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Discarding in the Dutch beam trawl fishery

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Abstract

Quantitative estimates of discarded fish and invertebrate have been made for the Dutch sole fishery in the period 1976-1990, based on 51 observations on commercial beam trawlers in the southern North Sea. Over the whole period the annual amount of discarded fish in the Dutch beam trawl fleet is estimated at 100 kt, about equal to the annual landings. More than 80% of the discards consist of flatfish, mainly dab and plaice. The annual amount of discarded invertebrate and debris is estimated about 170 kt. Discarding is higher in quarter 2 and 3 and in coastal areas. In the observed period, 44% of the annual discards were made in the plaice box, an area closed for beamtrawling with large vessels since 1989. Relative minor changes in the sorting behaviour of plaice and sole on board of the vessels have been observed. The impact of discarding on the marine ecosystem has been briefly discussed.

1 Introduction

Most marine fisheries are mixed fisheries directed to only a few commercial target species. The bycatch in these fisheries of unwanted specimen is generally discarded. Alverson et al. (1994) estimate that between 17.9 and 39.5 million tonnes (average 27.0 million) of fish are discarded each year in commercial fisheries all over the world. These estimates are based on a review of over 800 papers. The highest quantities of discards are from the Northwest Pacific while tropical shrimp trawl fisheries generate a higher proportion of discards than any other fishery type accounting of one third of the global total.

In general four types of discards can be distinguished: a) specimens of commercial species below the minimum legal landing size, b) over-quota fish which is not allowed to be landed when this results to exceeding legal quota, c) bycatch species of no commercial value and d) fish with an undesired quality, high-grading. Most discards of fish species do not survive, either because they are damaged in the net during fishing or during the sorting process on board (van Beek et al. 1990, Fonds et al. 1992; Fonds 1994b; Kaiser and Spencer 1994). Discarding may therefore lead to an under utilisation of the potential productivity of the commercial fish stocks. In addition, heavy bottom trawls, such as beam trawls, may catch or damage benthic organisms (Fonds 1994b). Discarded fish and damaged benthic organisms may provide food for scavenging birds (Camphuysen et al. 1995; Garthe et al. 1996) or scavenging bottom dwelling organisms (Kaiser and Spencer 1994; Bergman and Hup 1992; Bergman and Santbrink 1994; Lindeboom and de Groot 1998).

In this paper, discarding is studied in the Dutch beam trawl fishery in the North Sea. The main target species in this fishery are sole (*Solea solea* L.) and plaice (*Pleuronectes platessa* L.) with, in value, important by-catches of turbot (*Scophthalmus maximus* L.) and brill (*Scophthalmus rhombus* L.). Beam trawls have a close physical contact with the sea bottom and the tickler chains or chain matrices, which are used to activate the fish, to some extend penetrate into the surface of the bottom (Bridger 1972; BEON 1991). This fishing gear, in association with a small effective mesh size, can generate considerable amount of discards (van Beek 1990; Fonds 1994a).

This paper will present estimates of annual production of discards based on an evaluation of 51 trips made by observers on board of commercial beam trawlers between 1976 and 1990. Attention is given to species composition, size distribution of the discards, the spatial and temporal patterns in discarding and sorting behaviour on board. Finally the effect of discarding on the "plaice box", a closed area for beam trawlers > 300 hp in the nursery areas for plaice and sole is discussed.

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2 Material and Methods

2.1 Description of the fishery

The Dutch beam-trawl fishery in the North Sea is directed to mixed flatfish species in the southern North Sea. Since its introduction, in the mid-sixties, the fleet has expanded considerably and has replaced the fishery for flatfish with otter trawls. A relative small part of the activity of the fleet is directed towards plaice north of 55°N using larger mesh. The duration of a fishing trip is usually about 5 days. The number of vessels and mean horse power (hp) of the fleet for the period 1974-1994 is given in Figure 9.

The gear, operated by the fishery, is a twin beam trawl, fished on both sides of the vessel. In order to activate the fish on the sea bottom, a number of tickler chains is attached from the shoes of the gear and from the ground rope. Alternatively some vessels use chain matrix instead of tickler chains. A more detailed description of fishery, its history and the construction of the gear is given in Lindeboom and de Groot (1998).

In the period considered, the fleet has been restricted by individual transferable quota (ITQ's) for plaice and sole, bycatch regulations for roundfish (cod, haddock, whiting and saithe) and technical measures (minimum mesh size, minimum landing size, gear, vessel and area restrictions). The minimum allowed legal mesh size, when fishing for sole, is 75 mm before 1987 and 80 mm thereafter and is set in accordance with the gear selection characteristics of sole. In the period considered, the effective mesh size has been often avoided by legal and illegal provisions to the cod-end. Since 1988 the maximum allowed beam length is restricted to 12 m per beam. The maximum engine power of vessels, which entered the fishery after 1987 is restricted to 2000 hp. In the 12 nautical miles coastal zone and, since 1989, in an area called the "plaice box", introduced to protect juvenile plaice (Figure 1), the maximum allowed beam length is 4.5 m and the maximum allowed engine power is 300 hp.

2.2 Sampling scheme

The 51 discard trips, considered in this paper, were made in the period 1976-1990. Most trips have been carried out in the first and last quarter of the year. The trips are not evenly spread out over the whole period. In some years, sampling was focused on beam trawlers. In other years, mainly otter trawlers, pair trawlers or shrimpers were sampled. The best sampled years are 1978-1981 with 8-9 trips each year. In 1984-1988 no trips were made at all and in the other years the sampling intensity varied between 1-5 trips (Table 1).
The selection of the sampling vessels was not random. Many vessels did not have the capacity to carry observers during a whole week and therefore only vessels with an extra capacity of two beds were selected. This was also the reason why only 2 small coastal beam trawlers ≤ 300 hp were sampled. Also it was not known in advance which fishing grounds would be visited. Therefore it could happen that one ICES rectangle was visited 10 times during the whole period and other rectangles not at all (Figure 1).

2.3 Sampling procedures

Discards and landings were sampled by two observers attending the trip. Length distributions of landings and fish discards (all species) were obtained from a number of hauls during day and night. Discards and landings were sampled in the following standard way. After the catch was boarded on deck, the marketable fish was sorted out by the crew. From the remaining part of the catch a subsample of one or two boxes (of 40 kg) was taken. All fish discards in this subsample were sorted and measured by species. These length distributions were raised to the total volume of discard catch. The non fish fraction of the catch was estimated each haul in number of boxes. The content of this fraction, mainly existing of invertebrates and debris (garbage, dead shells, stones, etc.), has not been consistently recorded. Landings were measured several times per day but not by haul. From the landings sub-samples of 10 or 20 kg were weighted using a steelyard and length distributions were recorded by species. During bad weather conditions, when weighting was not possible, the weight was estimated by the observers. When landings had been sorted in size categories, sampling of landings was stratified to these categories. In only a few occasions, length distributions of some less important species have not been measured

As fish sorting procedures on board had developed in the eighties by the introduction of conveyor-belt systems, the standard procedure could not by applied in the last sampling period (1989-1990). In some occasions the set up of transport belts on deck was constructed in such a way that after sorting the marketable fish from the belt, the remaining catch immediately disappeared in sea through a pipe at the end of the belt. In these occasions a subsample of the discards was collected at the end of the belt and the volume of the discards and debris, was estimated by subtracting the volume of landings from the estimated total catch. In a single case, landings were measured in the fish market.

