Encyclopedia of Life Support Systems (EOLSS) ©UNESCO-EOLSS
January 1999

THE PROBLEM OF DISCARDS IN FISHERIES

Y. Morizur[a], B. Caillart[b] and D. Tingley[c]

[a] : Ifremer, BP 70, 29280 Plouzané, France
[b] : Cofrepêche, BP 70, 29280 Plouzané, France
[c] : MacAlister Elliott and Partners Ltd, 56 High Street, Lymington, Hants, UK

To cite this chapter : Morizur Y., B. Caillart, D. Tingley, 2004, The problem of discards in fisheries, in "Fisheries and Aquaculture: Towards Sustainable Aquatic Living Resources Management", edited by Patrick Safran, in "Encyclopedia of Life Support Systems (EOLSS)", Developed under the Auspices of the UNESCO, Eolss Publishers, Oxford ,UK, [http://www.eolss.net], chapter 5.52.12, 17p.

Keywords: discards, catch, bycatch, fishery, gear, species, target, impact, biology, ecology, economic, social, world, overview, wastage, marine

Glossary of terms : Refer to §2 of the Contribution "Controversial definitions"

Short Contents List

1. Introduction

It is now clear that the world's fishery resources are being subjected to exploitation at or above their capacity to produce maximum sustainable yields. At the same time as these trends are being felt, there is a very large wastage of fishery resources from discarding unwanted catches at sea. At the end of each fishing operation a part of the catch is often returned to the sea after sorting by the fishermen. A 1994 FAO report provided an estimate of global discards in commercial fisheries of 27 millions of tons per year compared to 50 million tons of direct human consumption. A more recent FAO document estimated that discards were in the order of 20 million tons in 1997.

The majority of the world's fisheries are multi-species in nature and consequently it is difficult to optimize management measures for all the species caught. Management measures are most often decided from the target species perspective. However, total catches are a compound of commercial species and also non-commercial and prohibited species. In addition, catches often contain juvenile commercial species. The use of selective gears attempts to avoid capture of these young, small- sized fish. Normally the technical regulatory measures include gear characteristics (e.g. mesh size in nets) and also minimum landing sizes in an attempt to ensure fishermen use the most appropriate gears and so limit discards.

Discards that cause the most problem are of species or individuals which do not survive when they are returned to the sea. The survival rate depends on the combination of species and fishing practice (e.g. gears). Towed gears generate low survival rates whilst at the other end of the spectrum, fixed gears do not generally damage individuals and so have very low discard mortality rates. Crustaceans, for example, have a higher survival rate after release than many fish species.

2. Controversial definitions

A variety of terms has been used in the literature related to wastage in fisheries and there have been many attempts at definition. Discards do not generally include offals which are returned to the sea during primary processing on board fishing boats. It is necessary to give a more precise definition of the word " catch " which can refer to total catch and also the retained catch (i.e. landings). The term " by-catch " used in scientific and popular literature has been subject to a variety of interpretations, some of which are overlapping or contradictory. By-catch can sometimes mean discards of target and non-target species. It can also be used as a generic term, applying to that part of the catch made of non target species or species assemblages. Therefore, by-catch can include discarded catch plus the retained catch of non targeted species. " Incidental catch " is an other controversial term which sometimes refers to the retained catch of non-targeted species and other times can mean catch of undesirable species like mammals, some of which are discarded because of regulations covering protected species. " Protected species " are those species under international protection as outlined by international conventions. In some regulatory frameworks (i.e. European fisheries regulation) protected species are dealt with alongside commercial species under fisheries management policies.

In this paper, catch will be used to mean total catch including target and non-target catch, landings will be referred to as retained catch and discards as non-retained catch. Care should be taken with interpretation of the discard ratio which is the ratio of non-retained catch versus total catch. This ratio may be expressed in numbers of individuals or in weight according to available data.

3. Reasons for discarding

Three are three main reasons for discarding at sea: management measures and economic and technical reasons.

Management measures in some fisheries place a legal obligation on fishermen to discard a part of their catch at sea. When the allowable catch quota is achieved for a species, landings of excess catch are prohibited and the fisherman theoretically have no other alternative but to dump the over quota volume at sea. However, in reality over quota catches are often landed illegally and are termed 'black fish'. Minimum landings size regulations protect juveniles from being landed but those that are caught by fishing gear must be discarded to ensure compliance. In some fisheries a specific small mesh size is allowed for a target species of small size but in order to protect other species being caught, there is a maximum threshold allowed in the landings for commercial non-target species expressed as a percentage of the retained catch. Closed and protected fishing areas are also used to restrict the catch of some commercial species which can not be caught at all or are allowed to be caught in a limited proportion. Some species are protected by regulations or international conventions such as the CITES list of endangered species (marine mammal, turtles, etc.). and should be immediately returned to sea when caught.

There is often a strong economic motivation for discarding. Some species have no commercial value locally or seasonally due to poor conditions whilst other species are caught in unmarketable sizes. After the majority of hauls, and especially during long trips, the catch is sorted to retain only that part of the catch which maximizes value. This is commonly referred to as high-grading and discards are made of part of the catch after taking into account the value of species, the processing time on board and the remaining storage space on board. Fish that are damaged during operations are often discarded because of their unmarketable aspect. Catch is sometimes returned to the sea even before it reaches the deck. This can occur on some pelagic trawlers if the species composition

in the catch is not deemed to be of sufficient value before pumping process to bring that catch of board is initiated.

In some cases, a part of the catch is lost for technical reason before arriving on board. This induced mortality is an accidental discard which can be estimated and can occur when catch is too heavy to be hauled on deck.

The regulatory, economic and technical reasons for discarding are summarized in Figure 1 along with the different steps of fishing. For each commercial species, there can be at least seven reasons for discarding:

- damage
- unmarketable size
- undersized individuals (MLS)
- quota (achieved)
- percentage of bycatch (achieved proportion)
- high-grading (maximization of the value of the catch)
- fishing techniques

