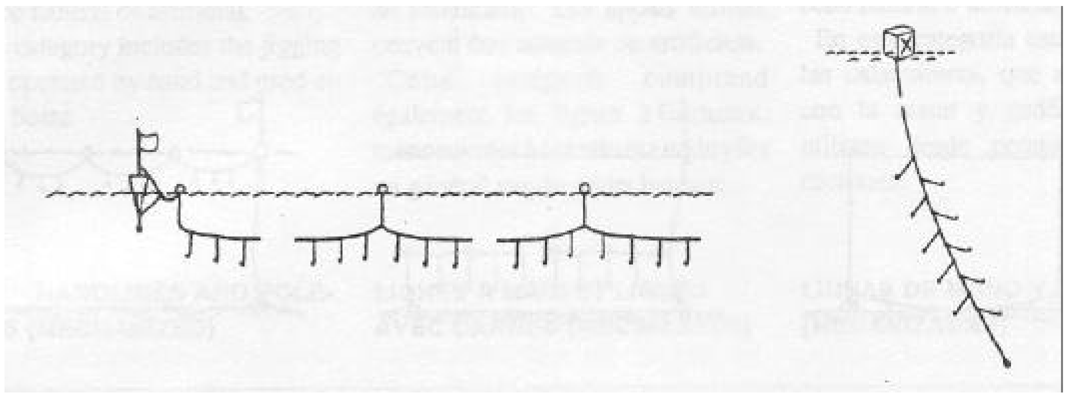
Tangle nets are large mesh nets (single sheet of netting) which have little or no buoyancy in the floatline. The target species are monkfish, and crustaceans (lobsters and crabs). Soak time (ie. the time between death of the fish and bringing it on board) in some fisheries, particularly those in deep water may be several days, resulting in significant discarding due to spoilage and scavenging of the catch. Little is known of the size selection of tangle nets, but because of the method of capture (entanglement) it is to be expected that this gear is undoubtedly less size selective than either gill nets or trammel nets.

3.2.5 Baited hook and line gear

Baited hook and line gear includes handlines, electric reels for fishing in deep water and longlines. In the case of handlines and electric reels, the terminal tackle consists of a lead weight and a small number of hooks, usually not more than six. Longlines consist of a mainline to which are attached branch lines at regular intervals with hooks. Different types of longline exist; bottom, semi-pelagic, vertical and pelagic. Bottom longlines target demersal species such as sea bream and cod. The semi-pelagic longline has floats which lift the mainline off the bottom, and is used for species such as hake. Vertical longlines are often used for very deep water species, whilst pelagic or drifting longlines are mainly used to target large pelagic fish (tunas, sharks and billfish) with hooks suspended in the water column. Generally speaking longlines and other hook and line gear can be made quite selective for both species and size by adjusting their location, hook and bait characteristics.



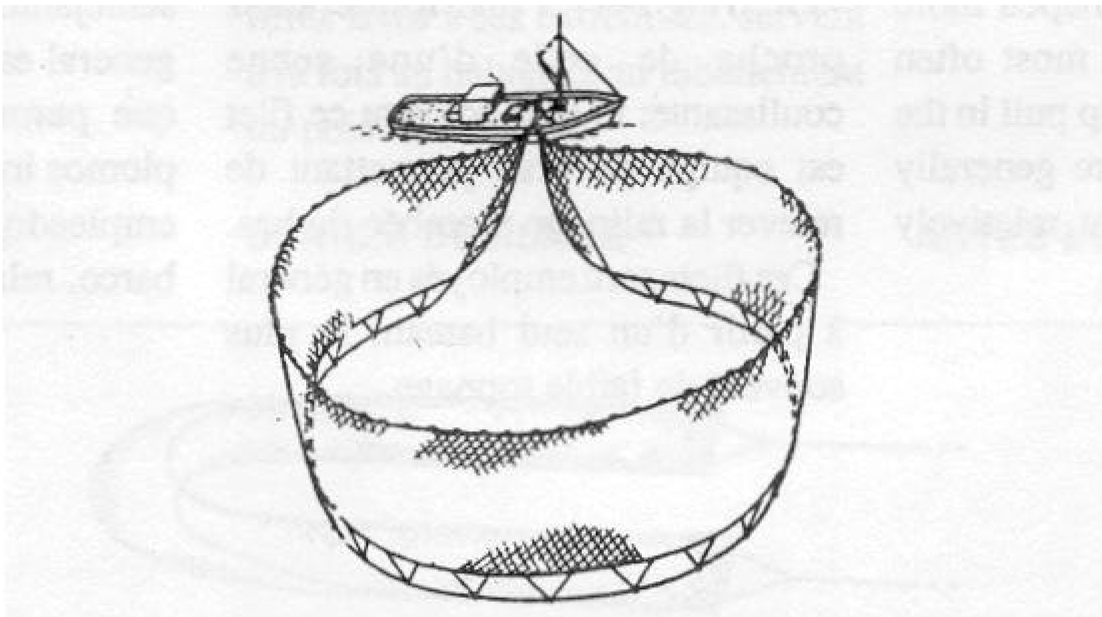
Box 9. Example of a fixed longline.



Box 10. Example of a pelagic longline.

3.2.6 Purse seine

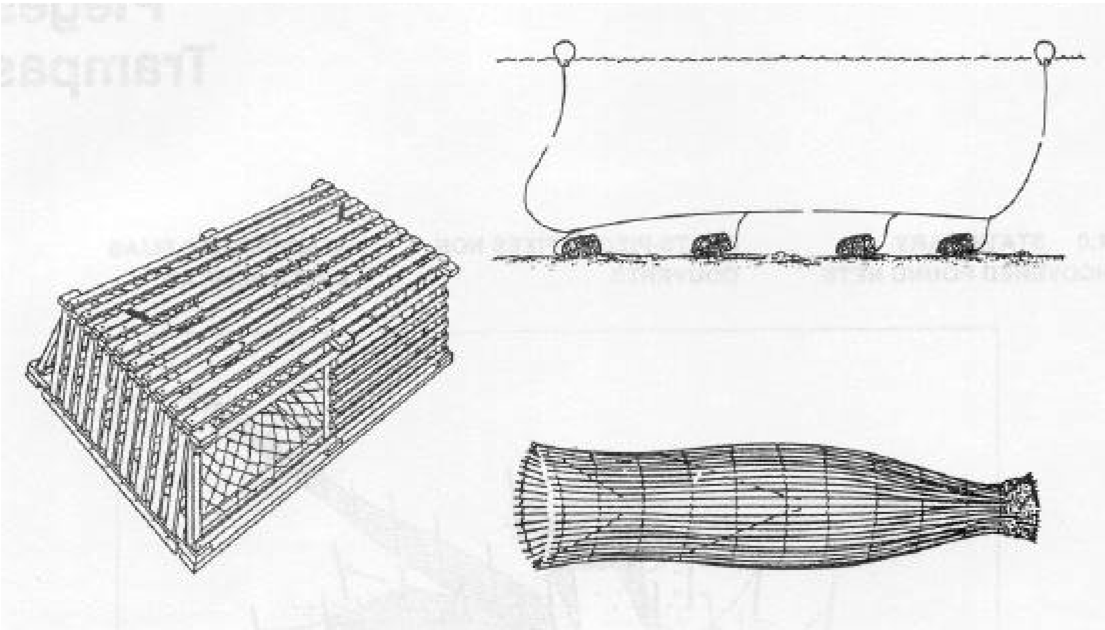
A purse seine is an active encircling gear, supported by floats, which is used to catch schooling fish in the upper part of the water column. The depth and length of the net can be considerable, more than 100 m deep and 500 m long in the case of large tuna purse seiners. Once the net has been set around the school, the net is 'pursed', closing the bottom as the net is hauled and trapping the fish. Whereas most purse seining is an open water activity targeting pelagic species, in some areas purse seines have been adapted to fish demersal species. Because they target schooling fish, which by definition tend to relatively homogeneous groups, the gear is quite selective for species, but not necessarily in terms of size.



Box 11. Example of a purse seine.

3.2.7 Traps and pots

Traps and pots are static capture gears which may or may not use bait as an attractant. Many different types of traps exist, with the design and size usually dependent on local custom, target species and available construction materials. Traps have one or more openings and chambers in which the catch remains until the gear is hauled. The fish, crustaceans or molluscs may escape back out through the opening or, if small enough, through the netting, or between the slats making up the sides and top of the trap. These gears are generally thought to be highly selective.



Box 12. Examples of fish traps.

3.3 Discards in different EU waters

Discards in EU waters vary considerably in terms of species composition, quantities, sizes and reasons for discarding. A summary of known information on discards in EU waters is provided in Table 3.

Target Fishery				**Discards**			**Comments**
Area	**Fishing method**	**Species**	**Average Annual catch**	**Species**	**Average discard ratio**	**Estimated annual quantity**	
IV bc	Beam Trawl	Sole, dab, turbot, brill, plaice	120,000t	Plaice/Dab/ Gurnard/ Invertebrates	Fish 83%	1976-90 study: 100,000t fish, 170,000t invertebrates/ debris	Discarding in sole fishery (80mm cod ends) much greater than in plaice fishery. Both species overlap. Plaice is discarded if undersize. Dab is also discarded if market conditions are poor. Gurnard is discarded due to very poor market conditions and no market exists for inedible invertebrates.
IV	Demersal Trawl	Haddock/ Cod/Whiting	80,000t Haddock, 40,000t Whiting, 100,000t Cod	Haddock/ Whiting	Haddock 76% Whiting 80%	1993 study: total 131,000t: Haddock 61,000t Whiting 32,000t	Different discard patterns for twin rig, single rig, pair trawls. Haddock fishery particularly reliant on incoming year class. Haddock are discarded if below MLS. Some whiting are also discarded above MLS due to poor market conditions.
VII/VIII	Demersal Trawl	Hake/ megrim /monk	15,000t Megrim 40,000t Hake	Hake/Megrim	Megrim: 40% by number 20% by weight Hake: 20% by number 5% by weight	1998 study: Megrim 3,000t Hake 2,000t	Discards include fish above MLS. Although discard rate has declined from much higher levels in recent years, discarding of juvenile hake in the Bay of Biscay is still high.
VII/VI /IV	Demersal Trawl	Nephrops	50,000t *Nephrops*	*Nephrops*/ Cod/Whiting/Dab Hake in Area VII	1996 study: *Nephrops 27%* 1990-96 study: *Nephrops*, Whiting, Dab 20-48%	*Nephrops* 13,500t	Discard rate varies widely between areas. Marketable *Nephrops* can be discarded due to processing pressures. Introduction of square mesh panels has reduced discards of gadoids which are below MLS.

Ivbc	Beam Trawl/ Shrimp Trawl	Crangon	14,000t	*Crangon/* Plaice / Sole/ Cod / Whiting	1996 study of potential lost annual landings: between 9,350t and 25,750t marketable fish	Total potential economic cost of discards to other vessels estimated at €25m per annum.	Elimination of discards or closure of fishery would allow Plaice quota increase of c12,000 tonnes. Discard ratio varies widely between areas. Majority of discards are due to undersize, though some whiting are discarded above MLS due to poor market conditions.
VII Celtic Sea	Gill net	Hake	300t	Catch of protected harbour porpoise	N/a	6% of local population pa, 100,000 in harbour waters but populations highly localised	Effort has halved since 1994. Research underway to evaluate use of Acoustic Avoidance Devices. Public perception of acceptability and lack of markets cause discards.
NE Atlantic	Bottom trawl	Roundnose grenadier	13,352t in 1996	50 species	90%	11,921 t	Deepwater fishery, 60 trawlers Deepwater productivity low, ecosystem particularly sensitive. On average, 24% by weight of the target species is discarded due to small size. Most of the other 50 discarded species are not marketable.
NE Atlantic	Bottom trawl	Nephrops and shrimp	5,543t in 1996	Torpedo ray, dogfish, conger eel, boar fish, hake	1996-97 study: 83%	35,000t in 1996	Deepwater fishery, south coast of Portugal. Discard species have no value (boar fish, dogfish, torpedo ray) or are of small size (hake, conger eel).
Greece	Otter trawl	Hake, sea breams, flatfish, shrimp	20,000t	Hake, red pandora, shrimp	1996-97 study: 40-50%	8,000-10,000t	Discarded hake are mainly of small size or damaged. Most other discards are of low or no value.
Ionian Sea	Bottom trawl	Demersal species	No data	29 species unmarketable, 35 discarded when undersized	1992-93 study: 45-47%		Essentially no difference in discard rates between small inshore and larger deep water trawlers. Discards due to mixture of undersize and lack of market.

Table 3. Impact indices for EU waters

Sources: Based on data abstracted from the following references:

1. ICES AFCM/ACME 1998. Report of the Working Group on Ecosystem Effects of Fishing Activities. ICES CM 1998/ACFM/ACME:1 Ref.:E.
2. Beek, F.A. van 1998. Discarding in the Dutch beam trawl fishery. ICES CM 1998/BB:5.
3. Morizur, Y., N. Treganza, H. Heessen, S. Berrow, and S. Pouvreau. 1996. By-catch and discarding in pelagic trawl fisheries. Final Report, Commission of the European Communities, DG XIV-C-1, Study BIOECO/93/017.
4. Anon. 1998. Baltic cod stock assessment: an international program to standardise sampling protocol, age determination and trawl surveys. Final Report, DG XIV/C/1 94/058.
5. Walther, Y. 1995. Bycatches of cod in Swedish trawl fishery for pelagic species in the Baltic Sea. Information fran Havesfiskelaboratoriet Lysekil Nr 2
6. Blasdale, T. and A.W. Newton. 1998. Estimated of discards from two deepwater fleets in the Rockall trough. ICES CM 1998/O:11.
6. Dupouy, H., Allain, V., and B. Kergoat. 1998. The discards of roundnose grenadier in the French fishery in ICES subareas VI and VII. ICES CM 1988/O:20.
7. Borges, T.C., Bentes, L., Castro, M., Costa, M.E., Erzini, K., Gomes, J., Gonçalves, J.M.S., Lino, P.G., Pais, C., and J. Ribeiro. 1998. Studies of the Discards of Commercial Fisheries from the South Coast of Portugal. Final Report Commission of the European Communities, DG XIV-C-1, Study Project No. 95/081.
8. Tursi, A. 1994. Length and age composition of ichthyc species present in discards from commercial fishing in the Ionian Sea. Final Report, Commission of the European Communities, DG XIV-C-1, Contract Nº 1992/14.
9. Machias. 1999. Poster in ICES Symposium on Ecosystem Effects of Fishing, Montpellier, France.