In addition relevant characteristics of the vessel (size, engine power), gear (mesh size, tickler chains) and hauls (duration, position, depth, fishing speed) were recorded. A summary of the recorded characteristics by trip is given in Table 1. This table also gives the level of sampling on board and the landings by trip (landed weight) standardised to 100 fishing hours (fh).

During a trip an average of 33 hauls (62 fh) were done of which 23 (44 fh) were sampled for discards. The average sample weight of landings was 562 kg, corresponding to about 4% of the total landings.

After each trip, a cruise report was written, containing a technical report of the trip, a description of the sampling procedures, lists with the recorded characteristics and tables with length compositions of landings and discards per 100 fh aggregated over the whole trip for all species separately. In general the number of discards and volume of debris were raised from the sampled fishing hours and the number of landings by raising from the weight of the measured samples to the actual landings by 100 fh.

2.4 Methods

Discard production and production of invertebrate and debris of the fleet were estimated in two different ways: method 1) by raising the weight of discards/fh and debris/fh observed on the vessels to the total fishing hours of the fleet and method 2) by applying the observed ratio of fish discards/total fish and debris/debris+landings to the total landings of the fleet. Both raising procedures were applied to various stratification's of the data: all trips combined, the trips grouped by period, all trips grouped by quarter, all trips in the plaice box rectangles and all trips outside this area

Fishing hours for the period 1976- 1983 were available from the national statistics. For 1989 and 1990, they were estimated based from a linear relationship between fishing hours (fh) and fishing days (fd) from the earlier period (fh = 986.6 - .67*fd, r = 0.55). Fishing hours by quarter were only available for the years 1976-1982. The quarterly ratio in this period has been used for the whole period. Proportions of effort inside and outside the plaice box were assumed to be the same as in the period 1974-1977 (ICES 1987)

Estimates of total annual landings by the Dutch fleet (landed weight) were provided by LEI-DLO (unpublished) and consisted predominantly of plaice and sole. The proportion of quarterly landings was assumed to be the same as the quarterly plaice + sole landings in the fleet database (unpublished). Catch ratios inside and outside the plaice box were based on national statistics of plaice, sole, cod and whiting landings per statistical rectangle in the period 1974-1977 .

The 95% confidence limits of the estimated discards and debris production were obtained from the confidence limits of the mean discards/fh and debris/fh (method 1) or the confidence limits of the observed percentages of discards and debris (method 2).

Numbers of landings and discards were available from the measurements on board of the vessels . The weight of the landings was obtained on board or from the "sale slips" in the fish market. The weight of the fish discards was estimated indirectly by converting length- into weight-distributions using the relationship:

$$W = c.L^3$$

where c is a species specific condition factor derived from unpublished length-weight relationships collected in market sampling programmes and surveys. In cases where no length-weight relationships were available, relationships of species with similar morphological dimensions were assumed. The condition factors are given in Table 2.

Unless specified specifically, landings have been expressed in fresh weight. This means that a fresh/gutted conversion factor (f) has been applied to the landed weight. The conversion factors used are the same as those applied in the Dutch national statistics and are also given in Table 2.

Distributions of percentages or proportions are usually not normal. Unless specified otherwise, all percentages and confidence limits are calculated from a weighted mean of the values over the strata using an arcsinus transformation as given by Sokal and Rohlf (1981):

$$\phi = \arcsin\sqrt{p} \quad \text{where } p \text{ is a proportion}$$

The mean and confidence limits of ϕ were converted back to proportions by:

$$p = [\sin(\phi)]^2$$

3 Results

During the sampling trips, 37 fish species or species groups were recorded. Some species were classified only at the genus level (some ray species) or family level (sandeel). 18 Species were present in landings and discards. All other species were only present in the discards. Table 2 lists the species and their prevalence of occurrence in the catch, landings and discards.

The average catch per fishing hour over all trips was 555 kg/hour. In general the invertebrate and debris fraction was the largest fraction of the catch varying between 0% and 75% of the total weight of the catch. On average 44% of the catch consisted of debris and invertebrate (Figure 2a). The percentage of landings varied between 5 and 62%. On average landings accounted for 31% of the total catch. The discarded fish fraction varied between 5% and 75%. The average percentage of fish discards was 25%.

By far the majority of the fish weight landed consisted of plaice (65%), 16 % of the landings consisted of sole and the remaining species, mainly cod, turbot, brill and whiting, contributed 19% to the landings (Figure 2b). Fish discards mainly consisted of flatfish species. Dab and plaice contributed 51% and 29% in weight or 64% and 20% in numbers to the total discards (Figures 2c and 2d). Only 2% consisted of sole while other species contributed 18% in weight or 14% in numbers to the discarded fish fraction.

The average landings and discards per 100 fh and the percentage discarded by species are given in Table 3. From the main target species, plaice and sole, 51% and 16% of the numbers caught or 27% and 10% in weight are discarded. From the most abundant species in the catch, dab, 98% or 92% in numbers or weight respectively are discarded.

Estimates of the total annual production of discards and debris based on a quarterly raising for all periods combined are given Table 4. The estimates are about 10% higher than those based on all samples combined, indicating a bias in the sampling of the fleet. The bias correction factors, applied to the estimates based on an annual basis are also given in this table. The table also indicates that discarding of fish and debris is lower in the first and fourth quarter. These lower discard rates differ significantly from the other quarters ($p<0.05$) and originate both from higher landings and fewer discards in these quarters.

Estimates of total annual amount of discards and invertebrate and debris, corrected and not corrected for sampling bias, and their 95% confidence limits are given in Table 5 for different time periods. The corrected estimates of the two different raising procedures are quite similar. Annual discard production varied between 63 and 137 kt. in the different periods, with a mean over all years of 95 kt. using method 1. Applying method 2, the discard estimates vary between 61 and 176 kt. with a mean of 97 kt. Annual debris production varied between 134 and 301 kt. in the different periods, with a mean over all year of 166 kt. using method 1. Applying method 2, the debris estimates vary between 124 and 408 kt. with a mean of 173 kt. The highest estimates of discards and debris originate from the most recent sampling period and differ significantly from the earlier periods.

Figure 3 shows the spatial distribution of discards based on the pooled samples. In this figure a distinction has been made between flatfish (mainly dab and plaice), rays and skates, and other fish (mainly gadoids). Flatfish discards show a clear pattern with the highest values in the rectangles near the continental coast and consistently decreasing further offshore. There appears to be no distinct pattern in the spatial distribution of roundfish discards. Rays and skates discards only occur in very small amounts in the southern and western North Sea.