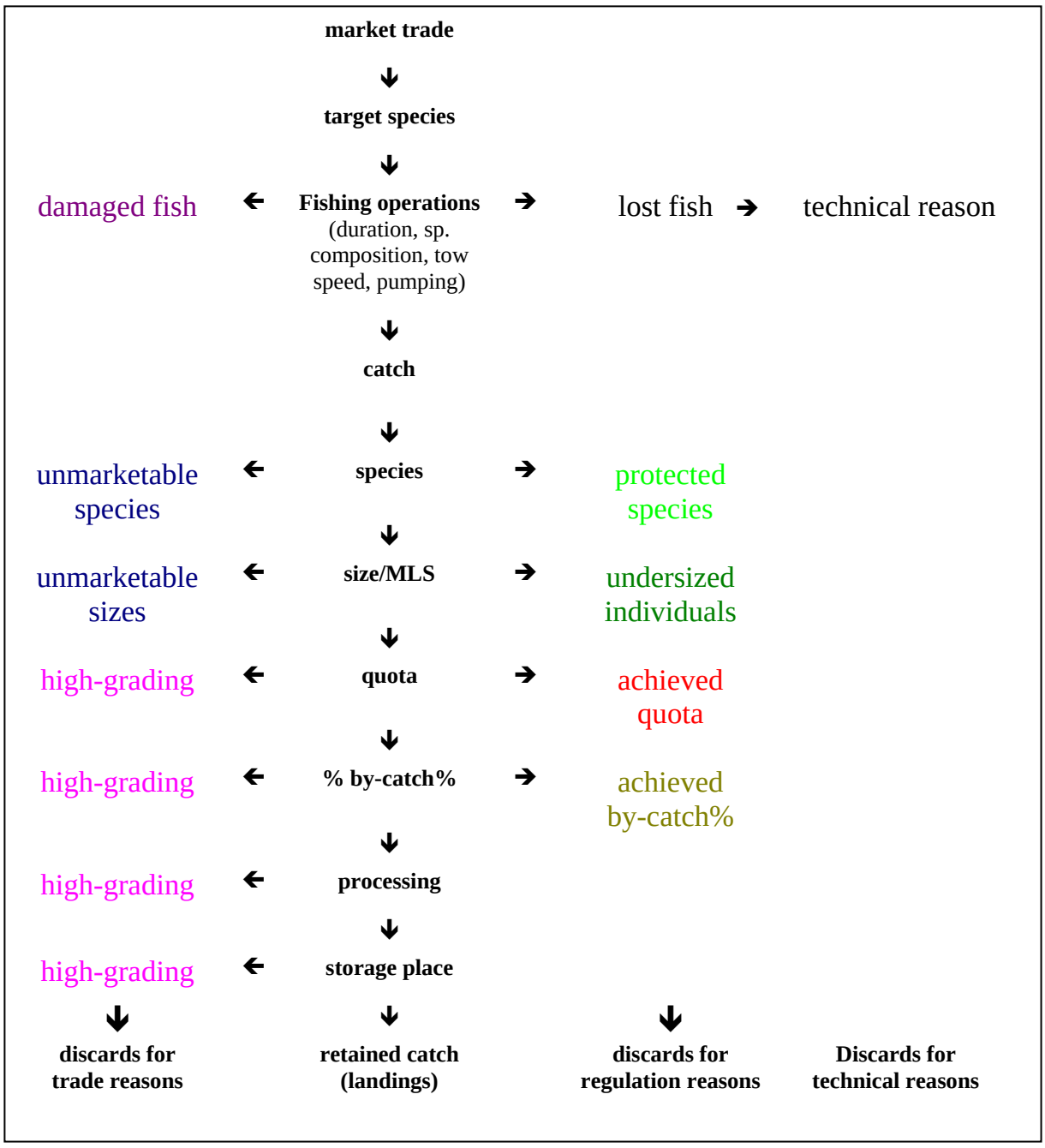


Figure 1 : Chart explaining the reasons for discarding during the process of fish catching

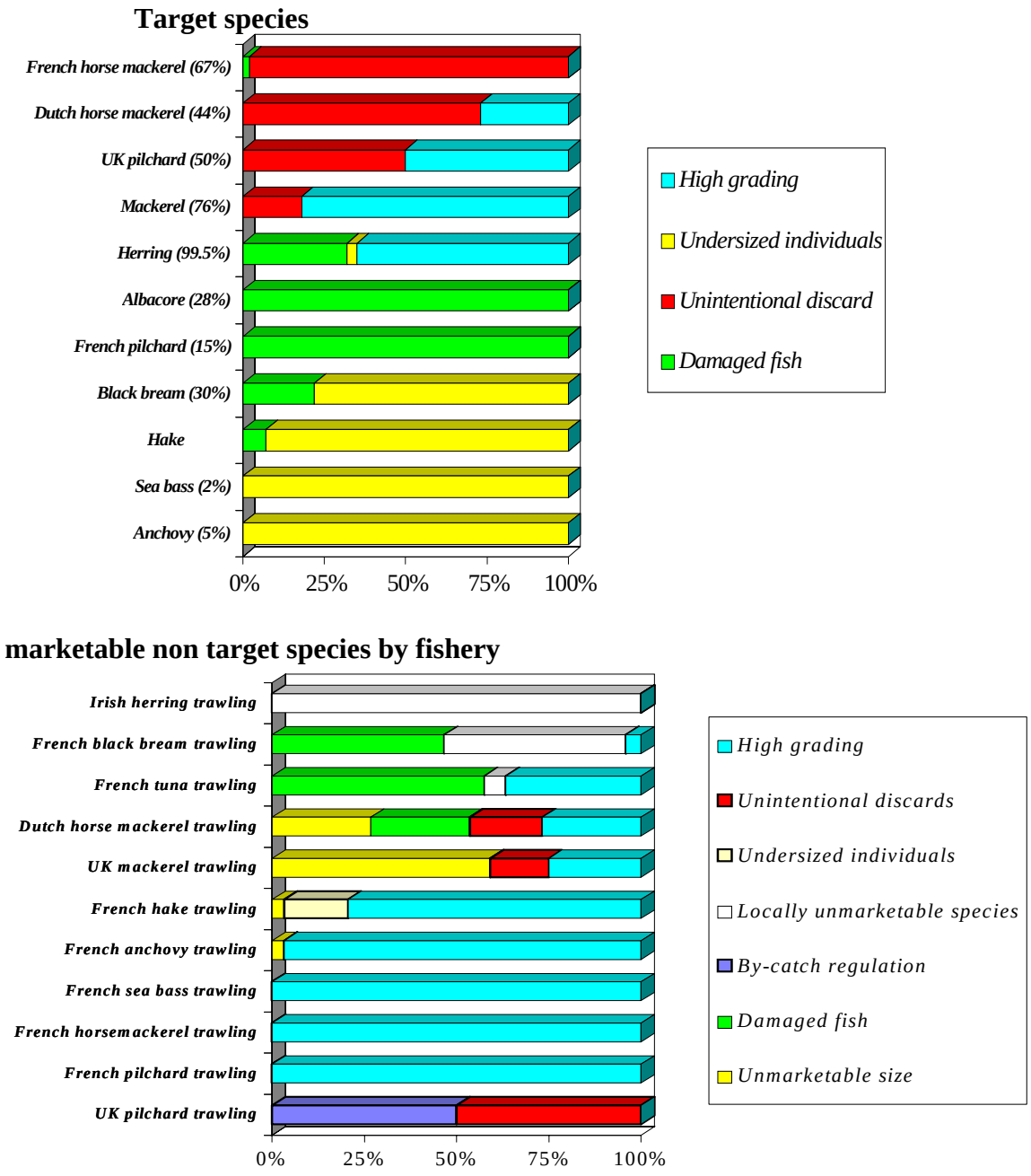


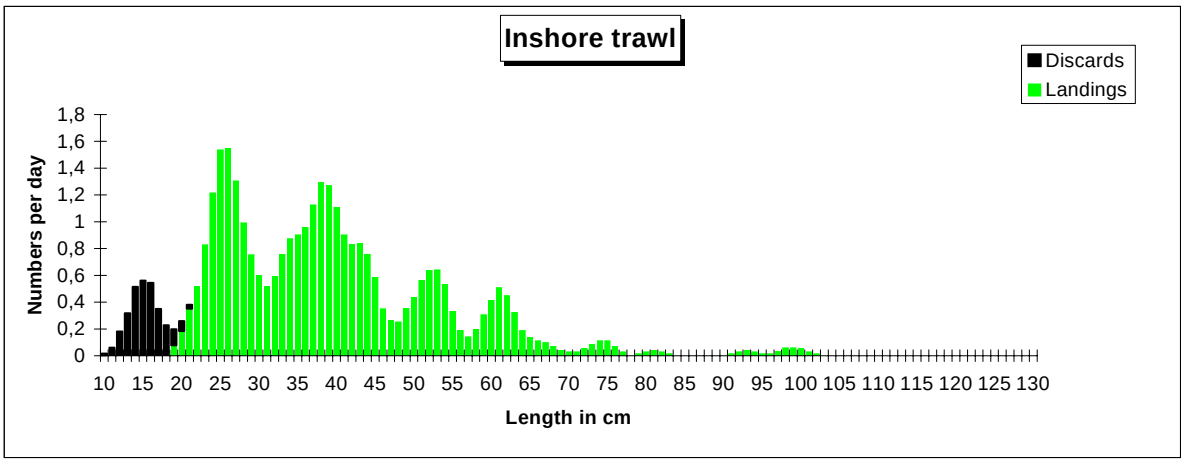
Figure 2 : Reasons for discarding target species and commercial non target species in pelagic trawl fisheries of the Northeast Atlantic.
Morizur Y., Tregenza N., Heessen H., Berrow S., Pouvreau S. (1997). *By-catch and discarding in pelagic trawl fisheries*, 124 pp. European Commission, DGXIV- Study /93/017.