3.3.1 Baltic

Relatively little research has been undertaken on the subject of discards in Baltic fisheries. The range of commercial species of significance is limited to cod, salmon, sprat and herring. Discards of under-sized cod are relatively low due to the use of large-meshed gill nets as the main gear targeting this species in Sweden[16]. However, some discards of juvenile cod are reported at certain times of year and recruitment is notoriously variable. In years of good recruitment, discarding of small cod can be significant. The International Baltic Sea Fisheries Commission has therefore recently recommended the installation of escape panels in trawls to enhance escapement of small cod[17]. Comparative studies of different gears; longlines vs. small-meshed trawls for eels and gill nets vs. trawls for cod have been carried out with a view to reducing by-catch and discarding in these fisheries[18].

The good market for small pelagic fish such as sprat and herring has meant that discarding has not been a particular problem in these fisheries. However, the collapse in 1999 of the Russian market for canned sprat produced by the Baltic states is now likely to alter this situation. The relatively selective fishing methods used for salmon result in negligible discards. However, given that there is a minimum size limit for salmon in the Baltic Sea, studies have examined survival of salmon caught with different gears[19].

3.3.2 North Sea and NE Atlantic

Recent studies[20,21] reveal that discards of fish, bottom living creatures and offal can be considerable in the North Sea. As shown in Box 13, discards appear to be about one third of the amount landed.

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[16] Baranova, T. and I. Shics. 1995. Latvian gillnet cod fishery in 1993-1994. ICES-CM-1995/J:8

[17] Lowry, N., Knudsen, L.H. and D.A. Wileman. 1994. Mesh size experiments in the Baltic cod fishery ICES-CM-1994/B: 29

[18] Gabriel, O. 1997. Untersuchungen zur Langleinenfischerei auf Dorsch und Aal in der Ostsee. Inf. Fischwirtsch. 44: 69-72.

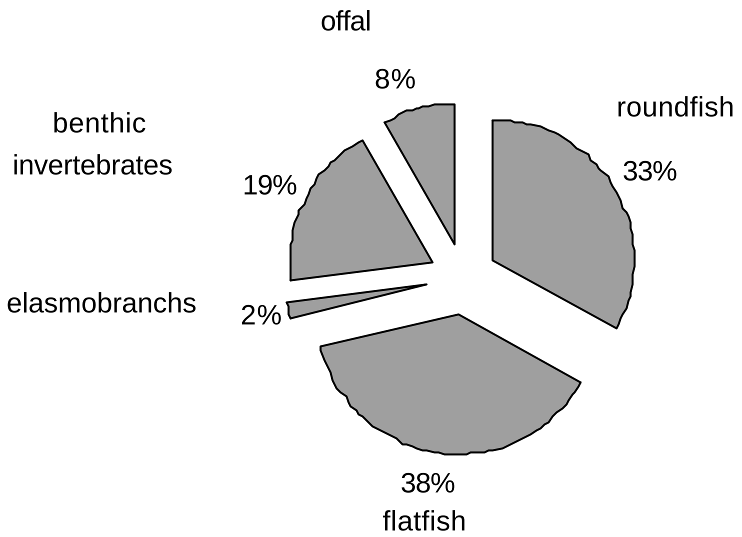
[19] Toivonen,A.L. and R. Hudd. 1993. Survival of undersized salmon after release from the trap net. ICES-CM-1993/B:10

[20] Camphuysen, C.J., et al. Consumption of discards by seabirds in the North Sea. Final Report EC DG XIV research contract (BIOECO/93/10). NIOZ Rapport 1995 – 5, Netherlands Institute for Sea Research.

[21] Garthe, S., Camphuysen, C.J., and R.W. Furness, Amounts of discards by commercial fisheries and their significance as food for seabirds in the North Sea. Mar. Ecol. Prog. Ser. 136: 1-11, 1996

In an EU-funded study literature and available data was reviewed on quantities of fish, benthos and offal discarded in the North Sea (not taking into account the coastal zone, e.g. Wadden Sea). The study estimated that in 1990, the total amount discarded was 789,000 t. Mean total fish biomass and landings for the 1990-1992 period were estimated to be 14,049,000 and 2,669,000 t respectively. The 1990 estimated discards were composed of roundfish (262,000 t), flatfish (299,300 t), elasmobranchs (15,000 t), benthic invertebrates (149,700 t), and offal (62,800 t). Garthe et al. (1996) reported that beamtrawlers accounted for approximately half of all the discards in the North Sea during the study period.

Estimate of total discards in North Sea fisheries during 1990 (% of tonnage)



Source:

Camphuysen, C.J., Calvo, B., Durinck, J., Ensor, K., Follestad, A., Furness, R.W., Garthe, S., Leaper, G., Skov, H., Tasker, M.L., and C.J.N. Winter. 1995. Consumption of discards by seabirds in the North Sea. Final Report EC DG XIV research contract BIOECO/93/10. NIOZ Rapport 1995 – 5, Netherlands Institute for Sea Research, Texel, 202 + LVI pp.

Garthe, S., Camphuysen, C.J., and R.W. Furness. 1996. Amounts of discards by commercial fisheries and their significance as food for seabirds in the North Sea. Mar. Ecol. Prog. Ser. 136: 1-11.

Box 13. Discards in the North Sea

Demersal trawling in other regions is also implicated in other regions. For example a study in Southern Portugal, reported in Box 14, showed that discard level reached 70% of the amount caught in some fisheries.

In a preliminary study of discarding in Algarve (southern Portugal) waters from March 1996 to June 1997, 5 métiers were studied: 1) crustacean trawlers targeting *Nephrops* and deep water shrimps at average depths of 400 to 500m, 2) fish trawlers operating on the continental slope and targeting a variety of demersal species such as hake, mullet, sea breams, cephalopods, and flatfishes, 3) pelagic purse seiners targeting sardines, horse mackerel and mackerel, 4) demersal purse seines generally fishing inshore and targeting high value sea breams as well as sardines, and 5) trammel nets fishing on the continental shelf and targeting a wide variety of demersal species (angler, sole, cuttlefish and sea bream).

A total of 236 discarded species of all taxa were identified, with 139 species that were always rejected, 79 frequently discarded, and 18 occasionally discarded. Discard ratios (weight) averaged 70% for crustacean trawlers, 62% for fish trawlers, 27% for the pelagic purse seiners, 20% for the demersal purse seiners, and 13% for the trammel nets. Fish were discarded for three main reasons: high grading (e.g. mackerel, sardine), for having no commercial value (e.g. *Capros aper* and *Macrorhamphosus scalopax*), and for being too small (e.g. angler).

Table 3. Comparison of discarding rates in five Algarve (southern Portugal) métiers.

Métier		Tows or Sets	Catch (kg)	Retained (kg)	Discards (kg)	Discard rate
Crustacean trawl	mean	2.73	1002.6	168.2	834.4	0.70
n = 11 (30 tows)	sd	0.47	824.3	68.8	820.9	0.23
Demersal purse seine	mean	2.36	3198.4	2069.5	1128.9	0.20
n = 14 (33 sets)	sd	1.55	3756.8	2861.2	2797.4	0.32
Fish trawl	mean	5.14	7196.9	1517.4	5679.5	0.62
n = 7 (36 tows)	sd	2.04	7033.3	687.0	7059.2	0.33
Pelagic purse seine	mean	1.38	9218.6	3710.0	5508.6	0.27
n = 13 (18 sets)	sd	0.51	11248.8	3860.6	11827.7	0.40
Trammel net	mean	1.00	106.1	96.7	9.4	0.13
n = 11 (11 sets)	sd	0.00	87.5	87.3	9.8	0.13

Source:

Borges, T.C. + 9 co-authors. 1998. Studies of the discards of commercial fisheries from the south coast of Portugal. Final Report Commission of the European Communities, DG XIV-C-1, Study Project No. 95/081.

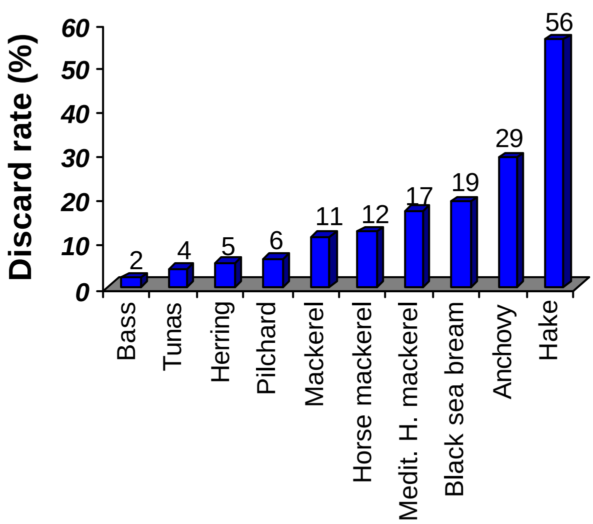
Borges, T.C. *et al*. 2000. By-catch and discarding practices in five Algarve (southern Portugal) métiers. Journal of Applied Ichthyology (*In press*).

Box 14. Discarding in commercial fisheries from the Algarve (southern Portugal)

Observers studied discarding in 11 pelagic trawl fisheries where the target species were anchovy (1), bass (1), black sea bream (1), hake (1), herring (1), horse mackerel (2), mackerel (1), pilchard (2) and tuna (1). Total catches of the target species in these fisheries ranged from 217 t of bass in 1994 to 110,000 t in the Dutch horse mackerel fishery for the same year. The target species made up from 31% of the total catch in the case of the hake fishery to 95% in the Irish herring fishery. Total discard rates ranged from 2% in the bass fishery to 56% in the hake fishery, with marketable target species making up between 31 and 95% of the total catches. In general, most of the discards consisted of other pelagic species, namely mackerel, horse mackerel, pilchards and sprats. Marine mammal by-catches (dolphins and seals) were reported in 5 of the fisheries (hake, tuna, sea bass, horse mackerel, and herring). Fish were discarded for a number of reasons, with the most common being mixed catches and high grading, quotas (e.g. for mackerel), undersized or damaged target species, gear failure, and unmarketable species.

Considerable variability was reported in some métiers, with season, fishing ground (inshore, offshore, nursery areas), height of the net and distance of the net from the bottom, and experience in determination of the composition (species and size distributions) of the schools detected with electronic equipment. However, the sampling effort for some métiers was low, which does not allow strong conclusions to be drawn.

Discard rates in some NE Atlantic pelagic trawl fisheries.



Source: Morizur, Y., N. Treganza, H. Heessen, S. Berrow, and S. Pouvreau. 1996. By-catch and discarding in pelagic trawl fisheries. Final Report, Commission of the European Communities, DG XIV-C-1, Study BIOECO/93/017.

Box 15. Pelagic trawl fisheries in the NE Atlantic (Morizur et al. 1996)

Fishing for pelagic fish may also involve discard high rates. A detailed study of pelagic trawling in several different Atlantic fisheries, illustrated in Box 15, showed that fisheries targeting hake are particularly implicated. Other pelagic fishing operations which may be implicated in high discard rates are for herring and mackerel, where large hauls may sometimes be slipped, and for tuna, where purse seining may be responsible for accidental capture of marine mammals.

3.3.3 Mediterranean

Mediterranean fisheries are characterised by a wide range of fishing gears/métiers and a wide range of species for which there is demand, even in the case of small fish (for example for "*fritto misto*" in Italy). Whereas seiners account for the bulk of the Mediterranean landings, there are significant trawl and artisanal components. Trawl cod end mesh sizes and mesh sizes of static gears, particularly those in the artisanal fisheries, are notably smaller than those in the north-east Atlantic and North Sea.

In most Mediterranean fisheries discard levels are relatively low. However there are two major exceptions. Significant discards and by-catches of fish and marine mammals as well as the capture of significant quantities of illegal sized target fish such as swordfish are occurring in the large-scale drift net and pelagic longline fisheries for tuna and swordfish. The by-catches and discards of these Mediterranean large pelagic fisheries have been studied in several EU projects (for example Regulatory discard of swordfish[22]). Throughout the Mediterranean for example, 43 % to 100% of the swordfish caught are below the MLS and sharks account for up to 30% of the by-catch in these longline and gillnet pelagic fisheries. These losses have become a reason for great concern, and following the UN agreement to impose a moratorium on large scale drift-netting, the EU has passed regulations to prohibit this gear from 1 January 2002.

Mediterranean trawl fisheries are also characterised by significant discards of non-marketable species of fish and invertebrates.

A number of EU funded projects have focused on discards in Mediterranean trawl fisheries. Four projects have focused on the fisheries of the central and eastern Mediterranean and the Ionian Sea[23,24,25,26] whilst a Spanish-Italian project[27] studied

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[22] De Metrio, G. (co-ordinator). 1999. Regulatory discard of swordfish (*Xiphias gladius* L.): effectiveness of the EU regulation regarding the catch minimum size of swordfish in the Mediterranean. Interim Report, Commission of the European Communities, DG XIV-C-1, Contract Nº 97/0074.

[23] Tursi, A. 1994. Length and age composition of ichthyc species present in discards from commercial fishing in the Ionian Sea. Final Report, Commission of the European Communities, DG XIV-C-1, Contract Nº 1992/14.

[24] Tsiminides, N. (co-ordinator) 1997. Analysis of trawls' discard operation in the central and eastern Mediterranean sea. Commission of the European Communities, DG XIV-C-1, Contract Nº 94/065.