The plaice box is situated near the continental coast in the German Bight and the rectangles bordering the Dutch coast north of the Wadden Islands (Figure 1) where the highest numbers or weight of plaice discards occur. Figure 4 compares the length distributions of landings and discards of plaice and sole from the trips in the plaice box rectangles and those outside the box area. The absolute amount of discards as well as the percentage of discards within the box is higher than outside the box for both species. The percentage of plaice discards in numbers inside the box was 78% compared to 31% outside the box. These percentages for sole are 21 and 12 respectively. Total production of discards and debris inside and outside the box rectangles is estimated in Table 5. A comparison suggests that in the observed period about 44% of the fish discards and 27% of the debris caught by the total fleet originate from the box area.

The size structure of the discards is given in Figures 5a-c for flatfish and other fish separately. About 87% of the discards in weight exist of flatfish species. By far the majority of flatfish discard production consists of dab and plaice within the length range 15-27 cm. Flatfish discards smaller that 15 cm include also considerable numbers of scaldfish and solenette but these contribute little to the total weight of discards. The majority of other fish discards consists of whiting, cod and grey gurnard between 20 and 30 cm. Other fish smaller than 20 cm may also include considerable numbers of bib, dragonet, hooknose and lesser weever.

Selection-ogives of the sorting process of plaice and sole are given in Figure 6 for the different time periods. The 95% confidence limits of the percentages retained of the most relevant not fully selected length groups are given in Figure 7. The minimum landing size for plaice in the Netherlands is 27 cm. At that length about 50% of the plaice catch is kept on board. Except for the period 82-83 the ogives for the different periods are almost identical. The ogive for the period 82-83 suggest that in that period a larger proportion of smaller plaice is retained. The difference with all other periods for selected lengths of 24-26 cm is significant ($p<0.05$). However, the difference is mainly determined by 1 vessel. When this vessel is excluded from the analysis the difference disappears. The sorting-ogive for plaice also indicates that the retention of plaice ≥ 27 cm has increased over time. The sorting-ogives are for sole indicate a change in selection behaviour between the first 2 periods and the last 2 periods. The minimum landing size of sole is 24 cm. During the last 2 periods a smaller proportion of undersized soles has been kept on board compared to the first 2 periods. The difference is significant ($p<0.05$) for length groups between 20-24 cm.

4 Discussion

In most fisheries discarding is an accepted feature by fishermen and managers, because bycatches of non marketable fish are considered unavoidable or can only be avoided at the expense of a loss of considerable amounts of marketable fish. In spite of the importance of discard information in relation the effect of discarding on the marine ecosystems and on assessments of the state of the stocks, relatively little research has been carried out and few literature exists. In the North Sea, only Scotland has a long established discard monitoring program in the fisheries on cod, haddock and whiting (Jermyn and Hall 1978; Jermyn and Robb 1981). In other countries discard information in fisheries for fish has been collected on an *ad hoc* basis (Daan 1976; de Veen and Rodenburg 1971; de Veen et al. 1975; Weber and Lamp 1983; Lamp and Weber 1984; Kirkegaard and Poulsen 1990; Corten 1990; Van Beek 1990; Fonds 1994a) or has started recently (Jensen et al. 1994; Cotter 1995). One of the major reasons for the relativly little historical effort in discard research is that representative, quantitative estimates are difficult and expensive to obtain. There is a large spatial and temporal variation, related to the seasonal distribution of the fish and the fleets and independent annual variation in abundance of the individual stocks. As a consequence, in order to cover all this variability, extensive sampling programmes are required to obtain adequate information which are very expensive. As an example, the information presented in paper is based on 100 man weeks sampling at sea of the Dutch beam trawl fishery only. Discard patterns can also differ by fleet. Also the amount of discarding is affected by changes in technical measures imposed on the fleet and the enforcement of these measures.

4.1 composition of catch

The Dutch beam trawl is the largest fishery for flatfish in the North Sea, taking about 80% of the total international sole catch and 50% of the catch of plaice. These species are also the most important commercial flatfish species in this area. On the observed vessels landings contributed 31% to the total catch. The bycatch of non marketable discarded fish in this fishery is estimated to be 25% of the total catch or 44% of the fish catch and consisted mainly of flatfish (dab and plaice). The observed percentage of fish discards of the total fish catch in the different time periods varied between 37 and 57% and was highest in the last period (1989-1990). The percentage of fish discards of the total fish catch was lower than found Lindeboom and de Groot (1998), based on Fonds (1994b), which estimate the amount of non marketable fish, also mainly dab and plaice, twice as high (in weight) as the marketable fish.

Also the amount of bycatch of invertebrate and debris was highest in the most recent sampling period. The total amount debris and invertebrate bycatch is 44%. It mainly consisted of one or more of the following items: echinoderms, mostly starfish (*Asterias rubens*) or heart urchins (*Echinocardium cordatum*); crustaceans, masked crabs (*Corystes cassivelaunus*) and hermit crab (*Eupagurus bernhardus*); fossil shells and bones; stones; rubbish as wood, beer tins, bottles, plastics and sometimes sand. In general the largest part of this fraction consisted of invertebrate, but on specific fishing grounds dead material the catch consists for a considerable part of dead material.

Discard rates by species, given in Table 3, vary considerably. Dab, the most abundant species in the catch, was almost entirely discarded mainly because of their small size and low economic value. About 50% of the numbers or 27% in weight, of all plaice caught were below the minimum landing size and were discarded. most of them having a length between 17 en 27 cm. The main reason for the high number of plaice discards is the relative small mesh size used in the fishery, which is set in accordance with the net selection characteristics for sole. From the mesh selection characteristics for plaice (summarised in Wileman 1992) it can be calculated that ,using a mesh size of 80 mm in the codend, 50% of all plaice with a length of 17 cm which enter the net are retained and that all plaice > 20 cm is retained. In order to avoid most of the catch of undersized plaice below the minimum landing size of 27 cm would require a mesh size of about 120 mm, which corresponds with a 50% retention at the minimum landing size. Such mesh size would also eliminate the entire bycatch most other species including dab, but, however, also the entire sole catches.

4.2 spatial and seasonal patterns

Spatial patterns of fish discards may vary between seasons and years because of migration of fish and variable success of recruitment in different nursery areas. The limited amount of data do not allow to investigate spatial and seasonal changes in detail. However, a comparison of the between all data over the whole period, illustrated in Figure 3, shows a clear spatial pattern for flatfish discards with the highest values in the rectangles near the continental coast and consistently decreasing further offshore. This observation is in accordance with the traditional distribution of juvenile flatfish in their nursery areas known from recruitment surveys (van Beek et al., 1989). The group "other fish" are dominated by whiting, cod, grey gurnard and bib, which differ in distribution pattern and annual abundance. The fact that such patterns for other fish combined can not be demonstrated does not mean that such patterns do not exist. Most individual species have a clear distribution and will be discarded only in areas where they are caught. Most rays and skate species are rare in the southern North Sea and occur only in certain areas (Knijn et al. 1993; Walker and Heessen 1996). Occasional discards of these species have only been observed within their main centres of distribution.