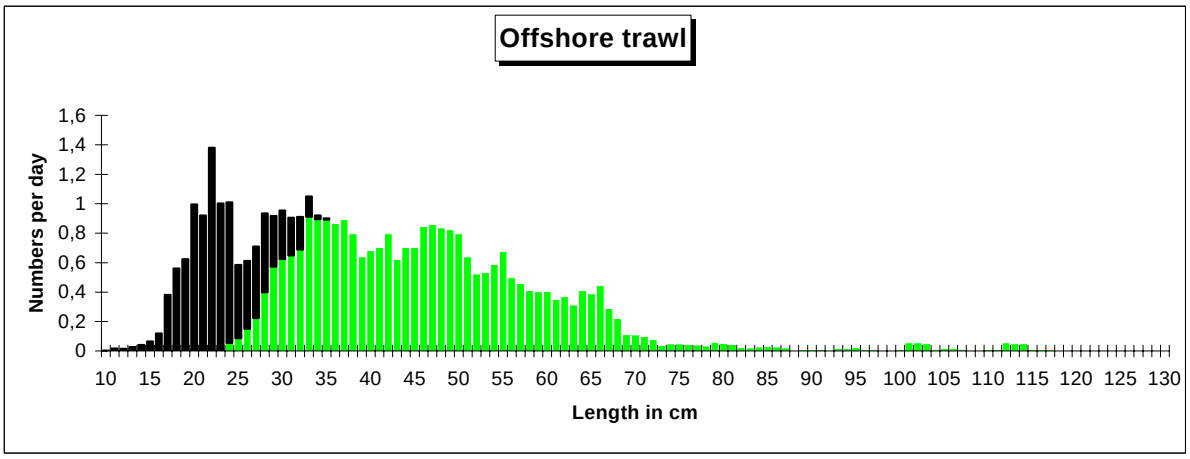
The problem of discard wastage cannot begin to be remedied unless the motivation to discard is understood. An example of reasons for discarding is taken from the study of discards in pelagic trawl fisheries of the North East Atlantic (Figure 2). Several ways of estimating discards exist but the most effective solution is to place observers on board vessels.

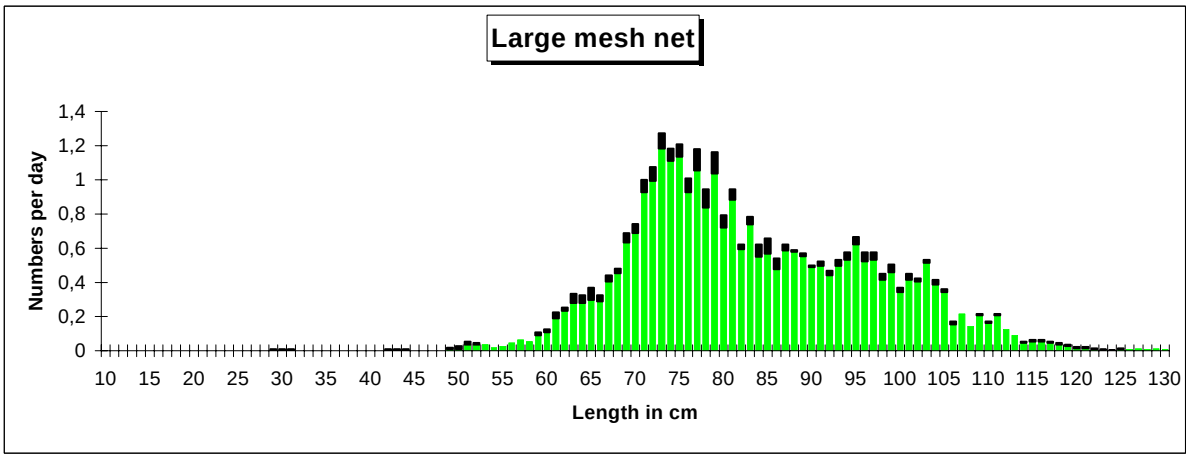
4. Variability in discarding practices

A high variability exists in discarding practices. Non target species and discards are quantitatively and qualitatively unequal in the different fisheries which have been investigated according to fishing techniques and areas. The selectivity of fishing operations varies depending on the type of gear being used which also has an effect on the survival rate of discards. Using the same fishing gear in different areas can induce different discard problems depending on local bio-diversity and species abundance of the fishing area.

The quantity and size of the discarded individuals of one species, sampled in the same area are not necessarily the same. This difference is illustrated in the western English Channel fishery for the anglerfish (Figure 3) and is due to gear selectivity and mesh size. The trawling discards are composed of juveniles and those of netting are damaged adult individuals.







Anglerfish catches in numbers per fishing day for trawling and per hauling day for netting

Figure 3 . Length compositions of anglerfish in catches (landings and discards) with different gears and mesh size (50-60 mm , 80 mm ; 270-320 mm).
Morizur Y., Pouvreau S., Guénolé A. (1996). *Les rejets dans la pêche artisanale française de Manche occidentale*, 127 pp. Collection Pêches maritimes, IFREMER, France.

Discards quantity can be locally different because of market and fishing practices. For example, a precise size range of a species can be landed specifically for the potting vessel bait market. This activity was observed for red gurnard in a study of discards from French inshore trawling in the Western English Channel (Figure 4). If a fishery is located in a nursery area, a high discard rate can be a result of the presence of juveniles although to counter this regulatory policy can be varied in a way that minimizes discards by controlling the fishing area and season.

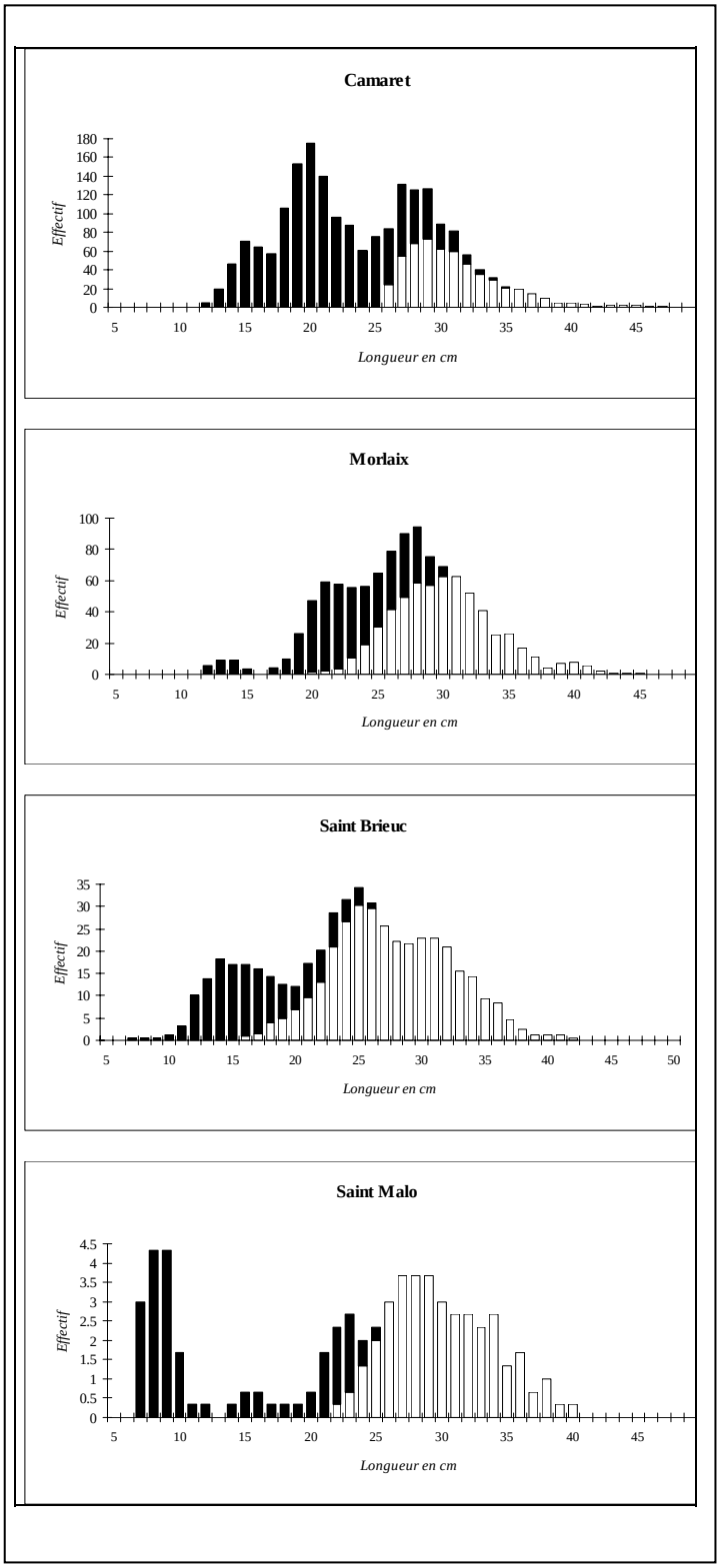


Figure 4 : Length compositions of red gurnard discards and landings at French ports from the Western English Channel (Morizur et al., 1996). At Saint-Brieuc, a size range is landed to be used as bait for potting vessels instead of being discarded.