[25] Tsimenides. N; Machias. A; Vatos.D; Giannoulaki- 1998. Analysis of trawls discard operation in the Central and Eastern Mediterranean Sea. Draft Final Report. Commission of the European Communities, DG XIV. Reference No 95/061

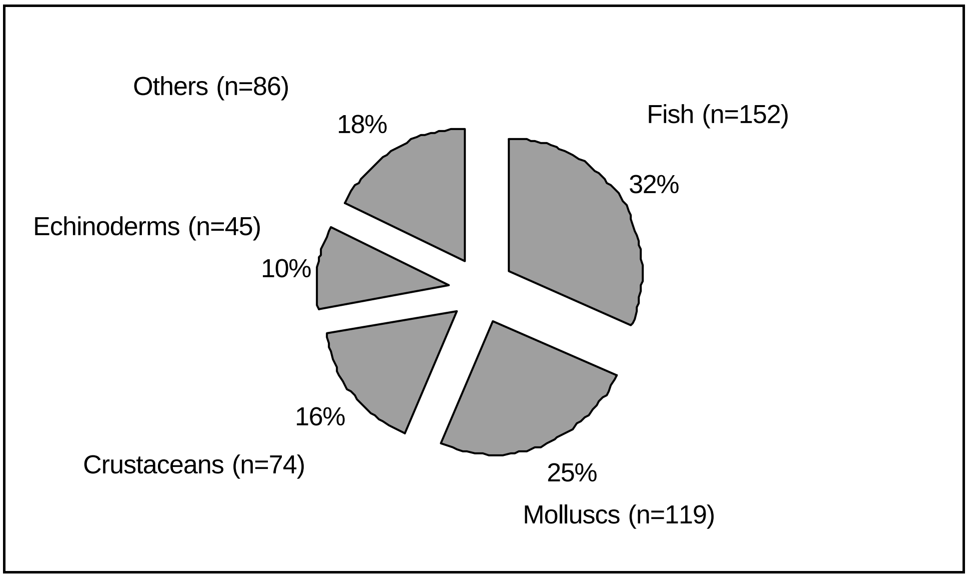
[26] Tsimenides. N; Machias. A; Vatos.D; Giannoulaki. 1999. Analysis of trawls discard operation in the Central and Eastern Mediterranean Sea. Interim Report. Commission of the European Communities, DG XIV. Reference No 97/0044

[27] Carbonell, A. 1997. Discards of the western Mediterranean trawl fleets. Commission of the European Communities, DG XIV-C-1, Contract Nº MED/94/027.

the discards in the western Mediterranean (see Box 16). These studies have shown that significant quantities are discarded from trawl fisheries, with the biomass rejected often exceeding the retained catch. Mediterranean discards are characterised by extraordinary diversity of vertebrates and invertebrates, with considerable variability in discard rates and composition with location, season, depth and gear type. The results suggest that substantial long-term monitoring is required to improve our understanding of the factors affecting discarding in this region, and of the implications of such levels of discarding on a fragile and stressed environment.

The first comprehensive study of trawl discards in the western Mediterranean (Spain and Italy) was carried out with sampling on board commercial trawlers from June 1995 to June 1996. Stratification was by port and fishing depth. Additionally, trawl type and horse power were also used to stratify the sampling in two of the seven ports.

A total of 609 species in 14 major taxonomic groups were caught, of which only 20% were of commercial value and landed. Of the 476 discarded species of fish (128 of bony fish and 24 of cartilagenous fish such as sharks and rays) were the dominant group. Discarding rates were highly variable, with means ranging from 13.1% to 52.5% of the total catch among the different ports. Depth was an important factor influencing commercial fraction, discard rates, discard composition and reasons for discarding. The discarded biomass ranged from a low of 2.2 kg/h at depths greater than 350 m to 118.3 kg/h in the lower depth stratum. Invertebrates and algae contributed significantly to the discards in stratum A, whereas potentially commercial species were particularly important in stratum B and non-commercial species dominated at the greater depths.



Discards species composition in western Mediterranean trawl fisheries.

Source:
Carbonell, A.(Coordinator) *et al*. 1997. Discards of the western Mediterranean trawl fleets. Commission of the European Communities, Final Report, Contract Nº DGXIV-MED/94/027.

Box 16. Discards in the western Mediterranean

4 Quantification of discards

4.1 Background

Fishing waters are divided by ICES[28] into notional areas for the purpose of gathering fishery data. The main areas in European waters are displayed in the map on the following page and they are used for fisheries management (catch reporting and quota allocation) and in scientific research and sampling.

4.2 Discard sampling programmes

The great variety of fisheries found within EU waters means that no uniform method for monitoring discards is possible. A number of countries have established sampling programmes, which have evolved to take into account different fleets and situations. Whilst Scotland has the longest running discard sampling programme (since 1975) other regions of the UK and countries such as Netherlands, France, and Ireland also regularly monitor discards. These programmes are described briefly below.

In other countries however, discard data has only been collected on an *ad hoc* basis. National surveys have been used to indirectly obtain information on discarding in the commercial trawl fisheries. In recent years, to address the lack of data, the European Commission has funded a number of ongoing surveys focusing on the discards of particular fisheries or métiers; in many cases these studies are providing the first quantitative and reliable information on discarding practices.

4.2.1 Scotland

Cod, haddock, whiting and saithe from seiners, light trawlers, *Nephrops* trawlers, pair trawlers and beam trawlers are sampled by technicians from the Scottish Office Environment and Fisheries Department. The sampling strategy involves sampling one vessel fishing in each major fishing area every quarter. Major fishing areas are defined as those with more than 10,000 hours of effort.

4.2.2 England

A regular sampling programme for the North Sea was started by MAFF in 1994 with the objective of assessing: 1) cod, haddock and whiting discards in otter, *Nephrops*, and pair trawls and seines, 2) *Nephrops* discards in the *Nephrops* fishery.Target sampling effort is approximately 12 hauls per quarter per fishing area.

4.2.3 Northern Ireland

The emphasis is on *Nephrops* and whiting discards, with sampling on four to six trips by selected vessels from three major ports, each sampled monthly. Changes over time are monitored by sampling the same vessels, whereas different vessels are sampled in order to study inter-vessel variation in discarding. Some sampling effort is also directed at the recently developed semi-pelagic fleet targeting whitefish.

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[28] International Council for the Exploration of the Seas

4.2.4 France

The IFREMER sampling programme is divided between the Celtic Sea and the Bay of Biscay, with further stratification based on ports and métiers. In the former area, three target trawl fisheries are monitored: 1) monkfish, skate and megrim, 2) *Nephrops*, and 3) whiting and cod. In the latter area, two trawl métiers are studied: 1) *Nephrops*, and 2) hake, megrim and monkfish. Two trips each by two 'typical' vessels for each métier are sampled quarterly in the Celtic Sea, whereas one to three vessels are sampled each quarter in each métier from 4 principal ports in the Bay of Biscay.

4.2.5 Ireland

Two sampling programmes are carried out. The older programme involves monthly sampling for whiting discarded by the *Nephrops* fishery in the Irish Sea. The more recent programme monitors discards in the main fleets operating out of five main ports, with two to three main métiers sampled at each port.

4.2.6 The Netherlands

The Netherlands Fisheries Research Institute (RIVO) has undertaken discard monitoring since the 1970s, mainly funded until 1998 by national government. Current programmes are integrated into a wider North Sea programme conducted principally in collaboration with UK, Germany and Denmark. The programme focuses on demersal fisheries (and particularly on the beam trawl fleet). There are 4 sampling periods per year, with a total of 5 fishing vessels at 4 geographic locations selected at random in each period. On each vessel observers collect discard data over a 5 day period.

4.3 Discard sampling procedures

Sampling on commercial fishing boats is constrained by the conditions on the vessel, the weather, the way the catch is normally processed, and by the attitudes and degree of co-operation of the crew. In some fisheries, particularly small-scale coastal fisheries, catches are small enough for the entire catch to be analysed. However, in most fisheries this is not the case and monitoring of discards is based on samples taken from the total catch.

The sampling effort necessary to achieve the required accuracy will vary according to the nature of the fishery. Discard rates vary substantially between trips even on the same fishing vessel. Sampling rates need to be high to get statistically representative results which can be extrapolated to the whole fishery. Whereas optimal sampling strategies for the more "single" species fisheries of the North Sea may be relatively easy to design, this may not be the case for fisheries with multiple species, or where there is considerable variability in the catch composition.

In designing a sampling programme for monitoring discards, a number of problems and factors must be taken into consideration. Several EU funded projects have focused on statistical considerations and sampling strategies. Examples are the

BIOECO project "Assessment of discarding rates for commercial species of fish"[29] and "On-board sampling of fish landed and discarded by commercial vessels"[30].

Perhaps the best studied European fisheries in terms of discards and discarding are those of the North Sea. This is largely due to the long-term Scottish sampling programme that has allowed comprehensive analysis of discard rates and discarding practices. This programme is based on random sampling of different areas and gears within each year. Sampling is made by on-board observers. Because of the high cost of such sampling, only 60 to 100 trips a year (corresponding to only 0.1-0.2% of the total) are sampled. This means that many areas and types of vessels or fishing gear are not sampled at all, with the result that the estimates are not very accurate. Recent work has investigated promising alternative statistical methods for estimating discard ratios. However, our understanding of this area is still relatively poor, and in any case the basic problem remains; for most European fisheries there is insufficient sampling to provide adequate data for measuring the impact of discards on the resources.

4.4 Research into new survey techniques for measuring discards

Currently, survey techniques for measuring discards are almost entirely based on the use of observers/technicians on board commercial fishing vessels. The major limitations of this survey methodology are:

- Cost of trained observers for data collection
- Often inadequate coverage in space and time
- Non-random sampling of the fleet
- Inadequate sample sizes
- Biased estimates of landings and discards

This approach also means that there is often a significant time lag between actual data collection and the use of the information for practical purposes (such as decision making with regards to TACs or area closures).

Stock assessment would benefit considerably from a real-time computerised data collection and analysis system. Although the use of such systems for fisheries management has increased world-wide in recent years, to date there are no specific applications for by-catch and discarding practices. However there is some interesting research and development (such as the FISHCAM project) which use computer-based data logging systems linked to a Global Positioning System (GPS) and a Geographic Information System (GIS).

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[29] Cotter, J. (co-ordinator) 1995. Assessment of discarding rates for commercial species of fish. Final Report, Commission of the European Communities, DG XIV-C-1, Study BIOECO/93/003.

[30] Cotter, J. (co-ordinator) 1999. On-board sampling of fish landed and discarded by commercial vessels. Final Report, Commission of the European Communities, DG XIV-C-1, Reference 95/094.

With such a system, vessel-based data capture can be matched to digital maps along with other relevant data bases (e.g. depth, temperature, bottom type). This would permit finer tuning of conservation measures such as effort restrictions and TACs, and the identification of critical areas such as nursery zones where discarding of juveniles may be important. Useful outputs could include up-to-date contour maps of discard rates, enabling the introduction of temporary closures when rates are considered to be too high. However, much more work is required before this objective can be achieved.

Accurate and timely data collection is only one requirement of successful research into discards. A 1997 review of fisheries discarding research in the NE Atlantic concludes that it is difficult to compare the results of different studies due to the wide range of methodologies used for surveying and the analysis of discard rates. There is an emerging consensus that wherever possible there is a need for standardisation of data collection methodologies and analysis, to ensure that results are comparable between studies.

Furthermore, some studies focus on a particular metiér or a fishery within one Member state's waters (eg. where there is known to be a discard problem). However the whole fishery may be exploited by a number of countries using a variety of different gears. It is considered to be more useful if a whole fishery can be studied, as opposed to one country's fleet or a particular metiér within a fishery.

4.5 Biological and economic modeling of discarding

4.5.1 Biological modeling

Suitably categorised discard data (e.g. by gear or métier, season, area, species, sizes) can be combined with information about the growth of fish, and be represented by a mathematical model, to predict the amount of discards which will result under any given set of circumstances. This type of biological modelling of discarding can be used to improve survey precision and sampling strategies, to predict discard quantities and composition, to gain insight into factors governing discarding practices, and to evaluate the impact at the species and ecosystem level.

In a good example of this approach applied to North Sea fisheries, Scottish researchers (Reeves, 1990) developed models for Scottish haddock discards for three gears (seine, light trawl, and *Nephrops* trawl) and three areas (Shetland, Buchan, and Forties). The models predicted discard numbers and rates of juvenile haddock, and were able to account for up to 84% of the observed variation in discard rates, suggesting that they could be useful in fisheries management.

However, another project which attempted to model discarding rates as a function of vessel characteristics, fishing grounds and seasons in a range of fisheries ("On-board sampling of fish landed and discarded by commercial vessels"[31]) met with less

[31] Cotter, J. (co-ordinator) 1999. On-board sampling of fish landed and discarded by commercial vessels. Final Report, Commission of the European Communities, DG XIV-C-1, Reference 95/094.

success. Although the authors concluded that the development of models of this type holds considerable promise, the main limitation remains the lack of suitable data for model building, with a particular problem being the lack of data on species abundance in the sea. This lack of data accounts for the fact that few comprehensive models of discarding have been developed to date, and none of these have had any significant impact on fisheries management.

4.5.2 Economic modeling

Research reported in Box 19 modelled survival rates of juvenile demersal fish in the North Sea trawl fishery for *Crangon* (brown shrimp), and incorporated economic data, such as prices, to a model which was used to calculate the numbers of juvenile fish lost due to discarding, and to estimate their value had they been permitted to grow to market size. This approach was used to quantify the future potential economic gains to the demersal fisheries which could be obtained by the introduction of mandatory technical measures for by-catch reduction in the shrimp fishery. The research was able to identify the species where the greatest economic loss was borne by discarding (to the plaice fishery) and to estimate those losses (€17.9 million per year).

The researchers concluded that whilst it is important to have basic information on discards in terms of numbers, weights and discard rates it may be misleading to base management decisions purely on these biological facts; rather it is more appropriate to take the next step and incorporate economic information into the analysis. After all, fishers fish to earn a living, not to maintain stock levels, although this is of course a prerequisite to long-term sustainability, both of catches and profits.

5 Impact of discards on the marine environment and the economics of fishery activities

5.1 Impact of discarding

Discarding is deemed as undesirable due to its negative impacts. The precise reasons depend on the perspective of the onlooker, as indicated in Table 4.

Perspective	Problem of discards
Fishers	• Reduced future catches due to discard of juveniles or accelerated stock depletion • Increased time and effort in sorting the proportion of catch to be discarded
Policy maker	• Limited information on discarding distorts stock assessment modelling and data analysis, the results of which are used to determine management measures
Society	• Reduce the supply of food potentially available for human consumption, or the manufacture of industrial products • They alter the marine environment by disturbing the ecological balance, affecting both marketable and non-marketable species.

