**The Discard Problem – a Comparative Analysis of Two Fisheries: the English *Nephrops* Fishery and the Dutch beam trawl Fishery**

**Tom Catchpole, Olvin van Keeken, Tim Gray and Gerjan Piet**


## Abstract

Discarding is the throwing overboard of unwanted fish or benthic animals[1] that have been caught by sea fishing vessels. Some estimates suggest that as much as 25% of the global amount of fish caught is discarded annually. In this comparative analysis of discarding in two contrasting North Sea fisheries – the English *Nephrops* fishery and the Dutch beam trawl fishery – we seek to identify their reasons for discarding, and to discuss the effectiveness of measures that might reduce their rates of discarding, relating causes/solutions to management measures, market forces and fisher's behaviour. Our findings are that despite the many differences between the two fisheries and their respective discard problems, one common thread – the importance of incentives - runs through both of them. Absence of incentives is the main cause of the discard problem, and presence of incentives is the main solution to that problem.


## 1. Introduction

Getting rid of unwanted fish by throwing them overboard is a widespread practice in commercial sea fisheries across the world. Annual estimates of the amount of fish discarded globally have varied during the last 20 years between 6.7 and 39.5 million tonnes (Pascoe 1997: 11; Alverson *et al* 1996; Kelleher 2004: Abstract). In some fisheries, the discard rate is high: for instance, in the North Sea *Nephrops norvegicus* trawl fisheries, up to 83% of the total catch in numbers is discarded, while in the North Sea flatfish beam trawl fisheries, discard rates of plaice (*Pleuronectes platessa)* reach 80% in numbers (ICES 2005). Discarding has been frequently criticised for wasting a valuable source of protein-rich food, at a time when many fish stocks are declining. The economic cost of discards, in terms of both the immediate and long-term loss of edible fish, has been calculated at "billions of dollars" (Alverson *et al* 1996: Chapter 3). Discards may even threaten the economic survival of fish species in some fisheries (Pascoe 1997: 18; Cappell 2001: section 10). Although there have been innumerable analyses of the causes of discarding, and many research projects designed to find ways of reducing the levels of discards, the discard problem remains a serious issue facing fisheries managers. In this study, we focus on two cases – the English *Nephrops* fishery and the Dutch beam trawl fishery targeting sole (*Solea solea)* and plaice – with a view to determining whether each fishery is unique in its discard problems and solutions, or whether there is some common ground between them. Our finding is that they do share one important characteristic – that the key to the causes of, and solutions to, their discard problems, lies in the absence or presence of appropriate incentives.

## 2. Methodology

This is an interdisciplinary study, in that it is based on both fisheries science and social science data. We chose to compare the English *Nephrops* fishery to the Dutch beam trawl fishery targeting sole and plaice because they offer a sufficient mix of similar and dissimilar features to make the comparison meaningful. Their similar features include the facts that they are both trawl fisheries in the North Sea and they both show high discard rates for target species (in case of the Dutch beam trawl fishery for plaice, but not for sole). Their dissimilar features include the facts that the English fishery targets crustaceans, whereas the Dutch fishery targets flatfish; the English *Nephrops* fishery uses otter trawls, whereas the Dutch fishery uses beam trawls; the English *Nephrops* fishery is located in the northern part of the North Sea, whereas the Dutch beam trawl fishery is mainly located in the southern part of the North Sea; the English *Nephrops* fishery operates in an area (the Farne Deep) which is not subject to restricted access, whereas the Dutch beam trawl fleet is not allowed to fish within the Plaice Box with vessels larger than 300 HP (Pastoors et al. 2000); and the English *Nephrops* fishery's discards are principally whiting (*Merlangius merlangus)*, which is a species whose spawning area is widespread

[1] In this study, we define discards in terms of discarded edible fish, crustaceans and benthic organisms. We exclude, therefore, discards of plant material, offal, sea mammals and sea birds.

throughout the northern North Sea, whereas the spawning area of plaice, a principal discarded species of the Dutch beam trawl fishery, lies in the southern part of its distribution area. The data that we use for the English *Nephrops* case were obtained by Catchpole during the course of his PhD research (2000-05) into the English *Nephrops* fishery, entailing natural and social scientific analysis of the trawling activity of seven otter trawlers, together with semi-structured questionnaires administered to, and in-depth interviews conducted with, 25 skippers (80% of the total number of North Shields *Nephrops* fishery skippers). The data that we use for the Dutch beam trawl fishery were obtained from the Dutch discard sampling program for 2001-2002: in 2001, four fishing trips were sampled on Dutch beam trawlers operating with 80 mm mesh size, while in 2002 six fishing trips were sampled. Social scientific data were obtained informally from conversations with fishers and at other opportunities

## 3. Case study I: the English *Nephrops* fishery

The English *Nephrops* fishery operates in the North Sea, off the north east coast of England adjacent to the Farne Deep. The main port is North Shields, where landings have an annual value of about £4 million. The fishery is seasonal, from September to April, and the mode of fishing is mostly single-rig otter trawling. Regulations stipulate a minimum mesh size of 80 mm; a large mesh diamond panel inserted near the headline; a square mesh panel at the front of the extension; and cod end twine thickness restrictions. There are minimum landing sizes (MLSs) for most commercial species; catch composition requirements [2]; and an annual quota for *Nephrops* of 4170 tonnes. There are also days-at-sea restrictions of 22 days per month.

The amount of discarding in the English *Nephrops* fishery during the 2001/02 season (September 2001-April 2002) was estimated at 3684 tonnes, which represents a discard rate of 43% [3]. Most of the discards were whiting [4] (2661 tonnes), which constituted 72% of the discards by weight, and 16% of the total whiting discards in 2001-02 in the whole of the North Sea, where whiting is currently outside safe biological limits. The estimated potential economic value of the whiting, haddock and cod discarded in the fishery in 2001/02 is £1.8 million (Catchpole 2005c).

### 3.1 Causes of discarding

In assessing the causes of this discarding, let us divide the analysis into management measures, market forces and fisher's behaviour. Management measures include quota and catch composition restrictions, and MLS regulations. However, there is no evidence that the extent of whiting discards is affected by either quota or catch composition restrictions. This may be because the chances of inspection are very low, and even when inspected, the chances of prosecution for an offence are very slim [5]. Fishers state that quota limits are the least frequent reason for discarding either *Nephrops* or fish.