For all these reasons, the level of discards is different according to world areas (Table 1). Just over one-third of total discards originate from fisheries conducted within the Northwest Pacific. The main other areas are Northeast Atlantic, West Central Pacific and Southeast Pacific. All species are subject to different levels of discarding (Table 2). For example, shrimp and prawn fisheries suffer the highest rates of discarding while lobster fisheries are among the least affected, with discards often being of released alive.

As discard ratios are typically expressed by weight or numbers, it is impossible to conclusively rank fisheries by the highest recorded discard ratios. The discard rate varies according to the gears used and Table 3 indicates the discard rate by weight. Shrimp trawls create the highest discard ratios whilst pelagic gears (pelagic fish trawl and purse seine) generally have the lowest discard rates. A high variation is observed between pots and trap fisheries, with the highest rates found in the Bering Sea.

AREA	**% [(a)] of global discards**
Northwest Pacific	33.81
Northeast Atlantic	13.59
West central Pacific	10.28
Southeast Pacific	9.63
West Central Atlantic	5.93
West Indian Ocean	5.45
Northeast Atlantic	3.42
Southwest Atlantic	2.97
East Indian Ocean	2.97
East Central Pacific	2.84

[(a)]: *% expressed as a % to global world discards*
(modified from FAO, 1994)

Table 1 : Top ten world area with the highest weight of discards (modified from FAO, 1994*).*

Species groups	% [(a)] of global discards
Shrimps, prawns	35.21
Redfishes, basses, congers	13.44
Herrings, sardines, anchovies	10.32
Crabs	10.28
Jacks, mullets, sauries	9.65
Cods, hakes, haddocks	9.40
Flounders, halibuts, soles	3.50
Tunas, bonitos, billfishes	2.74
Squids, culletfishes, octopuses	0.71
Lobsters, spiny-rock lobsters	0.42

[(a)]: % expressed as a % to global world discards
(modified from FAO, 1994)

Table 2 : Top ten of species group with the highest weight of discards.

Shrimp trawl	0.91	0.94
Gear	**Discard rate [(a)] mini**	**maxi**
Shrimp trawl	0.91	0.94
Non pelagic fish trawl	0.67	0.84
Pelagic fish trawl	0.00	0.01
Longline	0.21	0.53
Purse seine	0.00	0.45
Danish seine	0.26	0.33
Pot/Trap	0.26	0.78

[(a)] : discard rate is expressed as discards / total catches
(modified from FAO, 1994)

Table 3 : Discard rates by gear type.

In many of the world's regions, more than half of the total volume of discards is generated by shrimp fisheries. Discard volumes from the all shrimp fisheries in the world were estimated at 9.5 millions tons by FAO (1994). These fisheries are mainly concentrated in the Northwest Pacific and West central Pacific (these two areas represent more than half of the total estimated global discards) and in the West central Atlantic.

5. Case studies

The following regions have been chosen to illustrate the variety and extent of the discards problem in fisheries. The geographical focus ranges from the Northwest Atlantic fisheries, to the Northeast Atlantic region, which is primarily fished by European Union member states and the Madagascar shrimp fishery.

5.1 The Northwest Atlantic fisheries

The results of a comprehensive discard study program in the U.S. fisheries Northwest Atlantic region were reported at a 1998 symposium of the American Fisheries Society. Discard problems in this area manifest in several important ways:

- marketable species too small
- species with no current market
- protected species caught unintentionally.

The discard rates of sub-legal sizes of species such as haddock and yellowtail flounder *Limanda ferruginea* appear to vary with the year class strength. This is accentuated by the fact that fishermen are attracted by the catch of abundant year classes and such behavior increases the quantity of legal discards. The example of the strong 1987 year class of yellowtail flounder on Southern New England illustrates the discard problem in the area. In 1992, 46.5 million undersized (sublegal) fish which represents about 60 % of the year class were discarded. The foregone value of this catch due to discards is conservatively estimated to exceed US$ 50 million.

The catch of non-marketed species is also relatively high. The predominant non target species caught in the yellowtail flounder fishery of Southern New England region is skate *Raja erinacea* which is not used for human consumption and is landed only for bait. Thus large quantities are discarded. Otter trawl and gillnet fisheries of this area have discards of spiny dogfish *Squalus acanthias*, red hake *Urophycis chuss*, sculpins, sea raven *Hemitripterus americanus*, four-spot flounder *Lepidorhombus boscii* and ocean put *Macrozoarces americanus*. In the Gulf of Maine gillnet fishery targeted at cod, pollock and spiny dogfish, most of the discards result from unmarketable species.

Some catches of protected species (marine mammal, turtle and bird species) are reported in various fisheries, mainly those using long line or gillnet gear. Catches of dolphins, pilot whales *Globicephala melaena* and other marine mammal species and turtles have been monitored in offshore fisheries.

The data collected during 1989-1992 from the mixed species otter trawl fisheries of the Georges bank-Southern New England show that the discard rate for all species caught varies significantly according to mesh size (Figure5). This result has implications for the design of mesh retention studies in order to decrease the amount of discards in that area.