Table 4. Impact of discarding depending on perspective

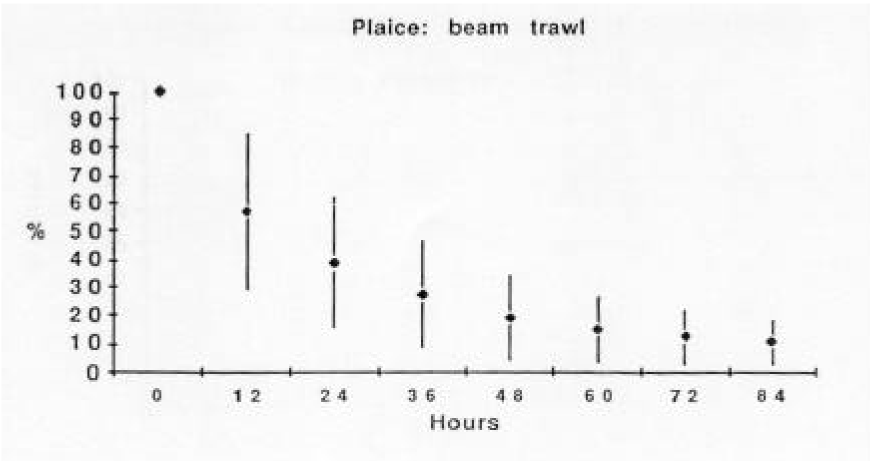
5.2 Direct effects

5.2.1 Discard Survival

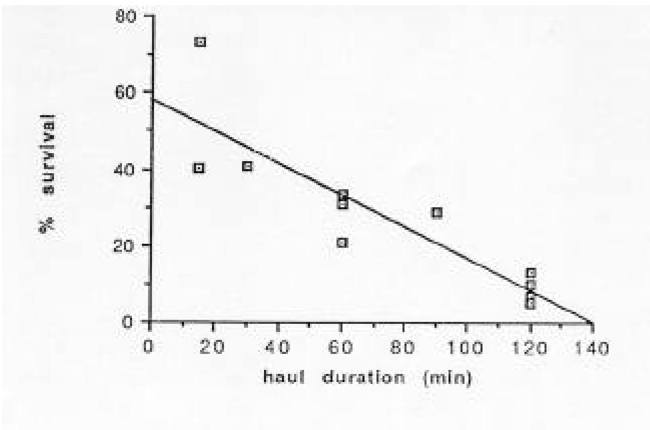
Discarded components of by-catch either survive or die. Several projects have investigated the survival of fish that are either discarded at sea, or pass through the fishing gear. Many fish appear unable to recover from the stresses of being herded into the net, being brought on deck, handled during sorting, then returned to the sea, as shown by the research reported in Box 17. The critical factor for fish survival appears to be the size; above 15cm survival rates appear to increase. Other factors which affect discard survival are the duration of the haul and design of the trawl.

Experiments were carried out by researchers from Holland on board trawlers to measure the effects of a number of factors on the survival of plaice and sole that would be discarded or that escaped through the meshes of the net. Using large tanks and divers, survival of discards was monitored over an 84 hour period. Overall survival of fish which would normally have been discarded ranged from 0% to 50% in plaice, and 4% to 40% in sole, with most of the mortality occurring in the first 48 hours, as shown in the first graph below. Fish caught with beam trawls, and those subject to longer tows (as shown in the second graph) were generally in poorer condition and did not survive as well as those caught with shorter tows.

Survival times of plaice after discarding



Survival of sole as a function of duration of tow



Source: Beek, F.A. van, P.I. van Leeuwen and A.D. Rijnsdorp. 1990. On the survival of plaice and sole discards in the otter trawl and beam trawl fisheries in the North Sea. Neth. J. Sea Res. 26 (1): 151-160

Box 17: Survival of plaice and sole discards in North Sea otter trawls and beam trawls

Dead discards enter the food chain and generally either are consumed at the surface, mainly by sea birds, or sink to the bottom where they are fed upon by scavengers, as discussed in Section 5.2.3.

5.2.2 Population level impacts

Discarding may have an important effect on the populations of target and by-catch species. If discards are significant in numbers and consist largely of under-sized individuals (i.e. high juvenile mortality) then a reduction in yield and spawning potential can occur. The consequences may be longer term changes in the amount of target and non-target species available, and lost production. However, in practice it can be difficult to demonstrate the impact of discarding on a population, because of the lack of detailed data on many fisheries to separate out this factor from other causes of mortality, such as general over-fishing.

An example which illustrates this difficulty is the hake southern stock in the Bay of Biscay where landings have decreased from around 60,000 tonnes per year in 1965 to less than 10,000 tonnes in recent years. In 1990 it was estimated that 38% of the southern stock hake landed were less than 24 cm total length (females do not mature until they reach a size in the range 49 to 58 cm). The stock is thought to be over-exploited, but scientific evidence for this is circumstantial. In part this is because of uncertainties concerning the overall level of discarding of small hake. In the Bay of Biscay trawl fisheries alone it is estimated that tens of millions of juvenile hake are discarded every year. Precautionary TACs have been recommended. Thus a combination of factors, including high mortality rates of juveniles due to discarding, and excessive fishing effort, may be factors contributing to the observed decline in this stock.

5.2.3 Ecosystem impacts

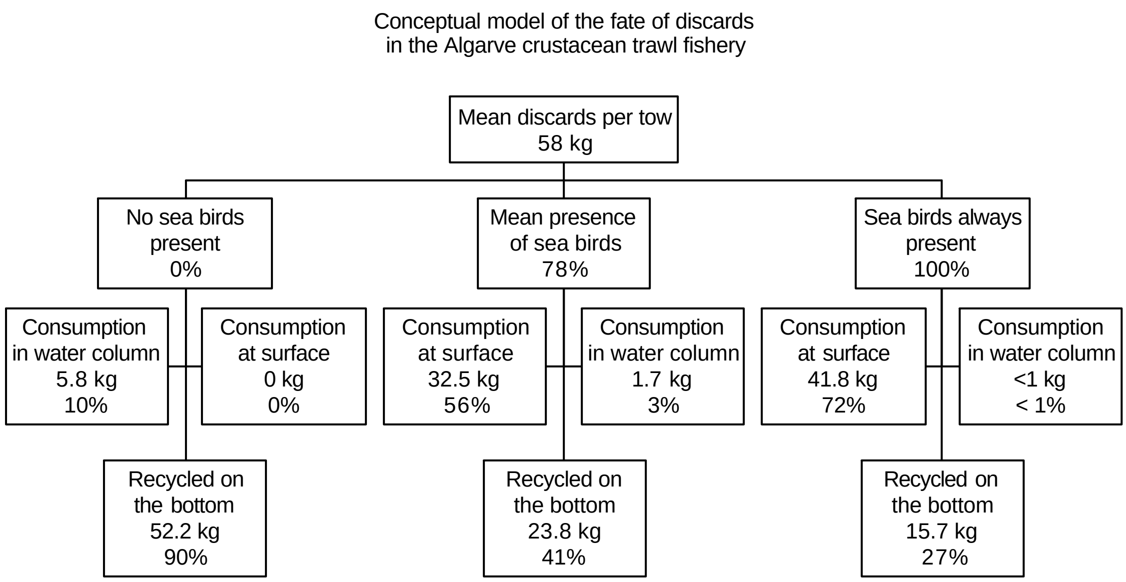
There is some emerging evidence that discarding of fish can cause changes in species composition and dominance in the marine ecosystem. Factors such as altering the availability of food supplies to scavengers, removal of the top predators, and the differential survival of discards can have an impact on the structure of communities of marine animals and plants, and on the food chain interactions between them.

These impacts depend to a large extent on the amount of discards in time and space, and their fate. In most fisheries dead or dying discards are eagerly consumed at the surface by sea birds. Only a small proportion of discarded animals float and, if they are not consumed by birds, they sink to be consumed in the water column, or by bottom dwelling scavengers. Work undertaken by researchers in Southern Portugal on the fate of discards in a deepwater crustacean trawl fishery has illustrated the possible direct consequences of discarding on the marine food chain (Box 18). This suggests that if discards are not consumed by birds at the surface, they are more likely to sink to the bottom, due to the relative scarcity of water column scavengers.

A study of discarding in the deepwater shrimp fishery of southern Portgual estimated that 63% of the total discarded biomass sank immediately, with sinking rates ranging from 3.4 m/min for small fish to more than 10 m/min for invertebrates such as gastropods

A conceptual model of the fate of discards was developed under three different scenarios: a) no sea birds present when discarding, b) sea birds always present and c) using the actual recorded mean presence of sea birds (78% of all tows).

Discards are dominated by bony fishes and these are preferred by scavenging seabirds. When sea birds are present during discarding, most of the discards are consumed at the surface. In contrast, in the absence of surface scavengers, most of the discards reach the bottom**.**



Source:

Castro, M.; Araújo, A.; Erzini, K.; Monteiro, P.; Bozzano, A.; Cartes, J.; Julià, A.; Rotlllant, G.; Sardá, F., 1999: Methodologies to study the impact of discards in trawl fisheries. Final Report, Commission of the European Communities, DG XIV-C-1, Study Project No. 96/063.

Box 18. A conceptual model of the fate of discards

A number of studies in European waters have shown that discards are a major food source for sea birds. Recent studies have estimated that approximately 40% of North Sea discards are consumed by sea birds, including 78% of the roundfish discarded by seiners and demersal trawls and 13% of flatfish discarded by beam trawlers.

Based on these estimates, it was concluded that up to 5.9 million seabirds could be supported by the total amount of North Sea discards. It should be noted that the actual number of scavenging sea birds is estimated to be between 3 and 6 million, suggesting a substantial dependence. In the Mediterranean, the dependence on this food source was illustrated by decreased breeding success when a trawling moratorium coincided with the breeding season. These findings suggest that successful measures to reduce discarding are likely to have important effects on seabird populations in European waters.

Discards reaching the bottom are composed mainly of larger fish, or fish of a shape that can not be swallowed by sea birds (e.g. flatfish), and invertebrates. High volume discards (e.g. slippage) may also result in large amounts of fish reaching the bottom. This may happen in small pelagic fisheries, and there are a number of anecdotal accounts of bottom trawlers "catching" quantities of decomposing pelagic fish. In other situations, such as trawl fisheries where sorting and discarding may take place as the fishing boat is underway, smaller quantities of discards may be dispersed over a wide area. In the above mentioned study of the deepwater crustacean trawl fishery, it was estimated that the mean quantity of discards reaching the bottom was very low, at only 0.013 g/m^2 of tow area covered by the trawl.

Some preliminary studies have been made to find out what happens to discards on the sea bottom. These use a variety of methods including baited traps and time-lapse remote photography. These are used to identify scavengers, estimate their density and to obtain estimates of consumption of discards. In both the Adriatic and southern Portugal small crustaceans, related to shrimps, were found to be extremely significant primary scavengers in deep water, with rapid consumption of discards. In the same studies it was found that some commercially important species of fish and crustacea were feeding both directly on discards, and on the primary scavengers. This suggests that in some fisheries discarding might even make a positive contribution to the populations of commercial species, an area which is worthy of further research.

5.3 Indirect effects

Good estimates of fishing mortality rates are essential for stock assessment and the formulation of scientific advice. Estimates of fishing mortality include factors to account for discards based on data collected through sampling schemes. Lack of discard data, or imperfections in data can cause mortality estimates to be inaccurate which in turn, can lead to inappropriate management advice and policies.

The management of the most important stocks is based on ICES Working Groups which meet to review data compiled from different countries, assess the status of stocks and project the stock development under different fishing scenarios. These assessments are then reviewed by the ICES Advisory Committee on Fisheries Management (ACFM) which provides the scientific advice on the basis of which managers propose Total Allowable Catches (TACs) for approval of the Ministerial Council.

The TAC recommended for a given stock is the level of catch which is considered by scientists to be sustainable, taking into account other sources of mortality which can affect fish populations. In order to calculate a TAC, scientists need information on the current condition of the stock in terms of numbers and amount of fish of different age groups, and knowledge of the reproductive capacity and migratory characteristics of the stock. It is also important to estimate fishing mortality in relation to other natural causes of death. Fishing mortality includes not only fish which are brought to the shore, but also fish which die due other fishing-related causes. This will include fish which are not landed, but nevertheless die due to injury or exhaustion (for example due to passing though the mesh of a fishing net), and it will of course include discards.

The 1985 ICES Working Group on Methods concluded that the absence of discard data was not important for short-term forecasts when discarding rates are constant. However, when discarding is variable or when long term forecasts are attempted, significant errors will occur if discard data are not incorporated in the analysis. The general consensus is that discarding rates in many important fisheries are high and variable. Therefore there is a strong need for long term monitoring of discards in order to improve age-based stock assessment. The worst case scenario is a situation where large numbers of one or a few age-classes are discarded and this is not taken into account. In this case, fishing mortality for the stock will be underestimated and the analysis will give wrong estimates of population age structure, possibly resulting in inappropriate TACs and a level of fishing which is unsustainable.

For the North Sea, discard data are included in the assessment of stock condition. For example Scottish data on haddock and whiting are used by the ICES North Sea Demersal and Northern Shelf Demersal Working Groups. Incorporating discard data in routine stock assessment is possible in this case because Scottish landings and discard data cover a large proportion of the total landings of these species. French data are used by the Southern Shelf Working Group, and Irish and Northern Irish data by the Northern Shelf Demersal Working Group.

However, for many species and stocks, where fishing effort is distributed among several nations and different gears, complete or suitable discard data may not be available for stock assessment purposes. This is a particular problem in the multi-species, multi-gear fisheries of the Mediterranean. In this region there is little or no data for stock assessment based on the relative abundance of different age classes, so even if perfect discard data were available, it would be of limited value.

It is argued that if there was a requirement to reduce discards by compulsory landing of some or all of the by-catch (i.e. is a partial or complete discard ban) there would be an indirect benefit of improved data availability for fisheries management. However some fisheries, such as the North Sea haddock fishery, already have good discard data and the scientists already factor fishing mortality of discards into their advice on TACs. Only limited extra benefits would be derived from additional samples landed. Data benefits from reduced discarding would therefore only occur where there was sufficient biological data to permit application of the stock assessment models, but where existing discard sampling systems were weak. These are quite specific circumstances and fisheries scientists believe that there is unlikely to be much short-term benefit to stock assessment estimates by reducing discards.