Seasonal patterns are observed in landings, discards and fishing effort (Table 4). Total landings are higher in quarter 1 and 4, as well on the sampled vessels (cpue) as in the national statistics (total landings). Because of the few number of observations in some of the considered periods the observations are pooled. However in the national statistics the pattern is consistent over years. The higher catches mainly occur from fisheries on spawning aggregations of plaice in quarter 1 and recruitment of a new year class in quarter 4. The cpue of fish discards and bycatch of invertebrate and debris was higher in quarters 2 and 3. No explanation is given for this observation but it is probably related to changes in the distribution of the fleet and the fish and may be related to a seasonal change in vertical distribution of benthic invertebrates due to their seasonal cycle of reproduction, feeding and resting phase. Also fishing effort in quarter 1 and 4, as recorded in the national statistics, is lower than in spring and summer because of less favourable weather conditions, but also closures of the fishery because of quota exhaustion at the end of the year, Christian holidays and traditional praying weeks.

4.3 estimates of discard production

The procedures used for estimating the annual production of discards and debris may give biased results, when the discard rates differ between seasons and sampling intensity is not proportional to the seasonal distribution of fleet effort or landings. Table 4 shows that sampling effort fleet in quarter 1 and 4 has been relative high in these quarters, while fleet effort and discard rates are lower compared to quarter 2 and 3.

The concentration of sampling in the period of relative low discarding may result in an underestimation of the total annual discard production. There are too few observations to estimate a bias for all periods separately. For all periods combined, the sum of quarterly raised productions compared with the production of all quarters combined indicates an 8% higher estimate for fish discards and a 4% higher estimate for invertebrate and debris when was raised using method 2, or 20% and 13% higher estimates respectively when was raised using method 1. Estimates of total bycatch production, given in Table 5 are corrected for this bias.

The total annual amount of undersized fish and other bycatch, produced by the Dutch beam trawl fleet, estimated from the samples, varies between the different time periods considered. The two estimates for each period given by the two different raising procedures are, however, close. Over the whole period the average annual production of fish discards was estimated 97 and 95 kt. by both raising methods respectively and about the same as the total amount of landings. Annual discards of invertebrate and debris were estimated 173 and 166 kt. respectively and about 75% higher than the landings.

The estimates of discards and invertebrate and debris vary considerable between the periods. In the first three periods between 1976-1983, annual estimates of discards varied between 61 and 101 kt. and those of invertebrate and debris between 124 and 243 kt.. In 1989-1990 theses estimates were considerable higher: 137 -176 kt. fish discards and 301 - 408 kt. invertebrate and debris. The 95% confidence limits of the estimates for the periods separately are considerable higher than those for all periods combined, especially when only a few trips have been made. The variability in the estimates by period, based on a few observations, is to a large extend determined by the areas visited by the vessels and timing of the trips. The estimates between periods are therefore not directly comparable. It is clear that the discard data available are too limited to prepare reliable annual estimates for separate periods. Therefore not much significance should be given to the variability across years. The observed increase in the bycatch in the latter period is , however, large and may be associated with an increase in fishing capacity of the sampled vessels. Figure 8 shows the mean cpue of landings, discards and debris plotted against mean engine power of the sampled vessels. The mean engine power of the sampled vessels in the period 1989-1990 is considerable higher than in the previous periods. Although the cpue of landings remained the same between the different periods, discards and in particular the bycatch of debris and invertebrate have increased considerable as vessels have become more powerful and are using heavier gear. Part of this increase may be explained by the larger surface of the sea bottom fished by the more powerful vessels. The mean beam length has increased from 10.5 meter in the first three periods to 12 meter and mean fishing speed increased from 5.6 to 6.3 nautical miles per hour (Table 1) resulting in a 30% increase in the surface fished per hour. This can, however, not fully explain the observed increase in bycatch. More important is the fact that the fishing power of the sampled vessels in the last period was considerable larger than those in the fleet. The mean engine power of the fleet in 1989-1990 was 1325 hp (Figure 9) while the mean engine power of the sampled vessel was 2880 hp (Figure 8). The estimates for this period should therefore be considered as overestimates. The most realistic estimates of the production of discards, invertebrate and debris production are those based on all samples over the whole period, because these take into account most of the spatial and temporal variation in discarding.

The annual proportion of sole of the total international landings, landed by the Dutch beam trawl fleet is rather constant and varied between 77% and 84% (average (81%) between 1996 and 1990. Assuming that all sole in the North Sea is caught by beam trawl fleets with the same discard pattern as observed in the Dutch fleet the total amount of fish discards in the sole fishery can be estimated by applying a raising factor: 100/81 to the estimates of the Dutch fleet. This leads to an estimate of average annual production of about 120 kt. fish discards and 210 kt. invertebrate and debris in the fishery for sole in the North Sea between 1978 and 1990. These values can be considered as maximum estimates because not all soles are caught by beam trawls. Sole, landed by Denmark is mainly caught by gill netters. Also small amounts of sole are caught by otter trawls or trammels by the UK, France and Belgium. However, these amounts are less than 5% of the total catch.

The estimates fish discarded in the sole fishery obtained in this study are considerable lower than those found by Fonds (1994a) and Camphuysen et al. (1993). Based on a four trips on research vessels using commercial 4 m and 12 m beam trawls in 1992 and 1993 Fonds estimated an annual production of 270 kt. dead fish by the sole fishery in the southern North Sea. The estimates of Camphuysen et al. are based on data from ICES (1995), Fonds (1991), Fonds et al. (1992) and Garthe (1993). His estimates of fish discards fore the years 1989-1993 range between 153 and 246 kt. and for benthic invertebrates between 131 and 210 kt.

The estimates of Fonds can not directly be compared with those obtained in this study, since his figures represent only dead discarded specimen where our estimates reflect all discards. Survival experiments with discards from commercial beam trawls (van Beek et al. 1990; Fonds 1994b) indicate that more than 90% of most discarded fish species is dead or eventually dies. An adjustment of Fonds estimates to total discards would lead to a total fish annual discard production of about 300 kt. compared with our estimate of 120 kt. Fonds estimates must be considered critically since they are based on a small number of observations. Our raising procedures applied to periods with limited data have showed large variations in the estimates associated with wide confidence limits. Also Fonds extrapolation of his observations to the whole fleet may be questioned because most of his samples came from coastal areas where discards have been shown more abundant than in other areas. Also all of his samples originate from quarter 2 and 3, for which our analysis showed significant higher proportions of discards than in other quarters. Finally, his estimates were obtained by raising the observed amount of discards per kg marketable sole to the total international sole landings. In the commercial beam trawl fishery, catches of sole are consistently lower during daytime compared with those made during darkness. This is related to the behaviour of the species which show a clear diurnal activity pattern (Kruuk 1963). Fonds observations all originate from daylight sampling and the ratio discards/sole can therefore expected to be higher and not fully representative to the fleet which operates day and night.