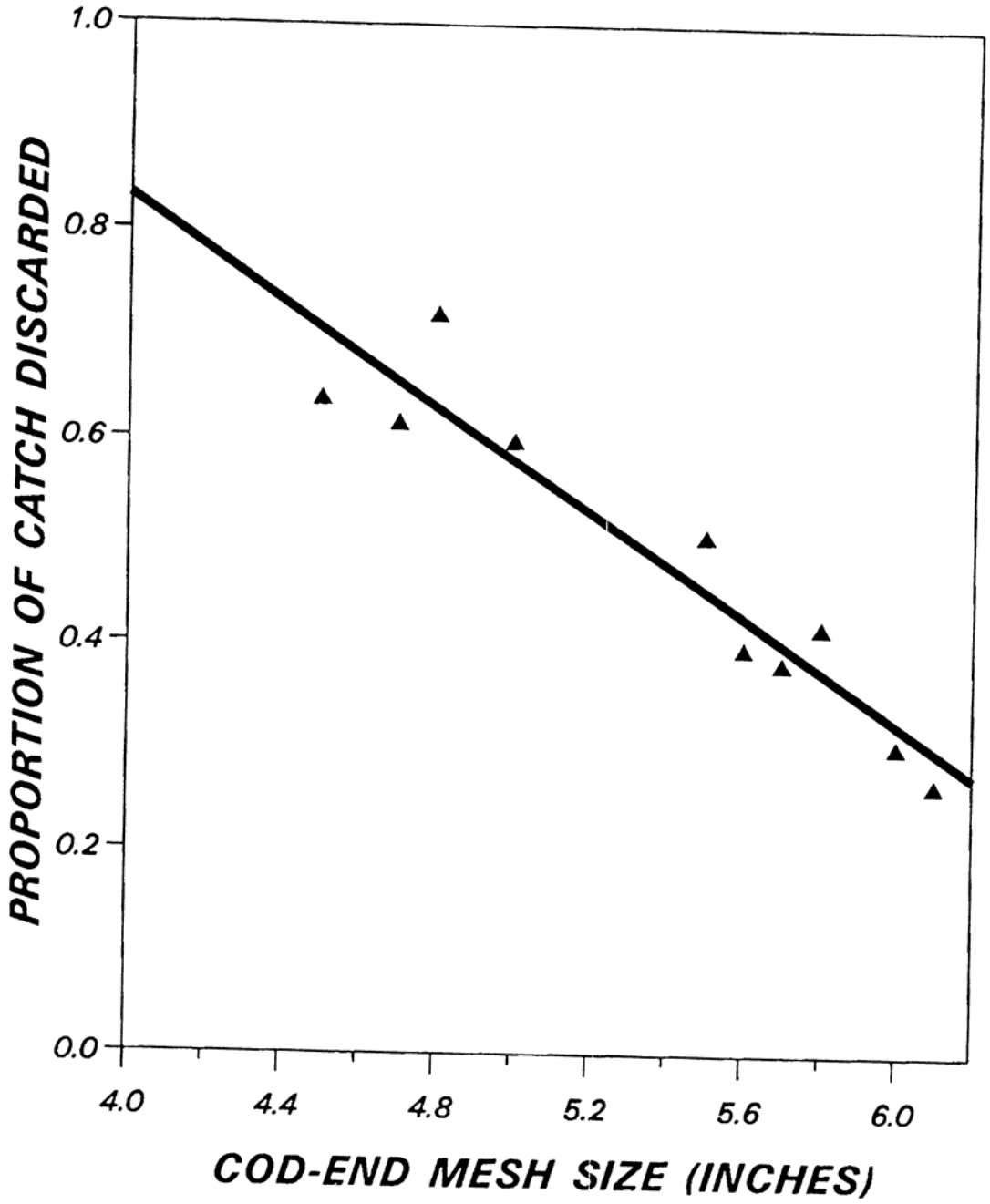


Figure 5. Effect of mesh size in trawls on the proportion of discards for all species in the Northwest Atlantic off the U.S., 1989-1992.
Murawski S.A. (1993). *Factors influencing by-catch and discards rates: analyses from multispecies / multifishery sea sampling*, 17 pp. NAFO SCR Doc. 93/115.

Differences also appeared according to the principal species sought. Flatfish fisheries produce proportionally greater discards while fisheries for groundfish (e.g. silver hake) and pelagics produce the lowest discard rates. The directed skate fishery also produces a relatively low discard rate but in general skate are discarded in quantity in most trawl fisheries; the overall discard rate is 89% for that species. Other factors influencing discards were year and tow duration.

5.2 The European Union fisheries

In the Northeast Atlantic region, the European Union encourages studies about discards. In 1992, the European Commission provided a synthesis report about discard practices in Europe. Updated reports are under-progress.

The problem of discards has been studied in some details for the North Sea where a number of different fisheries are prosecuted, using a variety of gears fishing for various target species. Some of the problems are exacerbated by the fact that different fishing nations exploit the same stocks.

The North Sea discard situation is summarized in Table 4. It can be seen that, in most instances, discards are made up of target species considered unsuitable for landing with the main reasons being:

- undersized fish
- quota already reached
- target species in poor condition for market (i.e. not enough eggs or fish exhausted after reproduction)

Fishing gear	Fisheries	**Discards**
Active demersal gears		
Trawl (for human consumption)	Nephrops, cod, haddock, whiting	Target species undersized, by-catches
Trawl (for fish meal)	Small fish (sprat, pout, sardine, sandeels)	Few, non selective fishing
Purse seine for demersal species	Cod, haddock, whiting, plaice, sole, …	Target species undersized, by-catches
Shrimp Trawl	Northern shrimp	Flatfish and juveniles of gadids
Beam Trawl	Flatfish (sole and plaice)	Target species undersized, by-catches, benthic organisms
Dredge	Shellfish	Flatfish, damages to benthic organisms
Active pelagic gears		
Seines, pelagic trawls	Herring, mackerel, sprat	Few discards of target species
Passive gears		
Nets	Various fish species (cod, turbot, monkfish)	Birds, seals, by-catches
Traps	Shellfish	Target species undersized
Longline and handline	Demersal species	Birds, some by-catches (sharks)

Table 4. : Overview of the main fisheries in the North Sea, with target species and discards.

Although the current situation raises some issues of concern for the future of the industry, little is known about the precise discard rate in the various fisheries. Performance of the demersal trawl gear, which is thought to be one of the less selective gears, have been examined. For example, in the North Sea Norwegian lobster *Nephrops norvegicus* fishery, approximately 22 per cent of total catches in weight are landed. Discards include *Nephrops* themselves (damaged, undersized) of which between 40 to 75 per cent are believed to survive. Non target species discards proportions were estimated as being whiting *Merlangius merlangus* up to 24 per cent, dab *Limanda limanda* 8 per cent and various species of skates (Rajidae). The North Sea beam trawl fishery provides another example of discards associated with demersal trawl gear. Vessels target primarily sole *Solea vulgaris* and plaice *Pleuronectes platessa* but also catch turbot, cod, brill *Scophthalmus rhombus*

and whiting. The proportion of landed weight varies between 5 and 43 per cent of the caught weight. Dab is the main species discarded (61 per cent in weight) followed by plaice (24 per cent in weight) and whiting (7 per cent in weight). The main reason for discards is the small size of the individuals. Pelagic trawling may be more species selective as catches of the target herring *Clupea harengus* and mackerel have little by-catch, but up to 15 per cent of the target species may be discarded due to quota limits (individual quotas prevail in this fishery) or inappropriate sizing for the market.

This North Sea situation is very conflicting and casts doubts over the way stocks are managed. For example, the aggregate quota for haddock is approximately 130 000 tons for the North Sea, but discarding data show that about 60 000 tons are discarded at sea, and the spawning biomass varies between 150,000 and 160 000 tons. These figures demonstrate that the volume of fish actually caught from the sea, though approximately half is discarded, is much greater than the official catch rates set by regulatory quotas . The same applies for whiting which is also protected by a TAC, but heavily discarded in many fisheries. This hampers durable and effective management of the natural stocks.

5.3 The shrimp fishery in Madagascar

Around eighty freezers trawlers of between 15-35 meters long work in this fishery and in 1993 8 360 tons of shrimps were landed whilst at the same time 35 000 tons of fish and crustaceans were discarded. The mortality rate of discards was particularly heavy, being estimated at 95 per cent. This large discard ratio is due to the low price of fish compared to shrimp even though the discards represented 20 000 tons of consumable fish.

Over 100 species of fish are caught by the shrimp trawlers, but only 30 of them make up 80 per cent of the total weight of the discards. The discards include valuable species such as barracuda *Sphyraena* sp., kingfish *Scomberomorus commersoni*, turbot *Psettodes erumei* and croaker *Otolithes ruber*. The average yearly weight of such valuable species is 4 700 tons. Discards also include less valuable species which could have some utilization on the local market. These are notably Indian mackerel *Rastrelliger kanagurta*, horse mackerel *Decapterus russeli* and sardine *Dussumeria acuta*. Annual yields of these species are estimated at 20 000 tons.

In the case of the shrimp fishery, the high value of the products and the dependency of the country on this activity for hard currency earning makes difficult the implementation of any regulation that would substantially decrease the catches of target species. Rather, given the high proportion of edible species caught, research programs have established some procedures to collect the by-catches at sea from the shrimpers and process and market them. This provides an alternative mean of durable management by using fish that would have been otherwise wasted.

6. Impacts of discards

6.1. Biological and ecological impact

Data suggest that the survival of most discarded species is low and therefore discards may be a significant part of the fishing mortality. Discards are sometimes so high for some species in the North Sea, the Northeast USA, some areas of Africa and off the Brazilian coast that they are reported in many years to equal or exceed the landings. A great number of species are affected by discarding. For example, in the Australian northern prawn fishery more than 240 species including 75 families of fish, 11 of shark and several crustaceans and molluscs have been recorded in the

composition of 30 000 tons of annual discards for this region. Data for the 1992 Bering Sea Pollock trawl show dumping of 130 species including 130 million pollock, 8.5 million rock sole, 3.2 million Pacific cod and 2.3 million flounders. Another 200 million pollock were reported to be discarded in other Bering Sea groundfish fisheries. Although these volumes are enormous, it should be noted that alone, they form an insufficient basis on which to draw inferences about their biological impact on fish populations. For example the hundreds of million pollock discards in the Bering Sea represent only 1.6 per cent of the exploitable numbers of pollock in that area and around 0.5 per cent of the exploitable biomass.