5.4 Economic impacts of discards and by-catch

5.4.1 General estimates of economic impact

Only a few studies have been conducted which attempt to estimate the economic costs and benefits of discards. A 1994 FAO Fisheries Technical Paper[32] suggests that the total costs of bottom fish discards in the North Sea could approach the value of landed catches (approximately 470,000 tonnes with an estimated first sale market value of around €700 million in 1997). A recent OECD study[33] reports that the number of haddock individuals discarded in the North Sea have been estimated to exceed the number landed (representing 84,000 tonnes of haddock in 1997 with an approximate first sale market value of over €100 million).

These values are likely to over-estimate the cost of North Sea discards since the majority of discarded fish could not realise market values if landed, as a result of their small size or poor quality. Despite this reservation, potential future losses to the target and non-target fisheries are considered to be significant.

The FAO report does not estimate marine mammal discards, except to say that several hundreds of thousands of animals are involved annually around the globe. Even if numbers of discards and resulting mortalities were known, it is particularly difficult to value losses of these species. However, there are economic considerations, illustrated by the value placed by consumers on their preferred choice of cans of "dolphin safe" tuna.

5.4.2 Target species discards

Discarding of commercial target species incurs an immediate economic loss and reduction of stock size. However if mortality (due to discards or other reasons) of juvenile fish is high enough, then the reproductive capacity of a population can be damaged. This situation is known as recruitment overfishing, and is of particular importance if the stock is at or near a level of maximum exploitation.

Aside from the biological repercussions of overfishing, significant discards of target species can affect the economic vitality of fisheries. Fishing is a profitable activity when marginal revenues are greater than marginal costs, i.e. the extra revenue earned from catching and selling one more fish is greater than the extra associated costs. The discarding activity itself increases costs (in the labour required to separate out the proportion of catch to be thrown overboard) and the accelerated reduction of stock levels induced by discards (particularly if stocks are at or near overexploitation) reduces marketable catches and hence revenues. Both of these factors lower profits. However the impact on profits as a result of discard-related stock depletion is not usually experienced by today's fishers; rather it is tomorrow's fishers who bear the burden of lower catches and, if effort in the fishery is unrestrained, lower profits.

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[32] FAO Fisheries Technical Paper No. 339: 'A Global Assessment of Fisheries By-catch and Discards' FAO 1994

[33] OECD, Towards sustainable fisheries; Country reports, European Union OECD/GD (97) 119, paris 1997

Reductions in current and future landings can also have an impact on both up- and down-stream associated shore-based industries, such as processing and marketing. In the long-run this can affect employment and the socio-economic structure of fishing communities.

5.4.3 Discards of commercial non-target species

Discards of fish of species of commercial value, but which are not the target species, may occur in mixed species fisheries when by-catch species are of small size or of a lower value to the target species. Such discards can also be due to by-catch limits, or to quotas set at levels which do not reflect the natural changes in relative abundance. The resulting economic cost of non-target species discards are borne directly as lost landings, and indirectly as lost future landings in other fisheries.

Box 19 presents an estimation of the biological and economic impact of lost whitefish landings as a result of discards in the North Sea *Crangon* fishery.

5.4.4 Discards of non-commercial species

The cost of capture and subsequent discard of non-target species of little or no commercial value can be measured by considering the price of labour, machinery operation and other inputs required to catch, sort and discard. It may be also be argued that processing time for target species is lost as a result of dealing with non-target species.

By-catch of limited or non-commercial species such as sharks, caught in the Mediterranean long-line pelagic species fishery, may have a significant, but as yet un-quantifiable impact on the wider marine eco-system. Sharks are top predators in the biological chain and a recent study (entitle "By-catches of Sharks in Large Pelagic Fisheries in the Mediterranean Area"[34]) has raised concerns that their excessive removal through by-catch and discarding could have a negative impact on the predator-prey relationship. This could in turn impact both positively and negatively on stocks of commercial species, thus affecting commercial fisheries in the region.

[34] Megalofonou, P. (co-ordinator). 1999. By-catches and discards of sharks in large pelagic fisheries in the Mediterranean Sea. DG XIV/C1. Interim Report Project Nº 97/50.

The EU fishery for brown shrimp (*Crangon crangon)* uses small meshed nets. The discarding of juveniles of commercial fish species (mainly plaice, sole, whiting and cod) in this fishery is a long recognised phenomenon. In 1996 a comprehensive pan-European discard study, the ECODISC study, was undertaken in this fishery[35]. The project developed a computer model which accounted for economic factors such as revenues, costs, gross margins, value-added and price-quantity relationships, as well as the biological fishery variables.

In terms of the impact of discarding, the research showed that discards of juvenile plaice resulted in the greatest numbers of individuals lost to the stock, as shown in the first table.

Discards of non-target juvenile fish by the European *Crangon* fleet

Species	Number of juvenile fish discarded (million)
Plaice	928
Sole	16
Cod	42
Whiting	55

Subsequent analysis (shown below) indicated that the losses due to discarding to the North Sea spawning stock of plaice were estimated to be between 6% and 16%. Potential annual lost landings were calculated to be on average 12,000 tonnes with a market value of €17.9 million. Similarly losses of sole were estimated to be €3.9 and €2.7 million for cod. Whiting discards resulted in the lowest value of lost landings.

The annual biological and economic significance of discarding in the European *Crangon* fisheries

Species	Losses to spawning stock biomass* (%)	Estimated annual lost landings** (tonnes)	Average value of lost landings (EURO Million)
Plaice	6.2 – 16.2	12,066	17.9
Sole	0.4 – 2.2	588	3.9
Cod	0.5 – 1.8	1,890	2.7
Whiting	0.6 – 1.7	1,525	1.2

* range shows 5% and 95% confidence limits of estimate

** mid-value estimate

Box 19. Economic quantification of commercial, non-target species discards

[35] Revill, A., S. Pascoe, C. Radcliffe, S. Riemann, F. Redant, H. Polet, U.Damm, T. Neudecker, P. S. Kristensen, D. Jensen. "Economic consequences ofdiscarding in the Crangon fisheries (The ECODISC Project)." Final Report, July 1999 (EC DGXIV 97/SE/025). DML (University of Newcastle)

5.5 EU Fisheries with significant discard impacts

The extent of a fishery's discard problem can be gauged according to the absolute volume of discards, the discard ratio, whether the stock is at, or near, overexploitation, and the economic importance of species being discarded. Studies relating to discards in European waters show that the problem is most important in fisheries using a limited number of métiers. Some of the main problem areas are:

- Trawls are the most significant fishing gear implicated in discarding. In particular, bottom trawling for *Nephrops* (Dublin bay prawn, or scampi) and beam trawling are implicated in rates of discarding with a significant biological and economic impact.
- Beam trawling also has the greatest impact on the bottom conditions.
- Pelagic trawling and purse seining can on occasions result in considerable discards
- Discarding by pelagic freezer trawlers using automatic grading machines to separate out the undesirable portion of catch of smaller fish is already illegal.
- Some fisheries using tangle nets and other static gear which are fished for long periods (days), result in significant discarding due to spoilage, a subject studied by a recent EU funded project[36].
- Longlining is generally not a cause for concern due to the selective nature of the gear. However, discarding is significant in the hake semi-pelagic longline fishery in Spain and Portugal

5.6 Role of discard reduction in conservation

The principal measure available for achieving a more sustainable exploitation of fisheries resources is the reduction of fishing capacities to bring them in line with available and accessible fishing potentials. In the EU, fleet restructuring measures, involving the decommissioning of fishing vessels, help to reduce discarding by limiting overall fishing effort. Present recommendations in Council Decision 97/413/EC, outlining development of the Multi-annual Guidance Programme (the main instrument used to direct fisheries effort reduction) indicate that cuts in fishing mortality of up to 30% need to be made in order to safeguard stocks.

Senior scientists covering North Sea stock management suggest that given '*appropriate*' discard reduction policies, a 5% reduction in fishing mortality may be achievable. Whilst a suitable discard policy will therefore not overcome the economic and ecological problems in EU fisheries, it does have a role to play, within a broader policy framework for effort reduction.

[36] Morizur, Y., P. Philiponeau and G. Detante. 1998. Sensibilisation des professionels au problème des rejets de pêche. IFREMER, Rapport final de l´étude DG XIV-c-1 1997/021.

5.7 Interventions to reduce discarding

Interventions to address perceived discard problems should be contemplated only where the ecological and economic impact of discards is particularly evident. Ideally, discard reduction measures should be specific and aimed at reducing the economic and regulatory motivations for discarding in particular fisheries.

International, regional and national agencies have intervened to introduce measures to prevent or minimise discarding. There are two basic approaches which have been adopted, often in combination. The first relates to changes to the regulations which govern fishing activity. Typically these types of regulations specify what can be caught, when, and by whom. They attempt to reduce discards by trying to get fishers to avoid fishing in areas where discards will be highest. This regulatory approach is discussed in Section 6. A second approach is by introducing what are known as technical measures (such as minimum mesh sizes and modified fishing gears) which improve the selectivity of fishing gear and reduce the capture of fish which are likely to be subsequently discarded. The technical approaches, which are often mandatory, will be discussed in Section 7.

6 Regulatory approaches to the problem of discards

Regulatory approaches to discard reduction involve the application of minimum landing sizes (MLS), limits to the quantities and proportions of incidental catches, closed areas (whether permanent or temporary) and prohibition of the practice of discarding.

6.1 Minimum Landing Size

In EU waters, as discussed in Section 2.3, regulations prohibit the retention on-board of fish below a defined Minimum Landing Size. The intention of the regulation is that by forcing discards of smaller fish on which effort is spent, fishers will be encouraged to redirect their effort to other areas with lower rates of discarding. Although few commentators or fishers question the need for an enforced MLS, their use can cause difficulties in selecting the correct mesh size (which might also be governed by regulations). Fishing nets are not very selective gears. For example setting a minimum mesh size which would allow the escape of 75% of fish below a biologically desirable MLS, would also allow a significant proportion of marketable fish above the MLS to escape. Few fishers would be happy to let this happen, and enforcement would be difficult. Raising the MLS without also introducing technical regulations that minimise the capture of fish below this size will serve only to increase the number of discards, and further alienate fishers.

Mixed species fisheries where both species are subject to MLS are even more complex. A reduction in the MLS of the larger species caught in a mixed species fishery may serve to reduce the amount of fish which is discarded, but can also be counter productive. In addition to sending out the wrong signals about reduction of effort on juveniles there may well be no market for these fish, or it may permit fishers to target effort where concentrations of juveniles exist.

6.2 Flexible quota allocations and licensing

Although there is no strong evidence that "quota discards" are a significant factor in the overall discard problem, they do undoubtedly occur. Furthermore, if present regulations were followed more strictly, the present illegally landed fish (so-called "black fish") would be discarded.

The pressure to discard or land illegally could be reduced by making it easier to comply with quotas over time by operating more flexible TAC management and quota allocations. This would permit above-quota catches to be landed by the assignment of mixed-species and/or multi-annual quotas, with the overall total TAC of each quota species within a given time period being the same. Thus a quota would be allocated for one or more species over, say, a two-year period, permitting the legal landing of fish, which would otherwise become either discards or "black fish" under the present arrangements. In practice, over-quota landings would be held "on-account", against the next year's quota. Such a system is already applied to some non-depleted listed stocks in EU waters. For example Council Regulation 847/96 contains provisions for 'banking and borrowing' of up to 10% of the quota.

6.3 Closed areas

The selective closure of areas to certain fishing methods more liable to cause discarding can encourage more sensitive methods of fishing, as it creates a positive incentive to fishers to change their fishing methods.

In recent years the concept of marine reserves as a solution to many fisheries problems has been strongly advocated. A number of small marine reserves (also known as "no-take zones") have been established in EU waters, where no fishing is ever permitted. So far, there is little evidence of any material impact on commercial fisheries. Given the wide geographic distribution of most EU commercial stocks, it has been argued that the implementation of marine reserves would only be effective if a significant part (up to 40%) of the total area was protected. Clearly such a policy would have enormous socio-economic implications.

More importantly, there are several closed areas within EU waters, where commercial fishing is prohibited for defined species at defined times by defined vessels. These include the "Norway Pout Box", the "Plaice Box" and several hake nursery grounds..

The Norway Pout Box is a defined area in the Northern North Sea, to the east of Shetland. Any vessel fishing within this box is subject to additional regulations, which prohibit the retention on board of Norway pout, beyond more than 5% of total catch. Effectively the area is closed to targeted fishing for this species. The objective of the regulation is to prevent the incidental capture of juvenile haddock (which are abundant within the Box) by vessels targeting pout, and which use 16mm mesh nets that are allowed for Norway Pout elsewhere.

The Plaice Box, an area stretching from the Dutch to the Danish coasts, was established in 1989. The aim of the box is to protect concentrations of juvenile plaice. It closes a nursery area for plaice to all vessels over 8 metres in length, although derogations do allow fishing by a fixed number of vessels up to 24 meters in length, with an engine power below 221 kW. The ICES working group, which recommended initially that the Box be created, suggested that the benefits to the stock of a complete closure have been significantly reduced because of the derogations.

Certain areas off the Iberian peninsula (Bay of Biscay and SW coast of Portugal) are also closed during part of the year to protect juveniles of hake.

Areas may also be closed to particular types of fishing activity even if other types of fishing that target the same species are allowed. An example of this in EU waters is the “Mackerel Box”, off the South West of England. The area contains a high proportion of juvenile mackerel, often mixed in with adult stock. The creation of the Box, has, in theory at least, reduced discarding by forcing the purse seiners to operate away from the concentrations of juveniles. Handliners, which also target the stock, are allowed to fish within the Box. This derogation was given on social and economic grounds, but it is true to say that handlining is a much more selective method than purse seining of fishing mixed stocks of juvenile and adult mackerel.

6.4 Temporary closed areas

Closures of fishing grounds may be introduced on a temporary basis, when by-catch or discard levels reach a certain level which is determined to be unacceptable. Although not applied in EU waters, the system is operated in Norway. When catches of undersized fish reach more than 15% by number, Norwegian fishers are obliged to inform the authorities who will then close the area. The sizes of area that are closed in Norway can vary from several hundred square kilometres in the case of some shrimp fisheries, to small fjords that cover only 1 or 2 km^2. Fishers must steam at least 5 miles before recommencing fishing activity, and if they again encounter this proportion of undersized fish they must repeat the exercise.