MLS regulations do not have much influence on the discard or landing patterns of either *Nephrops* or whiting, since large numbers of *Nephrops* under the MLS are landed, while a quarter of the whiting discards are above the MLS. MLS does however have a marked influence on the discards of cod (*Gadus morhua)* and haddock *(Melanogrammus aeglefinus)*, in that few of either of them above the MLS are discarded. Compliance with MLS is, therefore, a significant cause of cod and haddock discarding.

Turning, secondly, to the action of market forces, this is one of the major determinants of discarding levels of *Nephrops* and whiting in the North Sea *Nephrops* fishery (Catchpole *et al* 2005b: 53). The presence of demand for small *Nephrops* means that *Nephrops* discards are low; whereas the lack of demand for whiting means that 25% of the discarded whiting is above the MLS, and if the price for whiting is too low, none at all may be landed.

---

[2] The minimum percentage of legal-sized *Nephrops* is 30%; and the maximum percentage of by-catch of legal-sized protected fish species is 60%.

[3] In an earlier study, the discard rate was estimated at 59% (Evans *et al* 1994)

[4] 32% of the whiting on the fishery grounds that encountered a trawl were caught, and 86% of the whiting caught were discarded (Catchpole *et al* 2005b: 45).

[5] In England, the chances of being inspected on land are only 6%, while the chances of being inspected at sea are less than 1% (NAO 2003). Of the 109 offences detected by the North Sea District Sea Fisheries Inspectorate in 2000, only four cases resulted in prosecution (NEDSFC 2000).

Thirdly, fishers' behaviour is a crucial factor in influencing discard rates (EP 1999: section 5.3), in particular, their choice of gear selectivity. Fisheries scientists claim that the selectivity of the gear chosen by fishers is the main cause of discarding. Even when regulations require the adoption of more selective techniques, fishers have proved "adept at circumventing" these regulations (EP 1999: section 7.2; cf Pascoe 1997: 89). English *Nephrops* fishers do not consider that lowering discards will have an obvious conservation benefit, whereas scientists believe that lowering discard levels is essential for stock improvement.

3.2 Strategies to reduce discarding

Let us now consider strategies for reducing discards in the English *Nephrops* fishery. Firstly, management measures include relaxing quota and/or MLS restrictions to allow the landing of smaller, marketable, fish. But there is little evidence that either more quota or lower MLS would reduce the large discards of whiting, while the discard levels of cod and haddock are too low to warrant such steps. Another management measure is to restrict fishing time (effort control), which is an easier regulation to enforce than are quota controls. But there is no evidence that the current permitted days-at-sea regulations in the English *Nephrops* fishery – 22 days per month - have reduced effort or discarding, because weather and tidal conditions do not allow for more days fishing than the 22 days permitted. A further reduction in days-at-sea would cut total discards, but at a substantial cost to fishers' earnings. In a fishery that simultaneously targets a healthy stock (*Nephrops*) and stocks in poor condition (whiting and cod), reducing fishing effort is not an economically efficient way of cutting discards. On the other hand, regulators could allocate more fishing days to fishers using more selective gear. So, although fishing time restrictions do not in themselves offer a practicable means of reducing discards in the English *Nephrops* fishery, they can be used discriminately to encourage fishers to adopt selective fishing techniques (Catchpole *et al* 2005a).

This leads us to another management strategy for reducing discards – regulations on gear selectivity. This is the strategy that is most approved by fishers, and it has been applied to the English *Nephrops* fishery. Since 1992, the UK has introduced legislation for an increase in codend mesh size, two sizes of square mesh panel (SMP), and a diamond mesh panel in *Nephrops* trawls. In 2000, the EU made square mesh panels mandatory for all EU-managed North Sea demersal fisheries. However, although the whiting discard rate fell by 11% following the application of these technical measures, the amount of whiting discards still remained high (at 393 kg per vessel per day in 2001-2 compared with 434 kg per vessel per day in 1991 (Evans *et al* 1994). This suggests that high levels of discarding continued ,despite the application of new gear regulations and the compliance of fishers.

A discard ban is another possible management measure to reduce discards. Such a ban could pressure skippers into fishing more selectively than at present, but a discard ban in the English *Nephrops* fishery would result initially in large quantities of mostly undersized whiting being landed. This leads us to the question of how market forces can be adjusted to dispose of such unwanted produce: fishers would need an economic incentive to comply with such a ban.

Closed areas or spatial management is another measure that could be taken to reduce discards. However, in the case of the English *Nephrops* fishery, spatial management is not a feasible policy, because the area fished is relatively small – 58 km by 75 km – and there is no evidence that discard patterns are significantly spatially dependent. Closure of parts of this area would not, therefore, be effective in this fishery – the fleet would simply discard similar quantities in the places left open for fishing.

Secondly, market forces have already contributed the most significant solution to one of the discard problems in the English *Nephrops* fishery – the discarding of small *Nephrops*. The development of a new market for small-sized *Nephrops* during the late 1980s reduced the *Nephrops* discard rate from 85%[6] to 7%[7] (Catchpole *et al* 2005a: 427). If a similar market could be developed for small whiting, the high level of whiting discards could also be reduced. Changing consumer tastes is a long-term strategy; in the short term, undersized whiting could be used for fishmeal and fish oil (based on current fishmeal prices of £86 per tonne, the estimated potential annual value of these fish discards is

[6] Estimates of rates of discarded *Nephrops* by number varied between 85% and 57% (Catchpole *et al* 2005b: 46).

[7] During the 2001/02 season, this rate was cut to 5%, which is 93% lower than in 1991 (Catchpole *et al* 2005b: 45; 52).

£215,000). Much could also be done (and is being done by Seafish Industry Authority in liaison with fishers) to market fish products with a labelling scheme to show that they have been caught with a low discard component.

Turning, thirdly, to fishers' behaviour, there are two relevant issues here. The first issue is fishers' willingness to adopt more selective gear. In addition to compulsory selective gear such as square mesh panels, there is a range of discard-reduction techniques that could be voluntarily adopted by fishers in the English *Nephrops* fishery. An example supporting this claim is the experience of one skipper, who, in order to reduce discards, altered his trawl by lowering the headline height, using a large mesh size in the wings, and increasing the area of square mesh panels. Considerable research has been devoted to developing separator trawls or grids, with a success rate of up to 90% in separating whiting from *Nephrops* (Arkley 1988). The Netrasel project developed a two-grid separator system which not only separated fish from *Nephrops*, but also released undersized *Nephrops.* Seafish's Fisheries Development Centre in Hull has recently announced the result of a five year project to reduce discards in the English *Nephrops* fishery, with a coverless trawl designed to avoid the capture of unwanted by-catch in the first place. Seafish claim that the coverless trawl reduces the by-catch of whiting and haddock by over 60%, without affecting the catch of *Nephrops* (*Fishing News* 22/4/05: 8). Evidently, then, selective gear does exist which can reduce whiting and haddock by-catch in the *Nephrops* fishery (though, of course, not all by-catch is discarded).