The impact of discards on non target populations may differ significantly from the effects on target species and depends in part on the life cycle the species concerned. Species having life history strategies similar to the target species may not suffer to the same degree as species with different life history features. Species having low reproduction rates and low rates of natural mortality ("k" strategy) may suffer greater impacts than "r" strategist species especially if the target species are "r" strategy base. Therefore, low discard numbers of some species may have a greater impact than high numbers of others and a, associated decline can be observed in some non target populations.

In the North Sea, considerable changes have been observed in the size and species composition of the fish community during the course of the 20th Century. Some species which grow to a large size are much more scarce than they were before heavy exploitation, and there has also been a shift in favor of short-lived species that grow only to a small size. Observed changes in the size composition of the target species landed are related to fishing pressure. There are also indications that demersal fishing activities have resulted in a shift in the benthic community structure to the benefit of short-lived species with a high reproduction potential. This could mean that a considerable restructuring of the North Sea ecosystems has taken place. As an example, marine mammals and elasmobranchs (sharks, rays and skates) are at particular risk in this context due to their low reproduction rate.

Mammals and sea turtles are sometimes found in the catches of several gears (nets, trawls, drift-nets). Vaquita *Phocoena sinus*, a species of harbor porpoise in the Gulf of California, is caught in the gillnet fisheries of the area. This species is considered to be the most endangered marine cetacean in the world and a commercial fishery has been banned to protect vaquita. Impacts of fishing mortality exist for other cetacean species including harbor porpoise in the Northwest Atlantic, the striped dolphin in the Mediterranean and two species of bottlenose dolphin in South Africa, however, many other cetacean species populations do not seem to be suffering from excessive mortality. The National Research Council (1992) identified shrimp trawling as the most significant source of mortality for five species of sea turtle. As well as shrimp trawl fisheries, a number of other fisheries generate some sea turtles by-catch. In the North Pacific squid drift-net fisheries appear to have an impact on sea turtle stocks (leatherback turtle Malaysian stock and perhaps Mexican stock). Many research programs on fishing techniques are under progress to avoid such undesirable catches. The sea turtle exclusion device (TED) is increasingly being used in shrimp trawl fisheries.

Discards provide food for a range of marine scavengers. Field studies have demonstrated that there is intense competition for discards between scavenging species of sea birds leading to changes in the bird population from 1900 to 1990 in the North Sea. Discards not eaten by above surface scavengers will re-enter the marine food chain and become a protein source for other marine life such as fish and crabs. Scavenging fish species also consume discards on the sea bed and there is an occupation of certain ecological niches partly due to discarding. However, if long term alterations to species assemblages are detectable in many regions, it is not so easy to separate the discarding

effect from all the fishing impacts, which include removal of target species and habitat modifications caused by fishing gears. There is an evident lack of knowledge on the effects of discarding on the marine ecosystem which requires further investigation of sub-surface food webs.

6.2 Stock assessment impact

Discard information does not exist for all combinations of species and gears primarily because collection of such data is expensive. However, it is important to determine the impact of discards on the stock assessment calculations, and this important issue was examined by an ICES working group in 1996.

If discards are juveniles fish, then failure to account for them will result in underestimates of fishing mortality, especially of the stock size of young fish and therefore the recruitment estimate. There may not be such significant consequences for stock sizes and biomass at older ages. In contrast, the inclusion of discards volumes of adult fish will have a positive effect on estimates of stock biomass and variable effects on fishing mortality calculations.

Concerning the predictions made by stock assessment models, the effects of inclusion of discard data could be significant. The importance of discards to fishery predictions depends on the type of predictions, the assumptions of discards over time (constant or variable) and exploitation patterns by age. Long term calculations as equilibrium yield per recruit are most sensitive to the inclusion of discards in the assessment. When variable recruitment is combined with models assuming a changing partial recruitment (exploitation pattern) then the results are very sensitive to the inclusion of discards.

The inclusion of discards is however necessary to estimate the effects of discarding through the technical interactions between fishing fleets. A reduction of discards will benefit different fishing sectors. Although little of this type of research has been carried out in this field, it is obvious that some segments of a fishing fleet discard species, mostly at a juvenile stage, that are actually the target species of other segments. In the Bay of Biscay for example, the *Nephrops* fishery catch a large amount of juvenile hake which is the target species of its own net and longline fishery.

6.3 Economic and social impact

In the developed world fishing is essentially an economic activity: it has moved beyond being primarily a food gathering activity to being a means of generating income and ideally profit. Given the motivation to generate profit, it can be argued that most discards are economically motivated.

6.3.1 Valuation of discards

There are relatively few studies valuing the economic costs and benefits of discards compared to those concentrating on biological and technical issues. The total cost of global discards has been estimated as in the order of US$ billions. In the North Sea bottomfish fisheries discards of marketable species are estimated to equal the reported landings of that fishery. Alverson *et al* state that *"If these discards costs are even remotely accurate, the aggregate economic losses due to discards in many fisheries and regions of the world may easily approach the value of landed catches"*.

Several hundreds of thousands of marine mammals are thought to be discarded annually. Even if numbers of discards and resulting mortality are known it is particularly difficult to place economic

value on these species given that the affected birds and marine mammals do not have markets and therefore current prices. However, developments in valuation techniques, to create hypothetical markets for non-use goods allow for the estimation values that people place on knowing that dolphins or particular bird species, for example, exist.

The references above to discard valuation refer to direct values, i.e. the market value of species actually thrown overboard and presumed not to survive. However, indirect impacts of discards also carry a value, for example, the value of lost future catches of target and non-target species. The full range of economic impacts resulting from discards are discussed below.

6.3.2 Economic impacts

There are four major categories of economic impact resulting from discards:

- Income that has been foregone as a result of juvenile and adult target species discards
- Income foregone in other fisheries as a result of discarding juvenile and adult non-target species
- Costs associated with discarding non-commercial species
- The cost of managing discards and measuring their quantities;

6.3.2.1 Commercial species discards

Target species have to be distinguish from the non target commercial species.

6.3.2.1.1 Target species discards

Discard induced mortalities affecting mature, immature or non-legal sexes of target species incur immediate economic loss. Direct economic losses are also sustained if only the part of a target species with the highest value is utilized. For example, the practice of shark finning results in a discard of a substantial amount of body weight which fetches a much lower price than the high value fins.

If mortality is significant, future biological reproduction of the target species can be limited, particularly if the species is at or near over-exploitation. Damage to biological reproduction of a stock affects future generations of fishers who will have to exert more fishing effort (and hence costs) to generate constant returns if the stock becomes overfished. These future costs are not borne by the current fishers, they are externalities, and so do not affect the current decision to discard to the detriment of future fishers.

There is also a negative cost of target species discards to fish purchasers in the form of lost consumer surplus (that is a reduction in the benefit that purchasers get from their good, over and above the price, they pay for it). If the prices respond to changing volumes of fish reaching the market, when discards occur less target species reaches the market, therefore prices to the consumer increase and so consumer surplus effectively decreases.

6.3.2.1.2 Discards of commercial non-target species

Discards of target species in other fisheries occur when by-catch species are juvenile or of a lower value to target species. Such discards can result from quotas levels which do not reflect the natural changes in species abundance and shared habitats of fish stocks. The resulting costs of non-target species discards are borne directly by current fishers as lost catch, and indirectly as lost catch in

other fisheries. The cost of losses to other fisheries are external and so do not influence the target species fisher's economic decision to discard.

The UK east coast brown shrimp fishery discards substantial quantities of juvenile commercial and non-commercial fish as part of normal operations. A study of this fishery's discards estimates that the market value of annual lost landings revenue of non-target whiting, cod, sole, dab and plaice amounted to £ 2.5 million.

If future catches are reduced through discards, then the impacts are felt by industry operators beyond those actually involved in capture. Lost landings imply reductions in associated shore-based marketing, processing and service industries and potentially employment and the structure of local fishing communities.

6.3.2.2 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 labor, machinery operation and other inputs required to catch, sort and discard. It can be argued that processing time is lost as a result of dealing with non-target species. Higher fuel consumption, longer on-deck time for target species and associated reduction in quality and wear and tear on fishing gear and vessels have also been recognized as costs.