Norwegian authorities introduce closures within 24 hours, announcing the decision by VHF radio. In some areas closure encompasses all types of fishing. However, it is more common for an area to be closed to a certain type of fishing, allowing the more selective vessels to carry on. Onboard observers on some vessels, and random checks by the Coastguard, ensure that closures are observed. The closures appear to have the support of the bulk of the fishing industry, and it is not uncommon for fishers to volunteer information about excessive by-catch rates to the Coastguard.

Norway is able to apply this approach because many of the nursery areas found within its waters are far from areas with large inshore fleets. It is obviously much easier for large vessels to steam 20 or 30 miles to avoid juvenile fish than it is for a small inshore vessel. The inshore vessels also have a tradition of gill netting and jigging, which are inherently selective methods that preclude the capture of small fish. It is quite possible for these vessels to fish in areas of high concentration of juveniles without their exceeding the 15% threshold.

6.5 Discard bans

A discard ban prohibits the practice of discarding any of the catch at sea. Discard bans may be total (applying to all catches in all areas), selective (in that they prohibit discarding of certain species, whilst permitting that of others) or partial (in that they may apply in certain areas and times, and not in others). Discard bans work not only to reduce discards *per se*, but also to reduce the incentive for unwanted by-catch, by raising the cost to the fisher of this component, thus causing cessation of fishing at a lower by-catch rate.

There are no bans on discarding in EU waters. In fact the present approach makes it an offence to retain on-board, fish which is over-quota or undersized, and forces the discard of such fish. However, Norway does operate a ban on discards of all important commercial species within its waters, a policy that is diametrically opposite to the approach adopted in the EU.

Evidence from interviews with Norwegian fishers[37] suggests that, unlike the other regulations, the discard ban is flouted to some extent, although this is not considered to be widespread. Wherever possible the landed fish is utilised for human consumption. Norwegian fishers market all their fish through a national sales organisation, and this includes the low value fish as well. Fishers are compensated for their time and for the packing costs concerned, but are not paid the market value of the fish. Receipts from sales are used to defray the running costs of the organisation. Fish unsuitable for consumption are sent for fishmeal.

As in the EU, the aim of the discard policy in Norwegian fisheries management is the avoidance of the capture of unwanted or juvenile fish. However there are several features of Norwegian fisheries which make such a ban workable. Norway has fisheries that are in the main single species, making it much easier to introduce the optimal mesh sizes[38]. Rules on selective gear were introduced first (requiring technical measures such as mesh sizes and sorting grids). Temporary closed areas (as described above) were then introduced, further reducing the numbers of discards. By the time the discard ban was introduced the most important problem, which was eliminating the capture of fish that would be discarded, had already been largely tackled.

Given the generally positive experience in adjacent Norwegian waters, it is worthwhile to consider the possibility of a discard ban policy within EU waters.
However, a recent report for the European Parliament[39] argued that a general discards ban without first addressing the issue of over-capacity, would not be workable in the EU in the present environment. Although a general discard ban could be announced as

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[37] Megapesca Lda, Report for Science and Technology Options Assessment of the EU Parliament, Study on the Problem of Discards in Fisheries, 1998

[38] The Arctic cod fishery, for example, has a minimum mesh size of 140mm. Such a size would also be optimal for cod in EU waters, but the fishery there relies on associated catches of whiting and haddock, which would disappear if 140mm mesh was made mandatory.

[39] Megapesca Lda. Report on the Problem of Discards in Fisheries, Science and Technology Options Assessment, European Parliament, 1998

a target for the future, much more remains to be done with other management tools before it can be realistically considered as a feasible policy.

Selective discard bans could however be considered as options within a much shorter time scale. If other fishery management measures such as closed areas and more selective fishing gear show positive results (as they have in Norway), the introduction of discard bans for defined areas or fisheries could then be considered.

6.6 Discard reduction measures in pelagic fisheries

Fisheries for small pelagic species of fish can be regarded as a special case due to the large and relatively homogenous nature of the catches. These vessels concentrate on a few species such as mackerel and herring, and can undertake 'high grading' if the catch consists of too many small fish. Pelagic freezer vessels may have the capability of mechanically grading fish on board, making it easy for them to discard the portion of the catch that is not worth the costs of processing and landing. To prevent this, EU regulations stipulate that '*automatic sorting equipment must be installed in such a way that the catch resulting from grading … cannot be easily thrown back into the sea*'. However there is anecdotal evidence that discarding after grading is quite common. As a result some pelagic fishing vessels are prohibited from carrying grading machines at all.

The Norwegian approach to this problem is different. Under pressure from the Norwegian Fishermen's Federation, legislation was passed in the mid-1990s forcing fishers to land a fixed percentage of smaller grades of pelagic species. If a vessel lands only the largest sizes of fish, its quota is automatically docked for the percentage of smaller fish that it is deemed to have caught and discarded. This regulation removes the economic incentive to discard the lower value portion of the catch.

7 Technical approaches to discard reduction

Much recent research has concentrated on means of making fishing gears more selective i.e. allowing a greater proportion of undersized or unwanted species to avoid, or pass through, the fishing gear. Numerous projects funded by the EU have studied the size selectivity of different gears, and once a new technical approach is proved to be effective and practically feasible, managers have been quick to amend the regulations to require its use. Some of the selectivity devices used by fisheries managers include minimum mesh sizes, square mesh panels, sorting grids and separator trawls. These are considered in more detail in this section, along with other technical measures such as acoustic avoidance methods (for reducing catches of dolphins).

7.1 Minimum mesh size

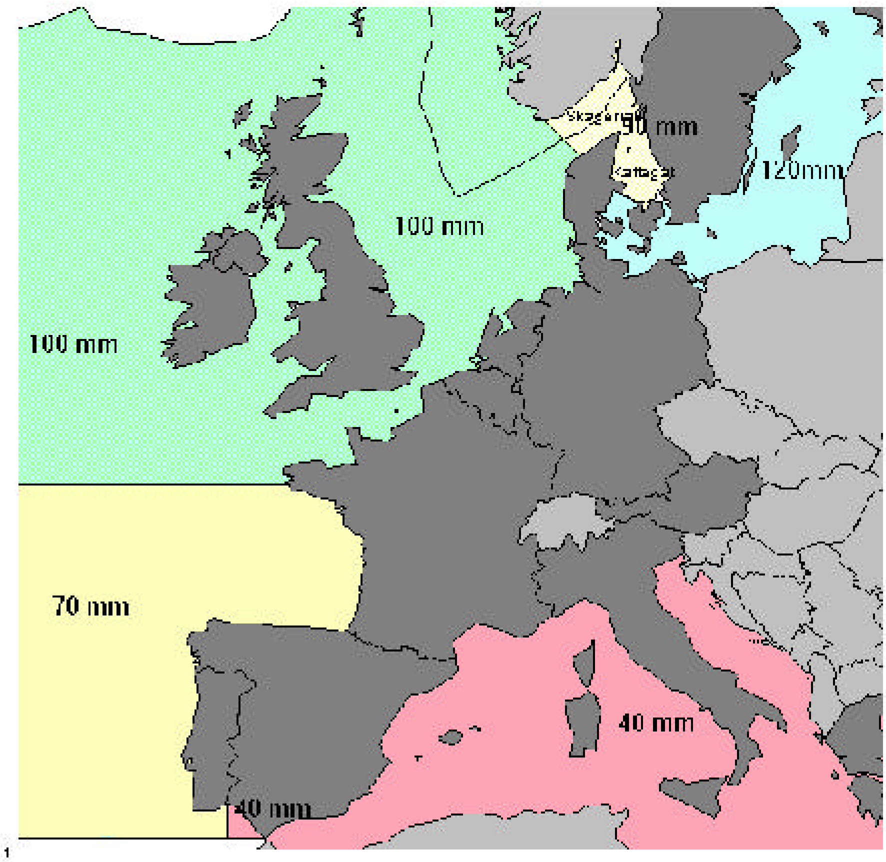
Minimum mesh sizes (MMS) have been implemented since the earliest days of the fisheries management, and continue to be an important tool. MMS regulations are the most basic form of technical measure, stipulating a minimum mesh size that may be used for nets in a particular area or fishery, thus permitting smaller fish to pass through the net.

In the EU MMS are applied by Council Regulation (EC) Nº 850/98 of March 1998 for the "*Conservation of fishery resources through technical measures for the protection of juveniles of marine organisms*". The regulation simplified previous minimum mesh size regulations which had been found to be difficult to apply. Although ideally mesh sizes should be based on the target species and not the fishing grounds, this regulation defines three major geographic zones: north of the 48th parallel, south of the 48th parallel to the Gulf of Cadiz, and Gulf of Cadiz and Mediterranean (as shown in Box 20).

MMS regulations may have little or no effect on the by-catch rate of non-target species and, on its own, an MMS policy may have little overall effect on the mortality of juvenile fish. For example, in the Irish Sea an increase in mesh size from 60 to 70 mm was found to make little difference in terms of whiting discards. As shown previously, there is good evidence that below a certain size, fish passing through a trawl will die anyhow from scale loss and exhaustion. It is also possible for fishers to adjust the tension of the net to reduce the effective mesh size, negating any regulation. The material used, shape of the mesh, length of the net, circumference of the cod-end and a host of other factors will all affect the effective mesh size of a trawl. More detailed regulations stipulating additional factors are often issued in an attempt to make the measures more effective, although they frequently do little more than provide additional measures to be circumvented.

Commercial practice in fishing dictates that it is often necessary for a vessel to carry nets of different mesh size. Currently it is possible to land any combination of fish, and to claim that the correct proportions of fish were caught with the appropriately sized nets (even if they were not actually caught with the legally stipulated nets). Attempts to plug this loophole by insisting, for example, that only one mesh size may be carried onboard a vessel at any one time, have met with fierce opposition from fishers in the past, leading to the need for derogations for many types of fishing. However the more derogations that are created, the more the regulations become weakened due to difficulties of enforcement.

Largest regulatory mesh sizes after the New Regulation is implemented



[1] Within the Zones under the jurisdiction of Third Countries National measures apply

Source:
Council Regulation (EC) Nº 850/98 of March 1998 for the conservation of fishery resources through technical measures for the protection of juveniles of marine organisms.

Box 20. Regulatory mesh sizes

7.2 Square mesh panels

It has long been recognised that the diamond mesh used in most trawls closes up under tension. In the UK both the Scottish Office and the Sea Fish Industry Authority have undertaken extensive research into the use of square mesh panels, much of it funded through the EU. Square mesh panels inserted in the top of the net slightly before the cod-end have been shown to allow smaller fish to pass through, where otherwise they would have been trapped in the cod end. Survival of these fish in the mixed demersal fishery in Scotland is as high as 90%, and a study on chartered vessels in the Scottish *Nephrops* fishery showed that up to 63% of undersized whiting and haddock were released, with little negative impact on the landings of *Nephrops* themselves, although some marketable whiting were also lost. As a result, the EU has brought in regulations requiring square mesh panels for the *Nephrops* fishery and some shrimp fisheries in the northern part of the region. However another multi-regional study[40] reported mixed results, with no improvement in terms of by-catch rates in some areas and even an apparent increase in the by-catch in some cases. Twine types and season were found to be important additional factors affecting selectivity, and this suggests that more research is needed in this area.

Even with the limited understanding, there are practical problems to overcome in the use of square mesh panels. They are harder for fishers to insert and repair, and their effectiveness depends on their position in the net, seabed visibility and light levels.

7.3 Separator trawls

It has long been known that different species of fish will behave differently within a trawl. Fish tend to swim in the mouth of the net, until they drop back, exhausted, into the tunnel and cod end. Certain species tend to rise as they turn back, whilst others will turn downwards. These behavioural differences can be exploited by separator trawls which divide the rear of the net into two sections, with different mesh sizes suited to the separate species. As shown in Box 21, one particularly promising approach exploits differences in behaviour between flat fish, round fish, and crustaceans such as shrimps and Norway lobster.

As with square mesh panels, separator trawls require fishers to learn to make, mend and fish with them. There will instinctively be a feeling that they may cause the loss of marketable fish, as well as create extra work. Research on separator trawls is not as advanced as it is on square meshed panels.

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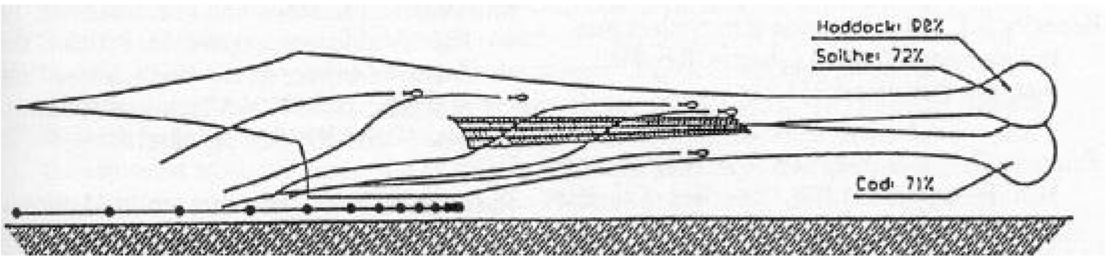
[40] "Selectivity of square mesh windows in fish and *Nephrops* trawls", SOAEFD, DIFTA, FRC and IMBC, EU Study Contract 1994/1084, Final report March 1997.

Horizontal panels of net in separator trawls have proved promising in terms of the reduction of the by-catch of unwanted species and sizes of groundfish. They work by expoiting behavioural differences between species as they enter the net; some species tend to swim upwards. Two parts of the trawl, with separate cod ends, are separated by a wide mesh panel. The cod ends have different mesh sizes. As illustrated in the figure below (from a Norwegian example), the majority of cod are retained below the separator panel whilst the haddock and saithe enter the upper trawl net.