A comparison between our estimates of discarded invertebrate and those by Fonds (1994a) is more difficult. Our estimate of 210 kt. annually, includes all specimen, dead and alive and a proportion of debris, which was not measured separately. His estimate of 120 kt. comprises of dead invertebrates only. Survival of discarded benthos is in general much better than for fish but varies considerably between species. For the most abundant invertebrate groups in beam trawl catches, starfish and crustaceans and shellfish, Fonds (1994b) estimated mortality rates of <10% and 30-60% respectively.

Camphuysen et al. (1993) applied for the years 1989-1993 the same raising procedure as Fonds based on a fixed proportion of discards and invertebrate in relation to 1 kg of sole landings. His annual discards estimates are therefore directly proportional to the total international sole landings. This is not correct since the sole landings mainly reflect the annual abundance of sole which varies independently from the abundance of the major discard species (plaice and dab).

Estimates of discarding in other North Sea fisheries are scarce. Daan (1976) estimated discards of whiting to vary between 70 - 90% in numbers in the Dutch gadoid fisheries in the period 1958-1974. His estimates for cod and haddock range between 4 - 28% and 20 - 94%. However, these fisheries have virtually disappeared in the nineties. The variability of discards of individual species is to a large extent caused by the variability of recruitment. Quantitative estimates of discarding for the total North Sea gadoid fishery are only available for haddock and whiting. Based on the Scottish discard sampling programme annual discards in the North Sea roundfish fishery, are estimated by the Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak (ICES 1998) to have ranged between 26 and 260 kt. for haddock (average 96 kt.) in the period 1963-1996 and ranged between 27 and 241 kt. (average 79 kt.) for whiting in the period 1960-1963. The highest estimates originate mainly from the sixties and early seventies when roundfish stocks were expanding. These estimates for these two species only, suggest that discarding of fish in the fishery for gadoids may be even higher than in the beam trawl fishery.

4.4 Plaice Box

In the time period that most discard trips were carried out, the Plaice Box did not exist and major fishing grounds of the beam trawl fleet were situated in that area. The box was established in 1989 for the second and third quarter and since 1995 for the whole year. The purpose of the box was to improve the exploitation pattern of plaice by reducing discarding of undersized plaice. If the box rectangles would have been fully closed to all fisheries which produce discards, the expected overall gain in recruitment was plaice estimated to be about 25% (ICES 1987, 1994; Rijnsdorp and van Beek 1991a) compared with a situation without the box. The results indicate that the absolute amount of discards as well as the percentage of discards within the box was higher than outside the box for both plaice, sole and total discards.

Van Leeuwen and Rijnsdorp (1997) investigated the distribution of plaice inside and outside the box using commercial vessels. They also found the highest amount and percentages of undersized plaice in the box. However, larger plaice was also more abundant in the box, indicating that fishing mortality in the box had been reduced by the closure. This is supported by their findings for sole where catches of undersized and marketable sole were also consistently higher in the box.

From the discard data it is estimated that about 44% of the annually discarded amount of fish originate from the rectangles in which the box is situated. The data suggest that discarding of plaice in the mixed fishery for sole and plaice would be reduced from 51% to 31% in numbers if the box was fully implemented. The analysis also suggests that overall amount of fish discards would be reduced from 46% to 38%, while the percentage of discarded invertebrate and debris would be somewhat reduced as well. The overall gain of the box, however, is less because of the allowance of exemption fleets in the box and an expansion of these fleets (ICES 1994). Also small areas in the box rectangles are not included in the box.

4.5 sorting behaviour

Changes in discard rates are not only caused by variation in recruitment but also by changes in mesh size, minimum landing size, market demands and accuracy in sorting the marketable fish from the total catch by the crew. Daan (1976) found considerable annual variation in the sorting behaviour of the crew in the sixties and seventies in the Dutch fisheries for cod, whiting and haddock. Such large differences have not been observed for plaice and sole in the periods considered between 1976-1990. The relatively large discrepancy observed the period 1982-1983 for fish lengths below the minimum landing size of 27 cm originates from only one vessel. The selection-ogives also suggest that the sorting of plaice > 27 cm has been better in the two most recent periods. The 95% confidence limits suggest that the difference is significant.

The increased efficiency in sorting plaice may be associated with the increased demand for plaice from the market and an increase in price. Although the change seems relatively small compared to those observed for other species in other fisheries, it affects the selection of the most abundant length groups in the catch. The change in sorting behaviour, but also effective changes in mesh size or minimum landing size introduce bias in the estimates of recruitment by VPA and studies in long term population dynamics (Rijnsdorp and Millner 1996) when they don't include realistic estimates of discards.

The selection ogives for sole show large and significant differences between the first two and the last two periods. The high retention of fish below the minimum landings size of 24 cm in the first two periods indicate that the minimum landing size had little effect on the sorting behaviour. The selection has, however, improved considerable in the last two periods.

Intentionally discarding of marketable fish, over quota fish or high grading has not been observed on the vessels, except for flounder. Landings of flounder, mainly caught during the spawning period, are not restricted by quota. In the industry this species is sometimes used as a replacement for plaice. In some occasions, bycatches of marketable flounders were discarded because of its low price or because it was expected that landings of this species would negatively affect the price of plaice.

4.6 impact of discarding on marine ecosystems

The main impact of discarding on marine ecosystems is the provision of additional food items for scavengers. The suitability of discards as food items depends on the preference of the scavenger species and the size and the shape of the food item. The average 120 kt. of discards by the beam trawl fishery consists for 87% of flatfish and 13% of roundfish. A relative small proportion of discards (mainly roundfish and small flatfish) can be utilised by seabirds. Camphuysen et al. (1993) indicates that 95% of discarded offal, 80% of discarded roundfish, 20% of discarded flatfish and 6% of discarded benthic invertebrates is consumed by scavenging sea birds. Applying these figures to our discard estimates for the sole fishery, this fishery would support 21 kt. of flatfish, 12 kt. of roundfish and about 13 kt. of benthic invertebrate to the food of seabirds. Discards of demersal and pelagic fisheries for roundfish can all be utilised by scavenging seabirds and have therefore probably a greater effect than the beam trawl fishery. Also high numbers of small fish are discarded in coastal shrimp fisheries (Tiews 1978; van Marlen et al. 1997). Van Marlen et al. estimated for 1996 that in the shrimp fisheries for Crangon *crangon* in the southern North Sea 112 million discards of roundfish, mainly gadoids and 1399 million discards of flatfish, mainly 0- and 1-group plaice and dab, are discarded which, because of their small size, are all potential food for seabirds.

Discards, not taken by seabirds, will sink to the sea bottom and serve as food for benthic scavengers. Major scavenging species, identified in the southern North Sea by Lindeboom and de Groot 1998, are small dab, whiting and dragonets, while many other species also show a scavenging behaviour. Of the invertebrate species, starfish, (*Asterias rubens*) swimming crabs (*Liocarnius*) and hermit crabs (*Pagurus bernhardus*) were considered to be the most important.

The main impact of discarding by the beam trawl fleet on the ecosystem is restricted to those areas where the fishery operates. A study on the spatial distribution of the effort of the Dutch beam trawl fleet (Rijnsdorp et al. 1997) indicates that 70% of the annual effort is exerted on 20% of the total area visited by these vessels, indicating that the major part of the discards occur in a relative small area.