The crucial question is, therefore, not technical but behavioural – how to persuade fishers to instal the selective gear. One way to do so might be to educate them more effectively about the adverse impacts of discards on the marine environment, and the consequential long-term damage to commercial species of fish. Significantly, however, only one North Shields skipper mentioned the conservation benefits of discard reduction, which suggests an ecological deficit in fishers' understanding of marine science. However, it is questionable whether fishers would be greatly influenced by environmental education about the long-term health of the marine ecosystem: they are more likely to respond to short-term economic incentives, such as access to otherwise closed areas. This path has been chosen in the Irish *Nephrops* fishery, where an 'inclined' separator trawl, which is designed primarily to reduce cod capture, but also separates whiting and haddock, while allowing *Nephrops* to be retained, has been made compulsory for fishing in temporarily closed areas in the Irish Sea (Rihan and McDonnell 2003).

However, to make this gear effective, fishers need not only to comply with the regulations by installing the gear, but also to become pro-active in tuning the gear to maximise its effectiveness. Innovatory gear often works well during sea trials, but is less efficient under commercial conditions. Moreover, even the most effective gear is not perfect, and some marketable fish will inevitably escape from more selective trawls. For instance, the Netrasel system resulted in a loss of up to 20% of the *Nephrops* catch (Radcliffe 2001). This is the main reason why fishers are reluctant to adopt more selective gear – they are not willing to risk a drop in their target catch [8]. Accordingly, regulators must find incentives that are sufficiently attractive to outweigh this risk. Privileged access to closed areas is one such incentive: another is direct subsidy, but the UK government is not willing to subsidise fishers.

This brings us to the second issue relating to fishers' behaviour – their participation in regulatory decision-making. An alternative, or additional, incentive to providing direct economic incentives as a means of persuading fishers to adopt more selective gear is to grant them opportunities (political incentives) to participate in the decision-making processes whereby such gear is introduced. According to critics of the present hierarchical or 'top-down' system of fisheries governance, it has not generated a culture of respect for the regulations, and there is consequently widespread non-compliance (Crean and Symes 1994). Moreover, the bureaucracy of the EU's system has meant that decisions to introduce more selective gear have sometimes been delayed for years: for instance, 20 years elapsed from the initial recognition of the value of square mesh panels, to the EU's regulation making them compulsory. A more participative system of fisheries governance would, it is argued, lead to greater compliance and speedier decision-making, by removing the sense of alienation from decision-making processes which 77% of North Shields fishers currently feel [9], and by conferring a greater sense of

[8] It is encouraging to note, however, that 55% of North Shields skippers believed that discarding could be reduced without a significant loss of *Nephrops* (Catchpole *et al* 2005b).

[9] One North Shields skipper wrote in a questionnaire return that "The fishery could improve substantially with proper management"; another said that "the stocks should not decline if managed

legitimacy on decisions [10]. Also, participation would widen the information base on which such decisions rely (Gray 2006). For instance, collaborative gear technology research between fishers and scientists has been shown to benefit from fisher's extensive knowledge of the marine environment, and to help instil in the fishers a greater sense of confidence in the scientific analysis of the long-term benefits to fish stocks of discard reduction strategies (Melvin 2003). Even being routinely consulted as stakeholders would enable fishers to be better informed about the harmful ecological and economic impact of discarding.

However, in the English *Nephrops* fishery, there is little overt appetite among most fishers for greater participation in fisheries governance: only 27% of North Shields skippers want to be more involved in decision-making [11]. There are three reasons for this reluctance. First, the fishers feel little sense of responsibility for marine resources. Unlike other inshore fisheries, where there is often a sense of communal ownership of the resource and an incentive to protect the fishery, the English *Nephrops* fishery, which has a transient fleet of which 70% is made up of visiting vessels, is characterised more by mutual competition for the target stocks, than a collective sense of proprietary stewardship over this resource. Second, the fishers do not trust each other in decision-making roles. Skippers ranked other fishers as being poor at protecting fishery resources. This perception was borne out by their behaviour in relation to a voluntary agreement made in 1989 by the North Shields Prawn Fishermen's Association to ban twin-rig trawls on the *Nephrops* fishing grounds, because they were too efficient at hoovering up the stocks: that agreement was subsequently breached by several skippers (NEDFO 1997). Third, the fishers have different institutional affiliations: the 25 questioned skippers working from North Shields were members of six different producer organisations and three different national fishermen's associations. This means that there is no single industry group ready to assume the role of representing the fishers in a future participative form of fisheries governance. Moreover, only 45% of fishers considered themselves well-represented by their respective organisations.

However, advocates of participation would argue that the North Shields fishers' lack of enthusiasm for participation should not deter us from pursuing it on their behalf. For one thing, fishers themselves recognise the need for better policies to deal with the discarding problem – 59% of skippers consider that too much fish is discarded, and 46% believe that there are advantages to themselves of discard reduction (for instance, reduced sorting time would improve vessel efficiency). For another thing, fishers may come to acknowledge that if they participate, then they are more likely to obtain the kind of discard reduction measures that they prefer and can live with. If they fail to take responsibility for getting involved in the decision-making process, then they may be at the mercy of environmental agencies and pressure groups that increasingly find favour with the governing authorities. Of course, there is no guarantee that fisher's participation will achieve what they want. But the alternative is a continuation of top-down regulative measures, with even more stringent restrictions on fishing opportunities and resultant costs to the fishing industry.