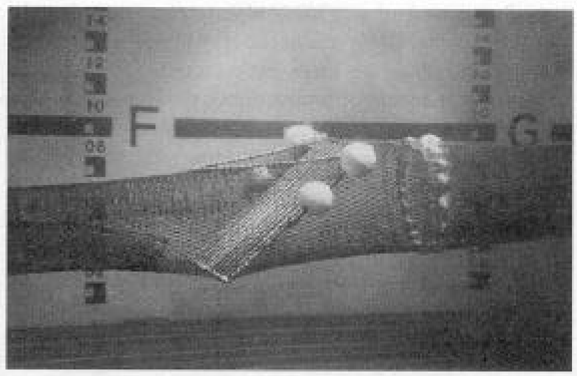
Source:
Engas, A. and C.W. West. 1995. Development of a species-selective trawl for demersal gadoid fisheries. ICES CM 1995, 20 pp.

Box 21. Separator trawls.

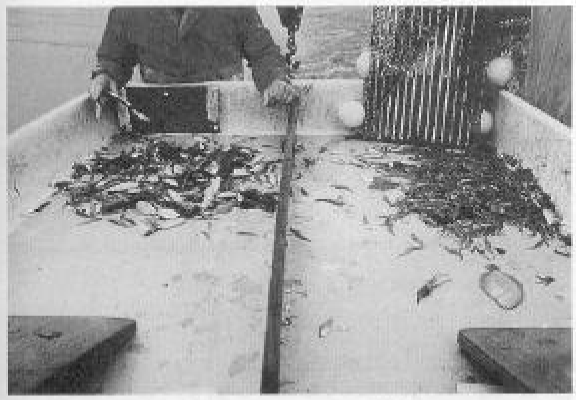
7.4 Sorting grids

Sorting grids are one of a number of different *by-catch reduction devices* (BRDs). They are rigid panels of spaced bars deployed in conjunction with a trawl net or a purse seine. In some cases, principally shrimp fisheries, the grid is set in the tunnel of the net in front of the cod end. Large fish can escape, and only small fish and shrimp passing through the grid are caught. In other arrangements the grid is located before and beneath the cod end, so that only the larger fish which cannot pass through the grid will enter the cod-end. The best known in European waters is the Nordmøre system, developed by the Norwegians, which allows the escape of fish whilst retaining the target shrimp which pass through the bars and enter the cod end. Box 22 shows the arrangement of the grid and the results.

Dramatic results have been obtained in fisheries all over the world using by-catch reduction devices such as the Nordmøre grid seen below. In this example from the Clarence River prawn fishery in Australia, a Nordmøre grid design was used in a trawl net to exclude unwanted fish by-catch whilst retaining valuable prawns that pass through the bars of the grid.



As seen in the picture below, the catches of trawls without (left) and with (right) a Nordmøre grid are significantly different, with a dramatic reduction in by-catch seen with the use of the grid.

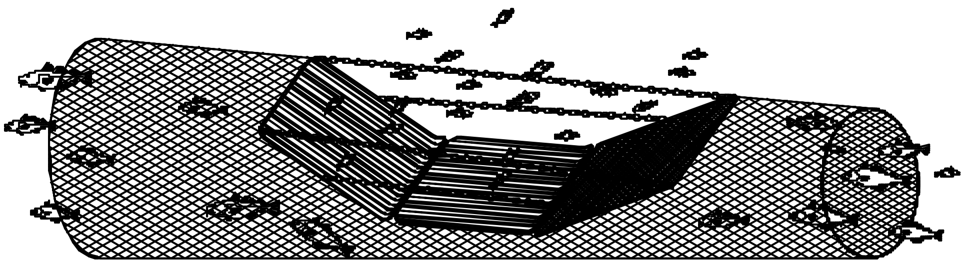


Source: Kennelly, S.J. and M.K. Broadhurst. 1996. Fishermen and scientists solving bycatch problems: examples from Australia and possibilities for the northeastern United States. pp. 121-128. Alaska Sea Grant College Program report 96-03.

Box 22. By-catch reduction devices – the Nordmøre grid.

Following the successful implementation of the Nordmøre grid in shrimp fisheries groundfish grids, more sophistcated designs such as the Sort-X and Sort-V type grids were developed in the early 1990's. An example is shown in Box 23. Experiments in the Barents Sea have shown that the use of these devices reduces the by-catch of small cod, haddock and saithe by 60 to 90% compared to trawls without a grid. Overall, juvenile fish by-catch is reduced from 40 –50% to less than 15% of the total catch with such grids.

Other BRDs in use in trawls around the world range from simple openings allowing larger fish to escape (e.g. Fisheye) to soft and hard turtle exclusion devices[41].

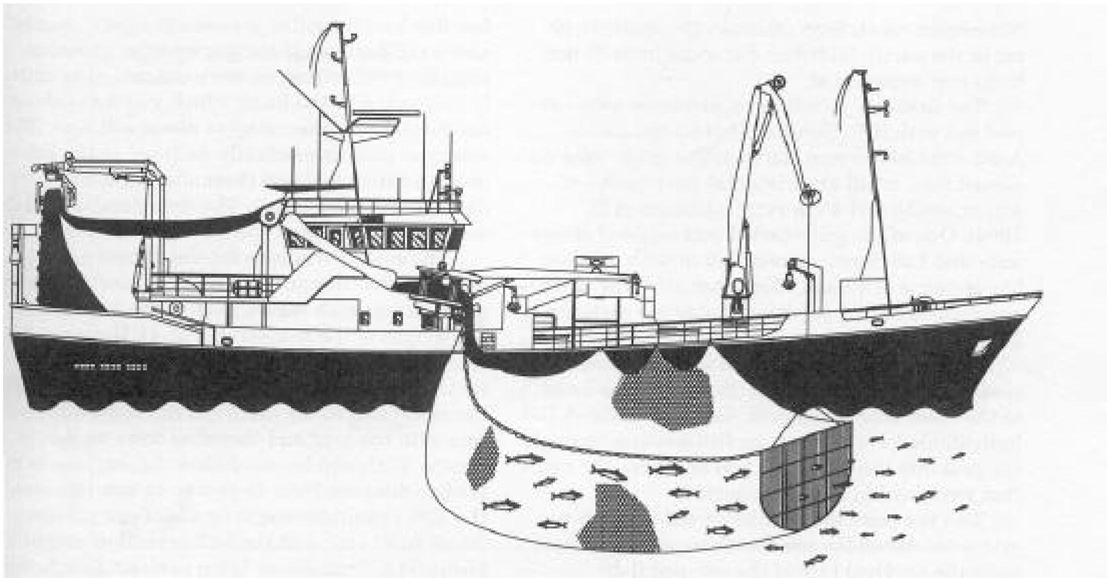


Source:
Isaksen, B. Implementation of responsible fishing technologies in Norway – A result of "unique" technology or due to the Norwegian management system (manuscript)

Box 23. Illustration of a Sort-X grid used in a demersal trawl.

Grids for seines have also been developed and proved as successful as grids for trawls in reducing the by-catch of small and juvenile fishes. An example is illustrated in Box 24. However, these have proved somewhat difficult to manipulate and use on board seiners. Square mesh panels have been installed in purse seine nets and proved equally good as an alternative.

[41] COFREPECHE 1999. Rédaction d'une publication sur les rejets et les prises accessoires des navires de pêche communautaires opérant dans le NE Atlantique. Rapport Final, Commission Européene Direction Générale de la Pêche, Projet 97/024.

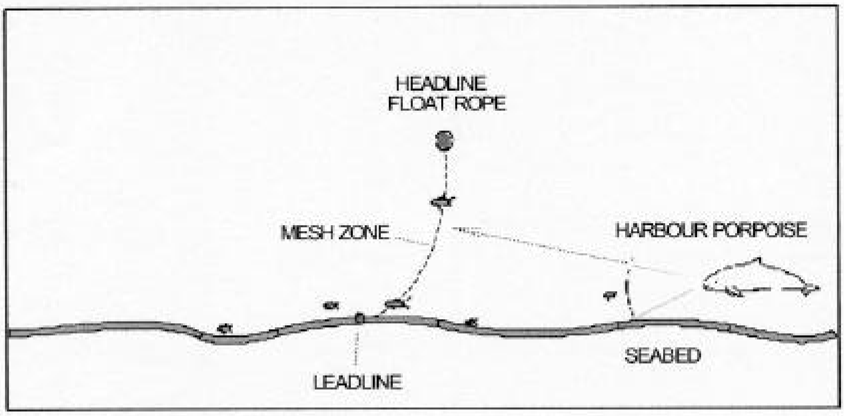


Source:
Beltestad, A.K. and O.A. Misund. 1996. Size selection in purse seines. pp. 227-233. Alaska Sea Grant College Program report 96-03.

Box 24. Illustration of a sorting grid mounted in a mackerel purse seine.

7.5 Cetacean acoustic avoidance devices (AAD)

The by-catch of marine mammals is of concern in a number of fisheries in EU waters, especially in the North and Celtic Seas. Particularly unacceptable levels of mortality have been reported in certain gill net fisheries. For example, between 1992 and 1994, it was estimated that 2,200 porpoises (6.2% of the Celtic Sea population) were entangled in gill nets in the Celtic Sea. Cetaceans swim into and are caught in gill nets when they fail to detect the headline and floats. The actual gill net meshing, although acoustically detectable at up to 10 m under ideal conditions, is far less detectable than fish prey and floats and headlines (Box 25). Furthermore, the actual gill netting may appear penetrable because of the diffuse echoes, causing the cetacean to attempt to swim through.



Failure to detect the headrope may occur when this is outside the vertical beamwidth of the sonar at the maximum detection range

Source: Woodward, B. and A.D. Goodson. 1994. Prevention of the by-catch of cetaceans by exploiting their acoustic capability. Final Report (12 months), Commission of the European Communities Study Contact, Reference PEM/93/04.

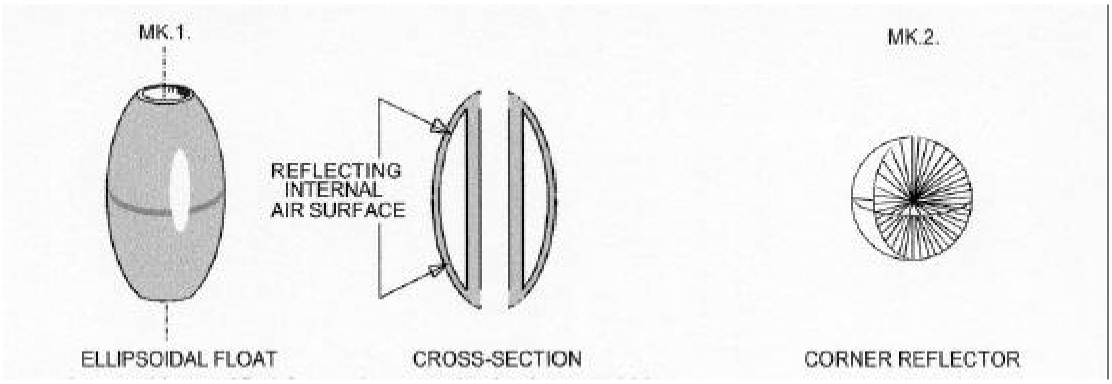
Box 25. Accidental capture of dolphins in fixed gears

Following these concerns, a number of projects have focused on methods of mitigating cetacean by-catches by inducing avoidance behaviour. These studies have studied active underwater acoustic beacons ("pingers") and the use of passive reflectors as well as cetacean behaviour and echo-location. There has been considerable international co-operation in this field of work both within the EU and with non-EU partners, particularly in the U.S., Canada and Japan.

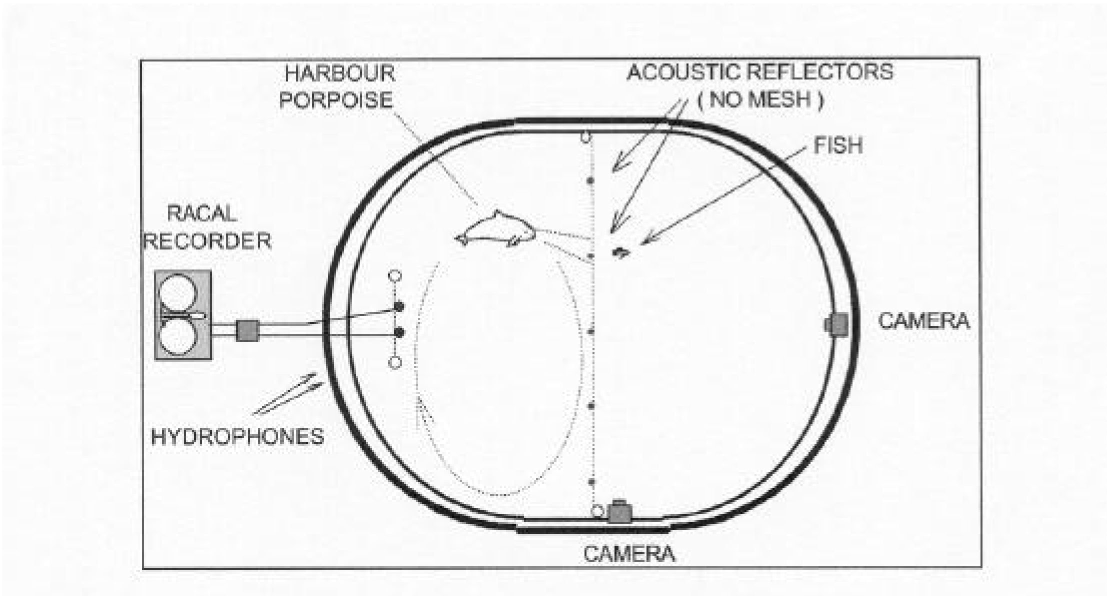
In an EU-funded project (illustrated in Box 26), experimental acoustic reflectors were designed and tested in sea trials. Significant differences in detectability were found between standard gill nets and those with reflectors, suggesting that such gear modifications may play an important role in reducing cetacean by-catch. Field data on dolphin behaviour and echo-location was also collected in underwater studies with seabed hydrophones and sonar buoys. This was used to optimise the design of the reflectors in relation to the dolphin´s sonar and to optimise the spacing pattern of reflectors on nets.

Studies have shown that significant reductions in cetacean by-catch can also be achieved with the use of sound beacons (or "pingers"). Preliminary work by described in Box 28 on a new generation of pingers suggests better results will be obtained in the future.