The impact of the fishery is on marine ecosystems is not limited to discarding only. In a comprehensive study on the effect of different types of demersal fisheries on benthic ecosystems, Lindeboom and de Groot 1998 claim that the impact on the ecosystem by benthic organisms damaged in the trawl track was considerable higher than that of discarding, mainly by the production of food for benthic scavengers in the trawl path, and a reduction of abundance of sensitive (large size, vulnerable) benthic species at the expense of an increase of opportunistic small sized and fast growing benthic species. Shifts in the benthic community from low productive and slow reproducing organisms to high productive and short living organisms such as polychaetes and small molluscs were also reported for a number of areas ranging from estuaries, coastal and offshore areas by Holme 1983; Reise 1982; Beukema 1989; Kröncke 1990 and Rachor 1990. Rijnsdorp and van Beek (1991b) considered that the observed increase in the availability of benthic food must have contributed to the considerable increase in the growth of North Sea plaice and sole has which has been observed in the sixties and seventies.

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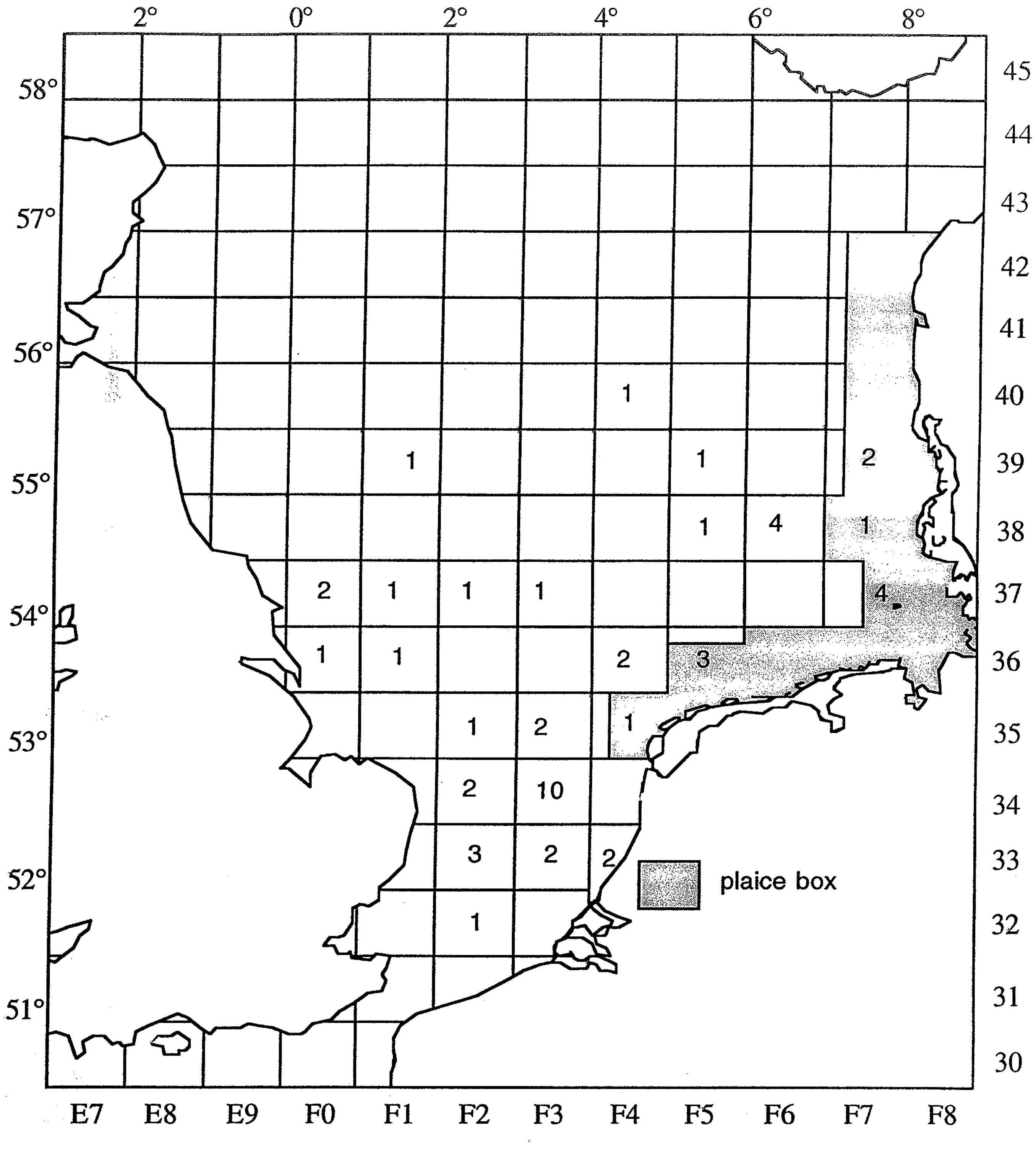
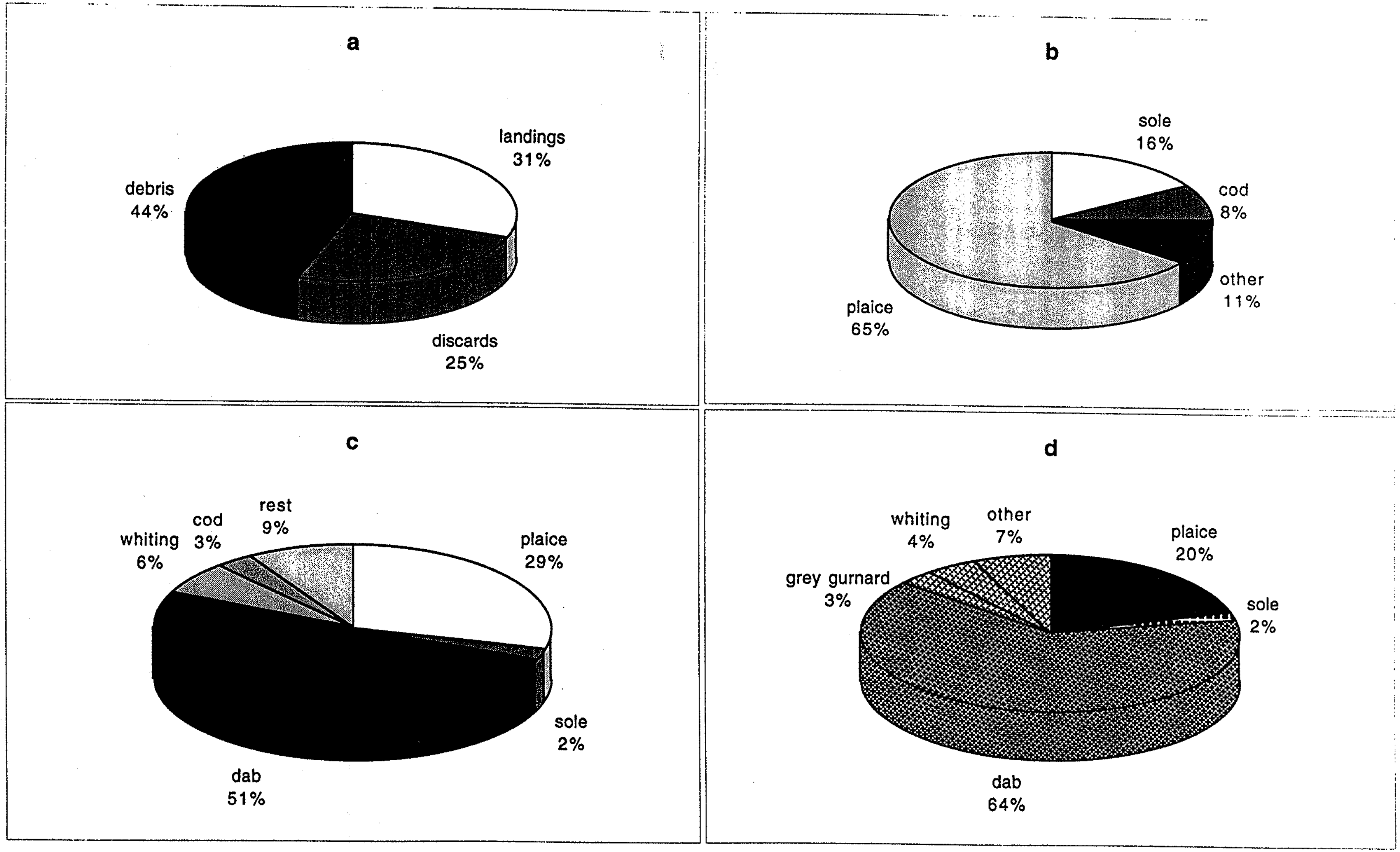