The cost of effort associated with discarding species of little commercial value in the Bering Sea Pollock fishery was approximately US$ 1.03 million in 1992, calculated by assuming that the processing plant was operating at full capacity and therefore discards of 6.2% of all Pollock caught represented a similar proportion of operational variable costs.

Many tons of non-commercial species are also discarded annually and it is almost impossible to value their contribution to the marine ecosystems and food chains, which could be significant and very difficult to value.

Discards can also damage species populations that currently have either no market value or that which is so low as to make exploitation uneconomic, but which may develop into medium or high value species in the future, e.g. sturgeon, whelks, etc.

6.3.2.4 Costs of managing discards

The cost of fisheries management, prevention of discards and research is substantial. It has been estimated in 1994 that the approximate global fisheries management budget related to discards is in the order of US$ 4.5 billion (This was calculated by assuming that 10% of US marine fisheries management costs are spent on discards and that the budget in other countries is half of that in the US, i.e. 5% of marine fisheries management).

Observer and enforcement costs must also be considered as direct management costs. The cost to fishery participants of mandatory changes in fishing gear or devices are also related to discards and should include the cost of their research and development.

If the quality of base data used in stock assessment is not reliable as a result of discards then the economic cost of distorted stock assessment research, resulting incorrect management measures and their associated impact on the fishing industry and communities could be immense.

6.3.3 Social impacts

The socio-cultural impact of discards vary between nations and sections of society depending on ethical beliefs, cultural differences and dependency on marine resources for food or sources of livelihood.

Data associated with driftnet fisheries indicates that the use of this type of gear in some fisheries produces relatively low discard rates, for example in the Northwest Pacific Squid Driftnet and Tasman Sea Tuna Driftnet fisheries. However, negative popular opinion in EU countries over their perceived high discard rates has forced the ban of driftnet fisheries resulting in large compensation packages to affected fishing operators, mainly in Italy, forced to stop using this gear.

The ethical issues associated with discards and bycatch of marine mammals appear to vary widely depending on the geographical position and beliefs of particular nations. By-catch of marine mammals and turtles is acceptable in some countries where their meat is actively sought, but completely unacceptable in other countries, often developed nations, where these creatures are not regarded as sources of protein but instead sometimes with affection and status as symbols of bio-diversity.

The effect of discards and bycatch in some developing countries or fisheries dependent sections of an economy is important when fish is a major source of food protein and generates significant export earnings and local employment. The increased specialization of fisheries has led to greater user group conflict over bycatch.

Discards in a fishery have an impact on the fishery because it affects the dynamics of the exploited stocks in term of yields per recruit. The bycatch species in one fishery may be the target of other fisheries. Therefore, discards also have a social impact because they can affect other fisheries; assessment of this effect is required to improve management of fisheries.

Measures can be taken to compensate fishermen who have had their target resource damaged by the discarding actions of others. Those fishermen responsible for the waste of the resource could be obliged to pay compensation which could take the form of quota reductions implemented to maintain the stocks at the optimum catch level. Such measures need to take into account the migration of species to determine the exact regional distribution of compensation.

7. Solutions

Government, industry and the general public want to see less waste of resources. They are working to achieve this aim by finding solutions to reduce the volume of discards. A simple solution which would achieve such a reduction is to reduce fishing effort but this is not a direct by-catch management policy *per se*. A decrease of fishing effort will reduce catch (and so discards) in the immediate short term. However, in the long term the level of discarding may increase even if effort is effectively contained due to the increased stocks of by-catch species. Other ways exist to improve the actual situation in fisheries. However more than one solution needs to be employed simultaneously.

7.1. Improve the trade utilization of species

Improving the economic value of fish discards by transformation could be applied in some fisheries

provided that the onboard storage problem is solved. Experimental processing of fish discards show that the products obtained have a dry weight content of 70-95 per cent and possessed excellent functional characteristics for application in a variety of food-feed formulations. In addition, processing discards from shrimp were used to prepare protein, flavor enhancers, chitin/chitosan and carotenoids.

Better use of catches has been suggested in some shrimp fisheries. For instance in Madagascar, a project for collection of fish caught by freezer trawlers using small boats was suggested. The objective was to produce 6 000 jobs with 16 000 tons of unused catch. Similar collections of bycatch from shrimp trawlers by packers have been reported in India, Nigeria and Cuba. It is recognized, however, that there are particular problems associated with the use of shrimp by-catch. The catch consists of a large number of small fish of many species which makes methods of utilization problematical. Juveniles of commercial species which were discarded have an economic value and may not be reduced to low value products (e.g. fish meal or oil); such under-utilization results in losses of a much higher proportion of nutritional value in all transfers through the fishmeal food chain. This continued wastage does not provide a long term solution to the problem.

Successful use of bycatch is usually market lead and efforts should continue to assist in identifying suitable marketing and product development opportunities where appropriate. However, where better utilization of catches is not possible, the management of bycatch remains an increasing concern.

7.2 Improve the selectivity of fishing operations

The fishing operations must be improved by several ways in order to diminish the bycatch and discards.

7.2.1 Adequate use of existing gears

In some cases it is not necessary to develop news gears where an improvement of selectivity can be achieved by using more appropriate gears already in existence. This point is well illustrated by an Australian fishery which damaged and killed a large number of undersized spanner crab *Ranina ranina* from tangle nets. Field trials identified the most efficient net configuration to minimize damage while maintaining catch rates. A hanging coefficient of 0.7, instead of the then used 0.5, was suggested to get tightly hung nets of mesh sizes between 25 and 85 mm in order to minimize the damage when crabs were disentangled and significantly decrease the number of illegal sizes of crabs in the catch. Better utilization of existing gears could help to mitigate bycatch and discards.

7.2.2. Increase mesh-size and improve gear selectivity

There have been successful introductions of efficient selective fishing gear and harvesting practices which seem to have lead to a reduction in discards in the fisheries concerned. These include actions to increase the release of non target species using in some cases the differential species behavior :

- the backdown procedure and the Medina panel in tuna purse seine
- the Nordmore grate in temperature water shrimp/demersal fisheries
- turtle exclusion devices (TEDs) in shrimp trawls
- square mesh panels, bottom-position fisheyes and other BRDs in trawls
- acoustic scaring devices (pingers) in gillnets
- escape windows in pots

- scaring devices in traps.

The addition of turtle exclusion devices in the fishery also reduces the catch of finfish as in the commercial shrimp fishery of the Gulf of Mexico. Several bycatch reduction devices have been tested in prawn fisheries and some designs have shown good results of substantially reducing finfish bycatch whilst losing only a small amount of target shrimp catch. As an example, the square meshes nets which keep their shape and allow smaller fish to escape reduce finfish bycatch by 30 to 70 per cent according to areas.

The introduction of such modified gears could be encouraged through the use of incentives for the fishermen. However, such changes in gear need to be economically feasible for the industry to accept them. The aim is to make sure that when the amount of discards is lowered, the catch of target species is not also reduced below economic levels and therefore the overall cost of fishing is not increased to uneconomic levels. It is apparent, however, that these techniques are not universally applicable and further efforts are required to develop suitable gear or gear modification for fisheries with high discards.

7.2.3. Spatial and temporal management of fishing effort

Spatial and temporal management of fishing effort concerns areas with a high concentration of juveniles of commercial species. Regulatory measures concern gears or species (e.g. mackerel box around Cornwall in the EU waters) whose targeting is forbidden in a precise area. The North Pacific Fishery Council adopted in 1998 a measure to reduce bycatch of halibut and crab by banning bottom trawl gear as a method of fishing for pollock in the Bering sea. In a number of fisheries (Gulf of Mexico, North Sea), some sensitive areas have been closed to any exploitation, mostly on a seasonal basis but also permanently (i.e. sanctuaries).

Some specific studies have assessed the impact of such closures, and found that there are some substantial benefits for the durable management in terms of recruitment. Juveniles that would have been caught and discarded are protected and are recruited to the fishery. The rationale for a closed area must therefore be along the lines of reducing uncertainty by improving chances for a good recruitment to the fishery, improving yield per recruit, protecting juvenile habitat and providing refuge for fish.