In summary, our first conclusion on the English *Nephrops* fishery is that there is a persistently high level of discarding in the English *Nephrops* fishery that contributes to the weakening of a stock (North Sea whiting) that is currently outside safe biological limits. Our second conclusion is that the main obstacle to discard reduction is lack of incentive rather than lack of technical ability. Historically, there has been an emphasis on developing technical solutions, but now we need to accompany technical research with measures designed to increase the incentives of fishers to utilise the technical tools that are available. Our third conclusion is that an understanding of fishers' behaviour is crucial to a solution to the discard problem, in order to find the best ways to incentivise fishers to introduce more selective gear. This entails consultation with the industry, formulating fishery-specific discard targets, emphasising the long-term economic costs of not discarding, and creating immediate economic incentives for not catching unwanted fish. Our fourth conclusion is that we must explore ways of increasing the political will of regulators to introduce adequate incentives to employ selective gear technology. If fishers were more involved in fisheries decision-making, they could help to stiffen that political will.

---

properly"; and a third remarked that "conserving stocks is good. But conserving fishermen is often overlooked" (Catchpole 2003).

[10] A North Shields skipper wrote in a questionnaire return that "Unless rules and regulations have fishermen's support and are seen to work by fishermen, it's futile" (Catchpole 2003).

[11] One of these skippers declared that we should "be running our fisheries ourselves" (Catchpole 2003).

## 4. Case study II: the Dutch sole/plaice fishery

The Dutch beam trawl fleet is the largest sector in the Netherlands fishing industry, with 374 vessels taking 252 million euros in 2003, 65% of the total fisheries revenue (Taal *et al* 2004). In 2003, the fleet comprised 173 inshore vessels with engine power between 261-300 hp, which are allowed to fish in the Plaice Box, and 147 offshore vessels with engine power above 300 hp, which are excluded from the Plaice Box and 12-miles zone. Most of the beam trawlers target sole and plaice in the southern North Sea, using a mesh size of 80 mm, while a small part of the fleet targets only plaice in the more northern areas using 100 mm mesh size. Landings of the two fish species have fallen during the last ten years: sole from 33,000 tonnes in 1994 to 19,000 tonnes in 2004; and plaice from 110,000 to 61,000 tonnes (ICES 2005). The fishery is regulated through individual transferable quotas (ITQs) for sole, plaice, cod and whiting. Usually the total allowable catches (TACs) are taken for both sole and plaice (ICES 2005). The market value of sole is on average four to five times higher than that of plaice.

For this case study, discards estimates were obtained from four fishing trips in 2001, and six trips in 2002, on commercial beam trawlers targeting sole and plaice with 80 mm mesh size. No trips were made on vessels targeting plaice with 100 mm mesh size, so the discard data below do not include this segment of the fleet. From these ten observed discard trips, the total amount of discarded material was estimated at 6,850 kg per vessel per day, while the total landings were estimated at 2,100 kg per vessel per day. So the overall discard rate (including all fish and benthic material) was 77% of the catch. The discards were dominated by plaice (1,400 kg) and dab (*Limanda limanda)* (1,300 kg), while the weight of the sole discards was 48 kg per day. Survival of plaice and sole discards was estimated at less than 10%, because most of them are severely damaged by the trawl (Van Beek *et al* 1990). Cappell (2001; para 8.1.3) estimates that the economic value of the marketable species discarded in the Dutch beam trawl fishery is about 160 million euros per year, 70% of the value of the landed catch.

### 4.1 Causes of discarding

In assessing the causes of discarding in the Dutch beam trawl fishery, we again divide our analysis into management measures, market forces, and fishers' behaviour. Relevant management measures include gear selectivity and quota. Gear selectivity is the main cause of fish discards. Their smaller body width and greater flexibility enables sole to escape through the mesh at larger lengths than plaice. The 50% retention length of plaice when using commercial beam trawls is about 17.5 cm, while the minimum landing size is 27 cm (Rijnsdorp *et al* 1981; Van Beek *et al* 1981; 1983). As a result, many undersized plaice, as well as dab, are caught and discarded. Turning to quota, in some years, marketable fish have been discarded due to low quota (Buisman *et al* 2001). Cappell (2001: para 8.1.3) argues that high-grading is "directly connected with the individual quota system". This is partly because of the mixed character of the Dutch beam trawl fishery, when, for example, the quota for plaice is almost fished up, but the quota for sole can still be taken. Moreover, fishers may high-grade to save quota for other periods in the year, when fish are more valuable.

Market forces have been responsible for some discarding of large plaice during the spawning season when quality is poor and prices are low (Buisman *et al* 2001), but high-grading can also occur when many individuals of a strong year class recruit to the fishery in a month, driving down prices because of the sudden large supply of these fish. During the discard observation trips, however, high grading was not observed.

Fishers' behaviour has contributed to the discard problem in that fishers have not responded adequately to the changes in growth and spatial distribution of juvenile plaice that have occurred during the last three decades. The average mean length of plaice in the 1990s/2000s is less than during the 1970s/1980s (Rijnsdorp *et al* 2004), and lower growth rates entail a longer period of time during which plaice are exposed to discarding. As a result, the distribution of notably the younger age-groups of plaice has shifted further offshore (Van Keeken *et al* 2006).

### 4.2 Strategies to reduce discarding

Turning to the three strategies that can be taken to reduce discards in the Dutch beam trawl fishery, we begin with management measures. Improving gear selectivity is an important management strategy, which has been a major preoccupation of the Dutch beam trawl fishery, resulting in considerable research efforts (Fonds and Blom 1995; Van Marlen 2000). One solution is to increase mesh size from 80 mm, allowing the juvenile plaice to escape through the mesh. Van Beek *et al* (1981) suggested that the most appropriate mesh size for a fishery targeting plaice should be not less than 120 mm, which would result in hardly any loss of marketable plaice. However, this would mean a considerable loss of marketable sole. Some fishers complain that the 80 mm mesh size already loses them marketable sole, and they use liners (nets with smaller meshes that are illegally inserted inside legitimate nets) to offset this loss (Buisman *et al* 2001; Cappell 2001: para 8.1.15). Other alterations to the gear could also reduce discards. Large mesh panels in the top of the net are used to allow roundfish (mainly gadoids) to escape, without significant loss of flatfish (Van Marlen 2003). This does not, however, address the problem of plaice discards. Reduction in the number of tickler chains reduces the catch of benthic animals, but at the cost of reducing sole catches. Other gear alterations like separator panels, square mesh panels and escape tunnels have also been investigated, but found to be ineffective in reducing juvenile plaice discards (Van Marlen 2000; Buisman *et al* 2001).