Figure 1 Spatial distribution of the discard trips, classified according to main ICES rectangles visited, and the location of the plaice box

Figure 2 Species composition of the catch

a. total catch in weight
b. landings in weight
c. discards in weight
d. discards in numbers



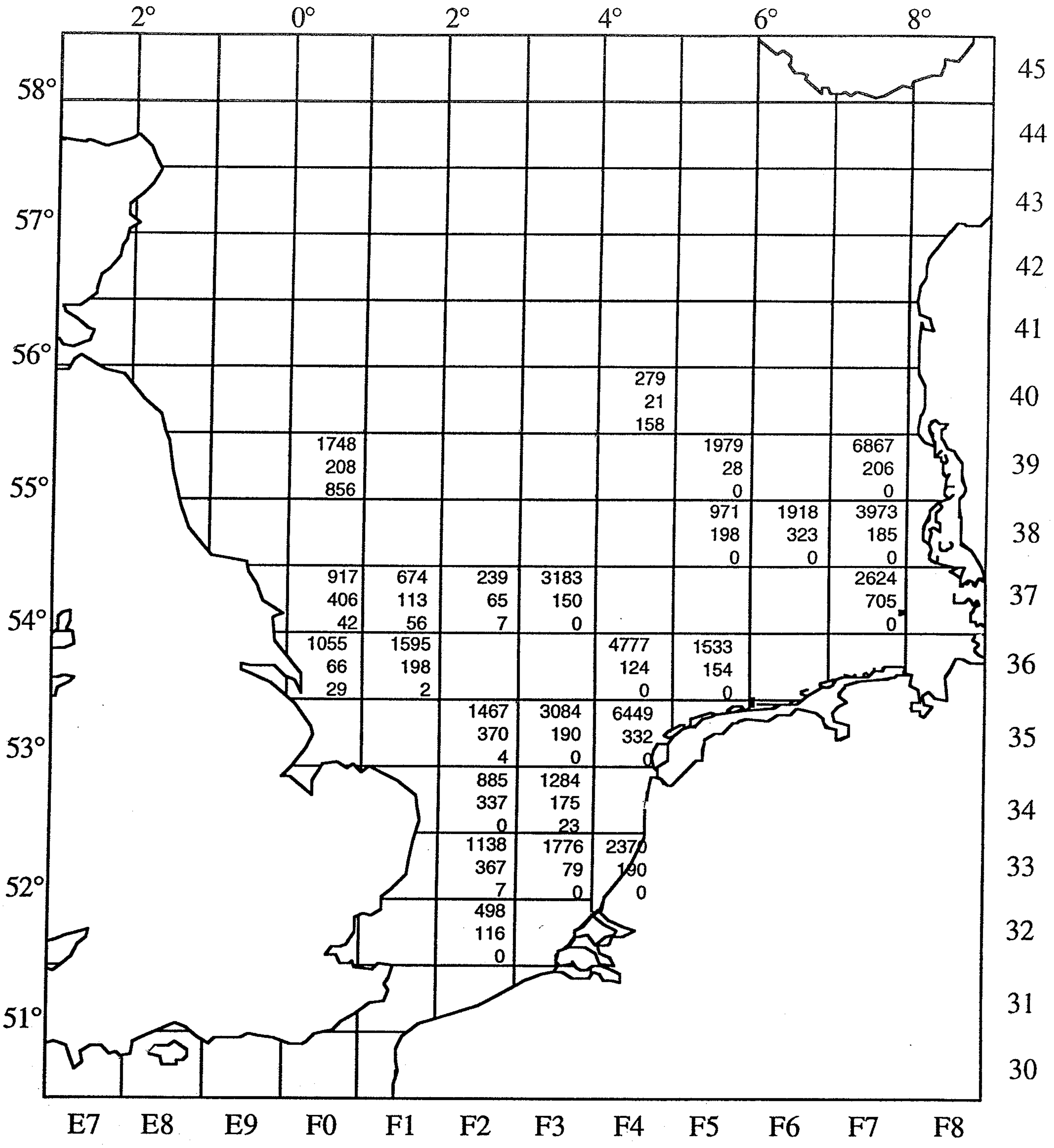


Figure 3 Spatial pattern of discard rates (kg/100 fh.) of flatfish (top), rays and skates (bottom) and other fish (middle)

Figure 4 Length distribution discards (black bars) and landings (grey bars) (vessels > 300 hp)