Acoustic reflectors were designed to enhance the acoustic detection of gill nets by dolphins. MK.1 is a commercial fishing float that must remain vertical in order to maintain a constant target strength. MK.2 is a metal experimental reflector. Deployment problems however need to be solved as these acoustic reflectors may cause tangling of the net.



The experimental set-up used to evaluate the effectiveness of acoustic reflectors in provoking avoidance behaviour in the harbour porpoise is shown below.



Source:
Woodward, B. and A.D. Goodson. 1994. Prevention of the by-catch of cetaceans by exploiting their acoustic capability. Final Report (12 months), Commission of the European Communities Study Contact, Reference PEM/93/04.

Box 26. Cetacean by-catch mitigation.

Future studies need to resolve problems in gear handling resulting from the attachment of reflectors and pingers. Active devices such as pingers are also more costly and require energy sources. Species specific studies of echo-location and behaviour in relation to warning devices and fishing gear are also required.

7.6 Bans on fishing gear

In an extreme form, a technical gear policy may operate to ban certain gear types which are considered to be too damaging in terms of discards. Such a policy has already been applied to EU drift net fishing for tuna, tuna-like species and swordfish. The advantage of gear bans are that they are easy to enforce by shore-based inspection, with 100% compliance being a realistic target. The disadvantage is that they involve the substantial cost of eliminating that fishing capacity altogether, or re-directing it to other fisheries.

7.7 Economic impacts of selectivity devices

Few research studies have directly investigated the economic costs and benefits of improved selectivity. One of the exceptions is the ECODISC Project described previously in Box 19. In addition to monitoring discards the ECODISC project also modelled the biological and economic benefits of improved selectivity to the trawl gear currently used in the North Sea *Crangon* fishery. The results indicated that the introduction of more selective gear would result in a net economic benefit when considering the impact on the *Crangon* and whitefish fisheries together. The analysis was based on estimates of a reduction of 15% of *Crangon* catch volume, and value of "recovered" lost landings of whitefish, particularly plaice, shown previously in Box 21.

The model suggested that the economic benefits of introducing selective gears to this fishery would vary greatly between individual countries, with effort levels and gross margins decreasing in Belgium, the Netherlands and the UK, whilst increasing in Denmark and Germany. These variations result from the fact that the costs and benefits of discard reduction are not distributed evenly. Furthermore a number of vessels have already adopted selectivity devices (they were already mandatory in Denmark at the beginning of the study) and these vessels have in effect been subsidising the other vessels in this fishery.

Note that a follow-up study is currently being carried out entitled "*DISCRAN: Reduction of discards in Crangon trawls*'[42]. This third and current study in the chain of research into discards in the *Crangon* fishery is due to be finalised at the beginning of 2001 and will generate more detailed catch and by-catch data in Dutch, UK, Belgium and German fleets for a range of net and sorting grid designs.

[42] Rijksinstituut voor Visserijonderzoek "Reduction of discards in Crangon trawls (DISCRAN)" Workplan (study in progress) (EC DGXIV 98/012). Co-ordinator: Rijksinstituut voor Visserijonderzoek, Netherlands

It is expected that the information will be directly used to define a technical regulation measure for *Crangon* fisheries. The project is being carried out in close contact with the fishing industry and it is hoped that the project team will be able to gauge how acceptable the new designs may be to the industry – a central element in the development of new gear designs.

Sorting grids are mandatory in certain fisheries, and are in widespread use in others. In most fisheries that have seen the introduction of grids, fishers have initially complained that they are unwieldy, unpractical and cause the loss of commercial species. However, in many cases the use of the grids has subsequently become a marked success. In some shrimp fisheries which were threatened with closure due to excessive levels of discarding, the introduction of grids has allowed these fisheries to stay open.

Experience from Norway, where this approach has been employed successfully, suggests that it takes a matter of a few weeks or months to master the new techniques (depending on the competence of the skipper and crew). A recurrent theme (especially in shrimp fisheries) is that once these technical difficulties have been mastered, fishers often use the grids out of choice. Used correctly, grids reduce the amount of discards to the point that sorting and cleaning the catch on deck becomes considerably easier. In one fishery (in New South Wales, Australia) the level of discarding dropped by 90% allowing skippers to fish with one crew member less.

7.8 Incentives for Introduction of selective gear types

Once sufficient practical research has been carried out, to determine that fishers can work successfully with new gear types designed to improve selectivity and thus reduce discards, the devices must then be introduced into the fishery, either through voluntary or mandatory schemes.

Some people argue that fisheries management agencies should provide economic incentives, for the installation and use of new gear to be effective. Possible options for consideration are by direct grant or preferential access to resources or both. In Norway, for instance, opposition to the introduction of sorting grids within the shrimp fisheries was overcome by at first restricting access to certain lucrative shrimp fishing grounds to those vessels which installed grids. The more open minded fishers who changed gears were soon able to recoup the expense of learning to fish with the new gear, by being given access to grounds that would otherwise have been closed to all shrimp fishing activity. Others followed, and a change to more selective gear occurred relatively painlessly.

However, such measures are dependent on the fishery. In the North Sea *Crangon* fishery, some fishers have already voluntarily swapped to using veil nets (a panel inserted in the belly of *Crangon* beam trawls) as a selectivity measure, whilst others have not. It would be unfair to introduce grants or incentives encouraging others to introduce these devices, particularly as those using the veil nets have been effectively subsidising the others in terms of higher prices resulting from the change.

The potential success of the different types of economic incentives used to introduce, and/or mitigate the effects of, a new gear therefore should be based on research which considers the economic circumstances and motivations of all fishers, and also the wider economic benefits that will be created outside of the target fishery.

7.9 Global application of selectivity devices

Perhaps the most optimistic scenario for the future is an extension of the use of sorting grids and other selectivity devices to reduce the by-catch of protected species, species of no commercial value and juveniles of commercial and non-commercial species.

The ICES Fisheries Technology Committee Study Group on Grid (Grate) Sorting Systems in Trawls, Beam Trawls and Seine Nets includes members form the EU, Canada and the USA. The Study Group recently reviewed the use of grids in fisheries around the world (Box 27) and found that in many fisheries, especially for shrimp, BRD use has increased significantly in recent years and these devices were extremely successful in reducing by-catch, mostly consisting of juvenile fishes. For example, in the Canadian otter trawl fishery for the 100,000 tonne northern shrimp (*Pandalis borealis*), the Nordmøre grid was made mandatory in 1994 and results show that by-catch of fish was reduced by 85% compared to the pre-grid era.

Country	**Number of shrimp vessels using grids**	**Number of finfish vessels using grids**	**Number of vessels using grids in industrial fisheries**	**Number of vessels using grids for other species (e.g. sea turtles)**
Argentina	75			
Australia	~ 100			
Canada	171(up to 100 more in 1998)		50	
Faeroe Islands	9 distant water	8 distant water		
		14 domestic		
Greenland	5 to 10	2 or 3		
Iceland	100	60		
Norway	450	112		
Russia	> 100	350		
Spain		18		
Sweden	13 (voluntary)			
Thailand			3000	
U.S.A.	150			
				36000

Source:
ICES Fisheries Technololgy Committee. 1998. Report of the Study Group on Grid (Grate) Sorting systems in Trawls, Beam Trawls and Seine Nets. ICES CM 1998/B:2.

Box 27. Estimates of grid usage (1998)
(note that many countries are not included because of lack of data)

8 Conclusions

There are many reasons for returning catch to the sea. Some unwanted catch is an inevitable consequence of many modern fishing operations, and this is frequently discarded by fishers. In the EU and some other developed regions, discards may also be caused by management regulations which prohibit the landing of fish accidentally caught in contravention of regulations on size, catch composition or quotas. In addition, catch may not be wanted by fishers due to economic reasons, frequently related to lack of demand and low prices, or to save space for more profitable fish.

Discard rates vary considerably both within and between fisheries, so it is often a problem to find out how much fish is actually discarded. Extensive sampling over a long time is required in order to understand the complex interactions of fisheries biology, gear technology, economics and human behaviour which give rise to the discards problem. Understanding is also hampered by the use of the different methodologies used for studying discards, in some cases within the same fishery. EU funded projects which encourage a harmonised and collaborative approach between member states have therefore done much to improve the quality and value of discards research, particularly on basic measurement of discards.

High rates of discards are particularly associated with trawl fisheries. The best studied regions within the EU are the North Sea and the Irish Sea. High discard rates of commercial species (sometime up to 80% of the landed catch) are encountered in the North Sea beam trawl fishery for sole and plaice, in the demersal otter trawl sector for cod and haddock, and in crustacean trawling for shrimp and *Nephrops*. Other EU fishing zones, such as the Mediterranean and the Baltic Seas, are not well researched, and the state of knowledge here is relatively poor. However, it is known that discarding is less of a problem in these regions due, at least in part, to the higher levels of utilisation of small fish.

Few discards survive, and whatever the reason for their occurring, the practice of discarding is seen by many as undesirable. This is especially so when fish resources are exploited at or beyond sustainable levels. Here the capture and discard of juveniles represents a loss of future economic yield and an additional, and possibly critical, source of mortality to the fish stock. Discards also impact directly on the ecosystem, sustaining higher than natural populations of seabirds and other marine scavengers. Whilst reduction in fishing effort must continue to be the main focus of fisheries management, both globally and in Europe, because of these negative impacts discard reduction is also a highly desirable part of the fisheries policy framework. For this reason, much research work continues with the objectives of improving knowledge as a basis for a better regulatory regime, and designing technical ways of reducing the amount of unwanted catch in fishing operations. These technical measures exploit physical or behavioural differences in different parts of the catch to separate target catch from by-catch, frequently by the use of special mesh panels or grids inserted into trawl nets. Acoustic devices have also been found to be effective in reducing the catches of dolphins in some fishing gears.

There is therefore no single solution to the complex problem of discards in fisheries. Certainly, improved understanding of the circumstances under which discards occur (eg. through the development of models) and better and more timely data, will continue to improve fisheries management decision making in respect of discards. The development and dissemination of new and improved selectivity devices will also provide tools for discard reduction. There is also the possibility that changes in demand will result in better utilisation, especially for small pelagic fish. Once a low level of discarding is achieved in any fishery then, as the Norwegian experience has shown, a complete ban may become feasible. In the meanwhile, many developed nation fisheries will continue to suffer from a chronic level of discarding. Only through continuous improvement to our state of knowledge of this subject can we be sure that the impact of this is kept to a minimum.

Annex 1: Experiences in other areas

The nature and scale of the by-catch and discarding problem varies from country to country and is largely a function of socio-economics and the type of fishery.

Developing tropical countries

In the multi-species fisheries of the developing tropical countries, there is very little discarding, since even the smallest fish caught are used for animal feed or dried or in the form of other fish products such as sauces for human consumption[2]. The bulk of discards in these countries originate from shrimp trawl fisheries where very small mesh sizes are used. Gear conflicts with inshore artisanal fishers has resulted in trawl exclusion zones, thereby reducing the by-catch of juvenile fishes. However, the demand for by-catch in these countries and the nature of the shrimp fisheries means that there is little incentive to reduce by-catch.

Compared to the tropical multi-species fisheries, by-catch and discarding is generally a serious problem in temperate fisheries of developed countries and is the focus of much research and management effort.

Japan

In Japan for example, by-catch and discard research and management is well advanced. The approach involves a wide range of technological measures as well as spatial and temporal closures of fishing grounds[43]. There is an extensive range of technical measures (gear modifications) and catch handling and sorting improvements is unsurpassed by any other fishing nation, with research and development projects addressing particular métiers along the Japanese coast. Local Cooperative Associations play an import role under the community based fisheries management plan, with measures in place to protect pawning fish and juveniles and reduce catches of non-target species and juveniles.

Alaska

In another example, Alaskan fisheries (which account for approximately 50% of the total U.S. harvest) also involve a considerable volume of discards. These consist of prohibited species such as halibut and salmon, species caught when the fishery is closed (regulatory discards) and undersized target species and low value species

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[2] Pauly, D. 1996. Fleet-operational, economic, and cultural determinants of bycatch uses in southeast Asia. pp. 285-288, In: Solving Bycatch: Considerations for Today and Tomorrow. Alaska Sea Grant College Report Nº 96-03, University of Alaska Fairbanks.

[43] Chopin, F., Y. Inoue, Y. Matsushita and T. Arimoto. 1996. Conservation harvesting technology – a perspective from Japan. pp. 293-300, In: Solving Bycatch: Considerations for Today and Tomorrow. Alaska Sea Grant College Report Nº 96-03, University of Alaska Fairbanks.

(economic discards)[44]. The approaches to the Alaskan by-catch problems have involved:

1. Fishery closures when by-catch limits for specified prohibited species are reached. For many species such as halibut these are gear and area specific and may be divided among fisheries as by-catch allowances.
2. Industry funded mandatory observer programmes, with observers on board at all times for vessels greater than 38 m, and the 30% of the time the fishing gear is being retrieved for vessels between 18 and 38 m. Observers are also required for processors on shore.
3. An extensive record-keeping and reporting programme requiring mandatory log-books and processor reports. The National Marine Fisheries Service (NMFS) has been developing a system that would allow real-time data recording and transmission.
4. Research on by-catch practices within various fisheries and gear types, discard mortality, the relationship of by-catch to stock status and the effect of by-catch on other fisheries.
5. Gear restrictions, including biodegradable panels in groundfish pots and gear specifications and modifications, particularly in trawls and gill nets.
6. A vessel initiative programme was initiated in 1991, whereby specific vessels are held accountable for the by-catch rate. The basis for this approach is the observation that specific vessels in particular fisheries often account for a significant proportion of the by-catch and discards.
7. An individual vessel fishing quota (IFQ) programme for the hook and line sablefish and halibut fishery which allows the retaining of by-catch of the non-target species in each fishery as long as the fish are of legal size.

However, as is the case in all over-capitalised fisheries, the race for fish in Alaska (with the extreme case being the one-day halibut season) exacerbates the by-catch and discarding problem and increases the frequency of area and time closures. As is the case for EU fisheries, the real solution must involve a decrease in effort.

[44] Pennoyer, S. 1997. Bycatch management in Alaska groundfish fisheries. pp. 141-152, In: Pikitch, E.L., D.D. Huppert and M.P. Sissenwine (editors), Global trends: fisheries management. American Fisheries Society Symposium 20, Bethesda, Maryland.

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