With regard to effort control, under the MAGP IV initiative, restrictions on tonnage, engine power and days-at-sea have been imposed. For example, on average, beam trawlers had 174 days-at-sea in 2001, but only 165 in 2002 (Taal *et al* 2004). Reduced engine power leads to a reduction in discards, but it also reduces the target catch, with a consequent fall in revenue. Reducing days-at-sea restricts the opportunities for high-grading, because it limits the time available for fishers to look for areas with higher quality fish. On the other hand, since steaming time is included in the days-at-sea, the incentive for fishers to steam to places far from the coastal area is reduced, and this may result in increased effort in grounds closer to shore, where there is a higher chance of catching juvenile plaice. Also, fishers claim that they need the present number of days to catch their quota (Cappell 2001: para 8.1.5).

With regard to quotas, Cappell (2001: para 8.1.5) argues that a reduction in the sole quota would reduce the incentive for fishers to use liners, and might even encourage them to use larger mesh sizes, which would cut juvenile discards. Also, in an attempt to reduce high-grading, the individual quota system could be changed by introducing multi-annual total allowable catches (TACs), which would give fishers more flexibility in distributing their landings over a longer period of time (Cappell 2001: para 8.1.5). Another management strategy to reduce discards is to reduce the MLSs, but a large reduction in MLS is viewed very negatively by fishers, because it would deflate market prices for target fish (Cappell 2001: para 8.1.5), and result in increased high-grading, if the quotas remained unchanged. A discard ban would result in large numbers of juvenile plaice and dab being landed, some of which could have survived being discarded [12]. It would also be unpopular with fishers, if the undersized fish came off their quotas.

Closed areas have played perhaps the greatest part in the Dutch management strategy to reduce discard levels, and the Plaice Box is the most important example of this policy. Discard observations during 1976-1990 revealed very high discard levels of juvenile plaice in the shallow coastal waters in the southern North Sea encompassing the major plaice nursery grounds. In 1989, the Plaice Box was established to protect juvenile plaice by excluding beam trawlers with larger than 300 hp from this area during the second and third quarters of the year. In 1994, this exclusion was extended to the fourth quarter, and since 1995, the area has been permanently closed to these vessels. After closure, the total effort in the Plaice Box decreased to about 6% of that before closure (Pastoors *et al* 2000). However, in contrast to expectations, the recruitment, yield and spawning stock biomass of plaice has *decreased* since the introduction of the Plaice Box (ICES 1999; 2004). Several hypotheses have been put forward to explain this failure of expectations. First, the high density of juvenile plaice and decreased food supply has reduced its growth rate (Rijnsdorp 1999). Second, small vessels are still allowed to fish in the Plaice Box (EP 1999) [13]. Third, the distribution pattern of plaice has changed, though the reason for this change is unclear (Pastoors *et al* 2000; Grift *et al* 2004; Rijnsdorp *et al* 2004; Van Keeken *et al* 2006). Juvenile plaice that were protected from the large beam trawl fishery by the Plaice Box have been moving out of this area at smaller lengths (Van Keeken *et al* 2004) and, as a result, discard observations during 1999-2003 showed high discard rates outside the Plaice Box (Van Keeken *et al* 2004), which before the closure were only observed inside the Plaice box (Van Beek 1998). Nevertheless, the Plaice Box still protects approximately 70% of the juvenile plaice (Grift *et al* 2004).

[12] Dutch fishers are traditionally more optimistic than are Dutch scientists about the survival prospects of discarded flatfish.
[13] The under-300 hp beam trawlers (eurocutters) which are allowed into the Plaice Box have a higher discard rate (57%) than have the over-300 hp beam trawlers (45%) (Cappell 2001: para 8.1.3).

Temporary closed areas (e.g. during the spawning season) are potentially useful in protecting plaice. Adult plaice lose weight and energy during spawning, and have lower market value as a result. Because these fish are vulnerable to being high-graded, temporary closures of spawning areas protect them from being caught and discarded. But the problem with temporary closed areas is that when they are re-opened, fishing effort may increase greatly, leading to a higher level of discards than before the closures, thereby reducing their gains. For instance, during the early 1990s, the Plaice Box was only closed for the second and third quarters, and when it re-opened during the fourth quarter, effort increased substantially (ICES 1994). Moreover, most fishers are opposed to temporary closed areas, because they fear that such closures will become permanent, like the Plaice Box (Cappell 2001: para 8.1.5).

With regard to market forces as a means of reducing discards in the Dutch beam trawl fishery, if MLS were reduced or a discard ban imposed, the problem of how to dispose of the undiscarded catch could be addressed by trying to persuade the consumer to buy juvenile fish. It is encouraging to note that in the last decade, markets for non-quota fish such as dab, flounder (*Platichthys flesus*), Norway pout (*Trisopterus esmarkii)* and grey gurnard (*Chelidonichthys gurnardus)* have been developed, and prices have been increasing for these species. As a result, the incentive to discard them is low, and fishers claim that most marketable non-quota fish is landed, even when prices are not high (Buisman *et al* 2001). However, marketing of juvenile plaice would do little to reduce their mortality.

Finally, with regard to fishers' behaviour, moves could be made to demonstrate more effectively to fishers the effects of their fishing practices, including reminding them that they are retaining only 2 in every 10 plaice they catch from an impoverished stock, the remainder being thrown back dead or dying. Damaging fishers' behaviour that could be ended is the practice of using liners inside 80 mm mesh nets to prevent the escape of a small number of sole above the MLS of 24 cm. Also, shorter haul duration and lower towing speed could be demonstrated to increase the chances of survival of some discarded species. Such proposals are currently unpopular with fishers because they would disrupt crew sleeping patterns, and reduce the target catch, but perhaps changes in fisher's behaviour could be brought about through greater participation by Dutch fishers in fisheries governance. Although the Dutch fisheries management system is formally one of co-management – i.e. where national representatives of fishers meet with government officials to formulate fisheries policy - in practice, the system works in a hierarchical, top-down fashion (Van Ginkel 2006: 136). However, Dutch fishers are more pro-active than are North Shields fishers, and making a reality of co-management could improve fishers' willingness to take part in formulating and implementing discard policies.

In summary, our first conclusion on the Dutch beam trawl fishery is that most technical solutions to the problem of high levels of juvenile plaice discards entail significant reductions in the target catch of sole, which fishers find unacceptable. Our second conclusion is that one spatial measure (the Plaice Box), has failed to reduce these high levels of plaice discards. Our third conclusion is that market forces, while they can help utilise catches of unwanted species, cannot solve the problem of reducing mortalities of juvenile plaice. Our fourth conclusion is that the incentivising of fishers to address the problem of juvenile plaice discards requires a greater sense of responsibility by fishers to engage in fisheries governance.