It is important to mention here the voluntary bycatch reduction program in the North Pacific Fisheries which aims to avoid fishing in areas with a high concentrations of crabs and halibuts, called bycatch “hot spots”. Scientific observation data are transmitted through satellite to a center which generates charts that are transmitted back to the vessels. These charts indicate the areas where bycatch is high and information is updated every 24 hours. In addition each vessel is provided with a list of other vessels and their bycatch rates which eliminates the excuse that the skipper did not realize his bycatch rates were high. This creates strong pressure which acts as an incentive to reduce bycatch. Vessels moving away from high bycatch areas exert peer pressure on any vessel that is reluctant to move. This conduces to sacrifice high target catch rates in order to keep bycatch rates low.

7.3. Modify management policy

Fishery policy is one of the two main reasons for discarding, therefore regulations have to be adapted to diminish the quantity of discards. in response to this fact, the EU has changed the

management of yearly quotas to allow more flexibility in fisheries management. Fishermen can now exceed a current quota level but face a penalty decreasing of the quota in the following years. Technical measures have also been recently modified. So for many species the minimum landing size is decreased or suppressed, permitting that some small fish may appear in the landings and therefore disappear from discards. The mesh size is also modified by taking better account of the main species in the catch.

Various regulatory approaches may contribute to high bycatch rates. Open access fisheries generally lead to "recruitment fisheries" and increased targeting of young small fish. In quota-controlled fisheries, excess of capacity may result in a "race for fish" which may discourage fishing practices that minimize bycatch.

A ban on discards is used in some countries (Norway, New Zealand). In Norway, all the catch has to be landed for ten stocks of seven commercially important species. However, it is not always clear of the exact effect of such measures which are often difficult to enforce. Observations at sea showed that landings did not conform to the observed catches. In New Zealand Individual Transferable Quotas (ITQs) are used with special measures to avoid high grading which was observed at the beginning of the ITQ system and until 1992. Discarding is now illegal, except in very limited circumstances. However despite advances in technology, fishers exercising their legal rights can accidentally catch species not covered by their quota entitlements. Four options are available to those who accidentally exceed their entitlement:

(1) the fish can be landed directly to a specified processor and the fisher receives no payment;
(2) the fish are landed and the harvest is traded-off against holdings of other species;
(3) additional quota necessary to cover the non target species can be acquired within a set period of time;
(4) a deemed value can be paid, bases on port prices, and may be refunded if additional quota rights are acquired.

The first two options are not frequently used and the use of the remaining two options varies depending on relative profitability. It should be mentioned that the deemed value system does not address the problem of high-grading. High-grading will still occur while the fishery has quota for the species being discarded. However, this practice could be mitigated by using value-based ITQs, but this management measure has not been tested in any fishery to date and there may be considerable problems associated with its implementation and acceptance by the fishing industry. While a wide variety of policy options exist, none can totally eliminate economic incentives to discard in some fisheries.

The solution of the global discard problems will vary between fisheries and regions. Species do interact and so in the Gulf of Mexico, for example, removal of fish predators on shrimp could positively impact on stocks as they do not prey or scavenge on discards; thus discards may actually benefit the stock of these populations. Simulation models of the US southeastern shrimp fishery suggests that increases in the population of finfish as a result of bycatch reduction may lead to increased shrimp predation and a decline in the stock of as much as 10 per cent. A clear understanding of the nature and the scope of specific fishery problems should precede the introduction of management and other measures.

The FAO estimated that about a 60 per cent reduction in the level of discards can be achieved through the increase due of selective fishing gear (existing of new) and the development of fisheries management policies that create the correct incentives for fishers.

8. Conclusions

Discard practices concern a great number of species and vary between fisheries. The current global discards level if unacceptable. Further desirable reductions are possible but some level of discarding will always be a feature of fisheries, regardless of the gear being used. There are many reasons for discarding, mainly economic reasons but also regulatory measures for conservation of commercial species. Management has to be improved to reduce discards in fisheries to enhance their sustainability by setting reasonable discard targets to be attained in different fisheries. There is a need to improve the selectivity of fishing operations particularly of gears such as trawls used in tropical industrial fisheries. The FAO Code of Conduct for Responsible Fishing operations should be applied and the introduction of selective gears by fishermen needs to be helped by the administration after positive experiments have been conducted on commercial vessels.

However more information is required on discards as many fisheries have never been investigated. Research should be developed to ensure a better understanding of ecosystem interactions and to provide answers to many questions that exist: What is the impact of actual discarding on the ecosystem ? What will be the effect of limiting discards using more selective gears ? There is a need also to assess the impact of regulations and marine policies and ability to lessen the waste of resources.

Summary

Discarding of unmarketable, restricted species and small size individuals of commercial species is a global, economic, environmental and political problem. The discard rates vary greatly in observed fisheries according to gear, target species, season and area. Details are provided for such case studies as the fisheries of Northwest Atlantic, the European Union fisheries and the Madagascar shrimp fishery. Discards have a variety of effects including biology, ecology, economic and social aspects. The effectiveness of various regulations to reduce the level of discarding has been reviewed and include technical, administrative and economic management measures. A great number of fisheries have not been observed and should be explored with scientific observation at sea. Research needs to be carried out on discards reduction methods and gear devices and the different management systems should be evaluated to determine their effects on limiting resource wastage.

Bibliography

Alverson D.L., Freeberg M.H., Pope J.G., Murawski S.A. (1994). A global assessment of fisheries bycatch and discards. *FAO Fisheries Technical Paper* **339**, 233 pp. Rome, FAO. [This is an extensive worldwide report on all the aspects of discard problem].

Castro K., Corey T., DeAlteris J., Gagnon C. (eds.), (1996). *Proceedings of the East Coast bycatch conference, RI, USA, 7-8 April 1995*. Rhode Island Sea Grant RIU-W-95-001, 160 pp. [This contains all aspects of the bycatch problem on the East coast of USA].

CEE-DGXIV/C/1 (1992). *Rapport de la Commission au Conseil sur la pratique des rejets dans les pêcheries communautaires : causes, conséquences, solutions,*. 46 pp. European Commission Report. [This is an analysis of discard practises and solutions in European countries].

Clucas I. (1997). A study of the options for utilization of bycatch and discards from marine capture

fisheries. *FAO Fisheries Circular* **928**, 59 pp., Rome, Italy. [This report is an overview of solutions for better utilization of discards].

Clucas I. and James D. (eds.), (1997). Papers presented at the technical consultation on reduction of wastage in fisheries. Tokyo, Japan, 28 October-1 November 1996. *FAO Fisheries Report* **547**, 338 pp, Rome, Italy. [This compilation of papers deals with solutions for decreasing discards].

Hall M.A. (1996). On bycatches. *Review in Fish Biology and Fisheries* **6**, 319-352. [This paper provides a general analysis of discards].

Pascoe S. (1994). Bycatch management and the economics of discarding. *FAO Fisheries Technical Paper* **370**, 137 pp. [This paper presents and economic perspective on the discarding problem and considers optimal discarding scenarios using bio-economic modeling].

Pitcher T. J. (1995). *Bycatches in fisheries and their impact on the ecosystem*. University of British Columbia, Vancouver, Canada. Fisheries Center Research Report **2**(1), 74 pp.(eds. Rattana Chuenpagdee). [This document provides a scope of the ecological impact of bycatch and discards].

Rawson M. V. (1997). *Fisheries bycatch: consequences and management*. Symposium of the consequences and management of fisheries bycatch, Deaborn, MI, USA, 152 pp. Alaska Sea Grant College Program, Fairbanks, AK-SG-97-02, USA, 152 pp. [This is a proceedings report of the 1996 American Fisheries Society symposium on bycatch].

Wray T. (ed.) 1996. Solving bycatch for today and tomorrow. Proceedings of the solving bycatch workshop, september 25-27, 1995. Alaska Sea Grant College Program, Fairbanks, AK-SG 96-03, 322 pp., USA. [This report is a compilation of papers presenting solutions for the bycatch problem].