## 5. Comparative analysis of the two case studies

In this section we compare the causes of, and solutions to, the discard problem in the two fisheries, employing again the three categories: management measures, market forces and fishers' behaviour. Management measures are divided into quota, effort restrictions, technical measures and closed areas. On quota, there is a contrast between the English *Nephrops* fishery, where quotas are the least frequent reason cited by fishers for discarding either the target species (*Nephrops*) or the largest bycatch species (whiting), and the Dutch beam trawl fishery, where quotas do seem to influence discard levels of marketable fish, especially at the end of the year. This contrast may reflect the fact that quota regulations are more poorly enforced in the English *Nephrops* fishery than in the Dutch beam trawl fishery. More flexible quota arrangements could help to incentivise fishers to reduce discards and/or blackfish landings in each fishery.

Days-at-sea restrictions below 22 days per month will reduce discards in the English *Nephrops* fishery, but at the expense of a substantial loss of fishers' earnings. Above this level it will not have any impact as weather and tidal conditions do not allow for more than 22 days fishing per month. In the Dutch beam trawl fishery, days-at-sea restrictions in combination with the current high oil prices encourage vessels to stay closer to shore to economise on steaming time, and this puts more pressure on juvenile plaice. However, in both fisheries, regulators could allocate more fishing days to fishers using selective gear than to those fishers not using selective gear, to incentivise all fishers to adopt selective gear.

Minimum landing size (MLS) is not a significant cause of discarding of either *Nephrops* or whiting in the English *Nephrops* fishery, but does cause discarding of cod and haddock. In the Dutch beam trawl fishery, the MLS for plaice contributes to the discarding of juveniles. Lowering the respective MLSs would reduce discards in each fishery, but at the potential cost of depressing fish prices generally, which is a disincentive for fishers. The same reasoning applies even more to a discard ban, which would drastically reduce fishers' revenues if complied with. Moreover, neither measure would lower the mortality rate of juvenile fish, only the discarding rate.

While skippers in the English *Nephrops* fishery acknowledge that poor gear selectivity is the main cause of discards, and have readily accepted square mesh panels introduced in 1992, the increase in minimum mesh size in 2002 only marginally reduced whiting discards (70% of the whiting catch is still discarded). With their existing technology, North Shields fishers could significantly reduce their whiting discard levels with only a small loss of landings [14], but most skippers seem to be unwilling to bear any loss to achieve discard reduction. Similarly, mesh size enlargement is seen as problematic in the Dutch beam trawl fishery, because it would sharply reduce the catch of marketable sole, even though it would reduce discarding of juvenile plaice. Again a lack of incentive is the key problem, though until selective gear is invented that will effectively separate young plaice from mature sole, it is difficult to see how to incentivise skippers in this fishery.

A closed area (or 'spatial management') policy is the final management measure to be considered in this comparative analysis. In the English *Nephrops* fishery, there is no evidence that closed areas would reduce discards, because the area fished is relatively small, and it does not have spawning sub-areas. In contrast, in the Dutch beam trawl fishery a closed area policy has been at the heart of its anti-discard policy, in the shape of the Plaice Box. However, the effect of the Plaice Box was less then anticipated during its installation. This could be partly due to the fact that juvenile plaice have shown an offshore shift in their spatial distribution in recent years, thereby moving to areas outside the Plaice Box where they are more vulnerable to fishing activity (Van Keeken *et al* 2006).

With regard to market forces, the development of a market for small *Nephrops* in the English *Nephrops* fishery during the last 20 years has resulted in a 93% fall in discard rates, although the lack of a market for whiting has meant that 25% of legally-sized whiting is discarded. In the Dutch beam trawl fishery, markets for non-quota fish have grown, so that most non-quota fish is now landed. However, developing a market for juvenile plaice is unlikely to result in a reduced catch of them.

Finally, with regard to fisher's behaviour, the message that comes from both fisheries is that at least some of the features of fishers' behaviour in relation to the discard problem could be addressed by greater engagement of fishers in discard reduction decision-making. In other words, in addition to economic incentives to persuade fishers to adopt selective gears, such as privileged access to closed areas or larger quotas or direct subsidies, fishers might be offered political incentives, such as participation in making decisions about the kind of discard reduction measures that should be taken. English fishers are less disposed towards participative governance than are Dutch fishers, but if they could be convinced that their engagement would improve the situation, they might be persuaded to take part.

## 6. Discussion

In the above similarities and contrasts, one theme runs through them all – the critical importance of incentives. According to most observers, the main incentive for any fisher in the main European fisheries (including the English *Nephrops* and the Dutch beam trawl fishery) is to maintain or increase short-term economic profits. On this view, any action that will reduce short-term economic profits is to

[14] This was demonstrated by a skipper who voluntarily made changes to his gear, thereby reducing discards by up to 30% (Catchpole *et al* 2005b).

be avoided, even if such action might increase economic profitability in the longer term. Applying this perspective to the English *Nephrops* fishery, we find that there is sufficient technical ability to reduce whiting discards at a relatively small economic cost, because it only marginally reduces *Nephrops* landings. But the positive incentive to reduce discarding in this fishery is more ecological, as it has only a limited market for whiting. Whiting is an important target species in some other North Sea fisheries, so the benefit of a reduction in whiting discards in the English *Nephrops* fishery would be seen mostly in these other fisheries.

By contrast, in the Dutch beam trawl fishery, technical measures such as larger mesh-sizes come at a substantial economic cost, because they considerably reduce landings of its most valuable species, sole. The positive incentive to reduce discarding is both ecological and long-term economic, because one of the main discard species, plaice, is also a major target of the fishery, albeit less valuable than sole. Thus what the two fisheries have in common is their lack of incentives to reduce discards because this will reduce their short-term economic profits. The difference between the two case study fisheries is one of measure: for the *Nephrops* fishery, the small reduction in short-term economic profits outweighs the ecological incentive to reduce discarding; whereas for the beam trawl fishery, the big reduction in short-term economic profits outweighs even the potentially large long-term economic and ecological benefits.

From our experiences of these two fisheries, how can we ensure that the long-term economic and ecological incentives compete more effectively with the short-term economic incentives? We are not confident that blunt enforcement of measures designed to prevent discarding, such as effort control, a discard ban or increased mesh size will work, because they would either be circumvented by disgruntled fishers or drive the fishers out of business. We are more optimistic about economic forces playing a constructive role in altering the balance between long-term and short-term incentives, but only if externalities or side-effects are brought into the equation.

Economic incentives have been successful in reducing discards where the technical ability to achieve discarding has been relatively high. Area closures and fishing time restrictions, although not effective (or appropriate) by themselves to reduce discards, have provided the necessary incentive for fishermen to adopt more selective fishing methods. For example, selective grid systems have been introduced in the Norwegian whitefish fishery (Isaksen 2000) and the Kattegat and Skagerrak *Nephrops* fishery (Valentinsson and Ulmestrand 2005) following restrictions on fishing opportunities. When using these designs, fishermen are rewarded with more fishing opportunities. Similarly, access to an otherwise closed area in the Irish Sea is granted to those fishermen willing to use a selective *Nephrops* trawl design (Rihan and McDonnell 2003).

The manipulation of market forces may also be a useful tool in generating the necessary economic incentive to reduce discards. For example, if the economic cost of environmentally harmful fishing practices were factored into the price of the fish, this would result in a decrease of demand, which could result in less pressure on the stock, and fewer discards of a resource which is severely under pressure. One way of doing this would be to impose a penalty on discarding, which could take the form of a tax per unit of effort per fishery. The difference between the two case study fisheries would be that for the *Nephrops* fishery this tax could be substantially lower than for the beam trawl fishery, because a relatively low tax in the *Nephrops* fishery will probably provide enough incentive to implement the measures necessary to reduce discards. The relatively high tax per unit of effort necessary for the beam trawl fishery corresponds to the relatively high external costs of discarding in this fishery. An additional advantage of this measure is that it would encourage fishers to develop and use more selective gear as well as reduce the pressure on the stock through market forces, because it would increase the price of the target stock. Whether such a proposal would be favourably received by fishers is, however, another matter.

Alternatively, managers could help to create a market for the discards. Such a measure would be more likely to succeed in the Dutch beam trawl fishery than in the English *Nephrops* fishery, because undersized plaice are more marketable than undersized whiting. If there were no concomitant increase in the TAC, this would effectively reduce the fishers' income as the discards are less valuable. Conversely, if there were an increase in the TAC, the incentive of short-term gain could result in high-grading, thereby diluting the beneficial effects of this measure. An important consideration in market development, therefore, is to determine whether the management objective behind discard reduction is to cut down waste or to improve stock condition. Creating a market for fish that is currently discarded could cut down waste but harm stock condition, because of an increase in the fishing effort exerted on juvenile fish.

The success of such measures critically depends upon how they are received by fishers. One way of helping to create a positive reception in the minds of fishers is to nourish the notion of fishers as committed to the long-term future of the marine environment. All stakeholders agree that discarding is a wasteful practice and should be avoided as much as possible, the fisher possibly just as much as any environmentalist. The problem outlined above - that it is not possible to prevent discarding and run an economically profitable fishing operation with the current functioning of market forces – depends upon the assumption that the main incentive for fishers in the EU is short-term economic profit. But this assumption does not entail that this is the fishers' *only* incentive. For many fishers, their long-term economic viability is at least as important as their short-term economic profit-maximisation. Moreover, for at least some fishers, the ecological health of the marine environment is also an important consideration – not least because they recognise that the environmental movement is steadily gaining ground in the corridors of decision-making in fisheries governance, and they cannot count on an indefinite period of immunity from the legal requirement that their activities must be evaluated for their environmental impact. In other words, other stakeholders may begin to hold fishers accountable for their actions, thereby incentivising fishers to consider seriously how to reduce their discard levels. Indeed, in the future, fishers may have to contemplate taking on a role of environmental stewardship as the condition imposed by society on their right to fish.

## 8. Conclusion

In this article, we have investigated the discard problem in two different types of North Sea fishery, with the aim of improving our understanding of what are the causes of high levels of discarding, and what solutions may be available. We have found that, while one of the most significant differences between the two fisheries is technological – in that the technology for reducing bycatch discarding without serious loss of the target catch already exists in the English *Nephrops* fishery, but does not exist in the Dutch beam trawl fishery – the solution to their discard problems in both cases depends ultimately on the incentives that fishers have for reducing discard levels. We argue that while the primary motive of fishers is short-term profit maximisation, they have two secondary motives – long-term economic viability and ecological sustainability - which can be built upon by adjusting market forces and by recognising the necessity for fishers to develop into environmental stewards.

## References

Alverson, DL, Freeburg, MH, Murawski, SA and Pope, JG (1996) *A Global Assessment of Fisheries Bycatch and Discards*, FAO Fisheries Technical Paper 339 [Reprint of the original publication in 1994], Rome, UN Fisheries and Agriculture Organisation

Arkley, K (1988) *Further Evaluation of the Application of Separator Panels in Trawls Used in the Nephrops Fishery,* Hull, Seafish Industry Authority

Buisman, E, De Wilde, JW, Cappell, R, Borel, G, Giron, Y, Vibier, F and Latrouite, A (2001) *Economic Aspects of Discarding*, The Hague, Agricultural Economics Research Institute (LEI)

Cappell, R (2001) *Economic Aspects of Discarding – UK Case Study: Discarding by North Sea Whitefish Trawlers*, Final Report for DG Fish, European Communities, and MAFF, UK, Nautilus Consultants

Catchpole, T (2003) Unpublished doctoral research material.

Catchpole, T, Frid, C and Gray, T (2005a) 'Discards in North Sea fisheries: causes, consequences and solutions' *Marine Policy* 29: 421-430

Catchpole, T, Frid, C and Gray, T (2005b) 'Discarding in the English north-east *Nephrops norvegicus* fishery: the role of social and environmental factors' *Fisheries Research* 72: 45-54

Catchpole, T (2005c) *A Multi-Disciplinary Study of Discarding in North Sea Fisheries*, PhD Thesis, University of Newcastle upon Tyne

Crean, K and Symes, D (1994) ‘The discards problem: towards a European solution’ *Marine Policy* 18 (5): 422-434

EP [European Parliament] (1999) *The Problem of Discards in Fisheries*, STOA Study No. EP/IV/STOA/98/17/01, Brussels, European Parliament

Evans, SM, Hunter, JE, Elizal and Wahju, RI (1994) ‘Composition and fate of the catch and bycatch in the Farne Deep (North Sea) Nephrops fishery’ *ICES Journal of Marine Science* 51 (2): 155-168

Fonds, M and Blom, W (1995) ‘Onderzoek naar vermindering van discard productie door boomkornetten’ Texel, NIOZ 95 V 05: 35 pp

Gray, TS (ed) (2006) *Participation in Fisheries Governance*, Dordrecht, Springer

Grift, RE, Tulp, I, Clarke, L, Damm, U, McLay, A, Reeves, S, Vigneau, J and Weber, W (2004) ‘Assessment of the ecological effects of the Plaice Box’ *Report of the European Commission Expert Working Group to Evaluate the Shetland and Plaice Boxes*, Brussels: 121 pp

ICES [International Council for the Exploration of the Sea] (1994) ‘Report of the study group on the North Sea plaice box’, Charlottelund, Denmark, ICES CM 1994/ Assess: 14

ICES [International Council for the Exploration of the Sea] (1999) ‘Workshop on the evaluation of the plaice box’, IJmuiden, The Netherlands, 22-25 June 1999, ICES CM 1999/D: 6

ICES [International Council for the Exploration of the Sea] (2004) ‘Report of the Working Group on the Assessment of Demersal Stocks in the North Sea and the Skaggerak’, Bologne-sur-Mer, France, 9-18 September 2003, ICES 2004/ACFM: 07

ICES [International Council for the Exploration of the Sea] (2005) ‘Report of the Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak’, ICES Headquarters Copenhagen, Denmark, 6-15 September 2005., ICES CM 2006/ACFM:09.

Isaksen, B (2000) ‘The Norwegian procedure and experience concerning acceptance of new selective technology by the industry’, in *Expert Consultation on Sustainable Fishing Technologies and Practices*, vol. 588, St. John's, Canada. 1-6 March, 98-105.

Kelleher, K (2004) *Discards in the World’s Marine Fisheries: an Update*, FAO Fisheries Technical Paper 470, Rome, UN Fisheries and Agriculture Organisation

Melvin, EPJ (2003) ‘Focusing and testing fisher know-how to solve conservation problems’ *Fisheries Centre Research Reports* 11 (1): 224-226

NAO [National Audit Office] (2003) *Fisheries Enforcement in England*, London, NAO

NEDFO [North East District Fishery Officer] (1997) *Report*, North Shields, North East District Fishery Office, DEFRA

NEDSFC [North East District Sea Fisheries Committee] (2000) *Annual Report*, London, DEFRA

Pascoe, S (1997) *Bycatch Management and the Economics of Discarding*, FAO Fisheries Technical Paper 370, Rome, UN Fisheries and Agriculture Organisation

Pastoors, MA, Rijnsdorp, AD and Van Beek, FA (2000) ‘Effects of a partially closed area in the North Sea (“plaice box”) on stock development of plaice’ *ICES Journal of Marine Science* 57: 1014-1022

Radcliffe, C (2001) ‘Nephrops trawl reduction using activating selection grids’ *FAIR CT* – 98 4164

Rihan, D and McDonnell, J (2003) 'Protecting spawning cod in the Irish Sea through the use of inclined separator panels in *Nephrops* trawls' ICES CM 2003/Z: 02

Rijnsdorp, AD (1999) 'The North Sea's "Plaice box" as a marine protected area' *ACP-EU Fisheries Research Report* Number 5, IJmuiden, The Netherlands, RIVO

Rijnsdorp, AD, Van Beek, FA and Leeuwen, PI (1981) 'Results of mesh selection experiments on sole with commercial beam trawlers in the North Sea and Irish Sea in 1979 and 1980' ICES CM 1981/B: 31

Rijnsdorp, AD, Van Keeken, OA and Bolle, LJ (2004) 'Changes in the productivity of the southeastern North Sea as reflected in the growth of plaice and sole' ICES CM 2004/K: 13

Taal, C, Klok, A, Van Oostenbrugge, JAE, Smit, MH, Van Wijk, MO and De Wilde, JW (2004) 'Visserij in cijfers 2003' *Periodiek Rapport* 04-07: 75pp, Den Haag, LEI

Valentinsson, D and Ulmestrand, M (2005) 'Mandatory use of species-selective grids in the Swedish Nephrops trawl fishery on national waters - Experiences after one year with new regulations', Institute of Marine Research, Sweden, Lysekil.

Van Beek, FA (1998) 'Discarding in the Dutch beam trawl fishery' ICES CM 1998/BB: 5

Van Beek, FA, Rijnsdorp, AD and Van Leeuwen, PI (1981) 'Results of mesh selection experiments of North Sea plaice with a commercial beam trawler in 1981' ICES CM 1981: 32

Van Beek, FA, Rijnsdorp, AD and Van Leeuwen, PI (1983) 'Results of the mesh selection experiments on sole and plaice with commercial beam trawl vessels in the North Sea in 1981' ICES CM 1983/B: 16

Van Beek, FA, Van Leeuwen, PI and Rijnsdorp, AD (1990) 'On the survival of plaice and sole discards in the otter-trawl and beam-trawl fisheries in the North Sea' *Netherlands Journal of Sea Research* 26 (1): 151-160

Van Ginkel, R (2006) 'Between top-down and bottom-up governance: Dutch beam trawl fishermen's engagement with fisheries management' in Gray, TS (ed) *Participation in Fisheries Governance*, Dordrecht, Springer

Van Keeken, OA, Quirijns, FJ, and Pastoors, MA (2004) 'Analysis of discarding in the Dutch beam trawl fleet' *RIVO Report* CO34/04: 96 pp, IJmuiden, The Netherlands

Van Keeken, OA, Van Hoppe, M, Grift, RE and Rijnsdorp, AD (2006) 'The implications of changes in the spatial distribution of juveniles for the management of North Sea plaice (Pleuronectes platessa)' *Journal of Sea Research* (in press)

Van Marlen, B (2000) 'Technical modifications to reduce the by-catches and impacts of bottom-fishing gears' in Kaiser, MJ and De Groot, SJ (eds) *Effects of Fishing on Non-target Species and Habitats*, Oxford, Blackwell Science

Van Marlen, B (2003) 'Improving the selectivity of beam trawls in The Netherlands: the effect of large mesh top panels on the catch rates of sole, plaice, cod and whiting' *Fisheries Research* 63 (2): 155-168