a. plaice within the plaice box
b. plaice outside the plaice box

c. sole within the plaice box
d. sole outside the plaice box

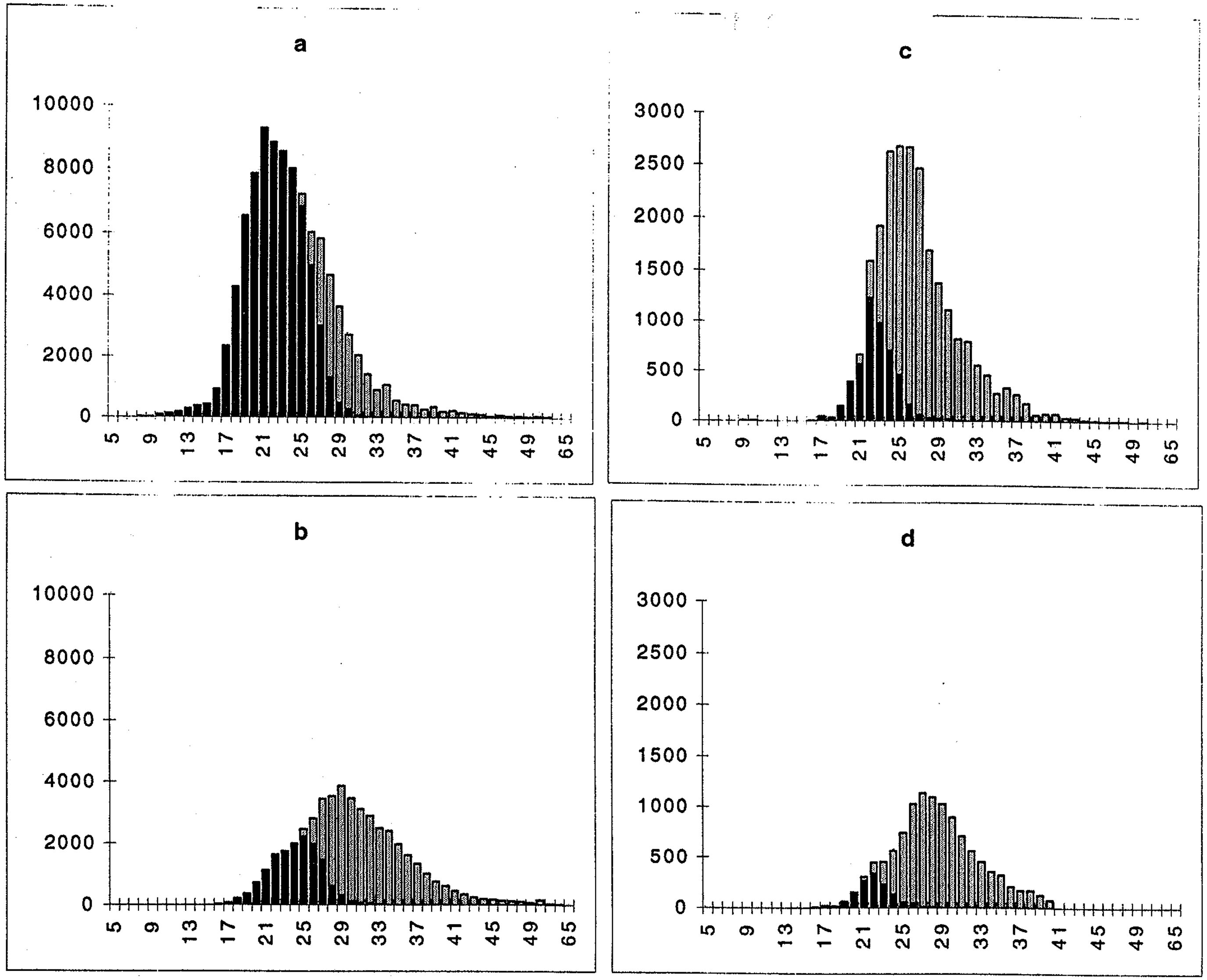


Figure 5 Distribution of discards per 100 fh by size class for flatfish and other fish separately
a. in numbers
b. in weight
c. in weight cumulative

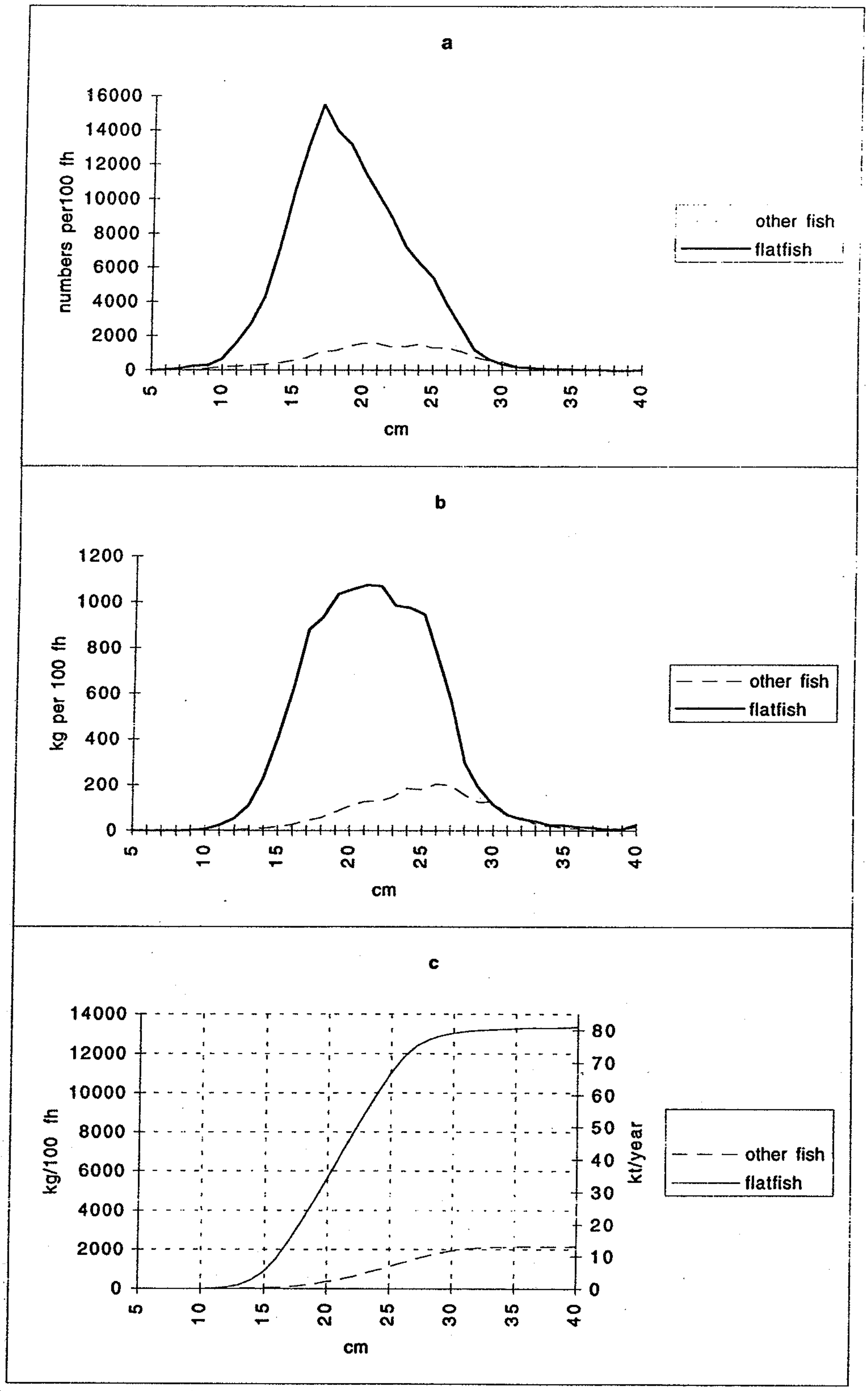


Figure 6 Weighted means of the percentage of the total catch retained on board by cm size class of plaice (A) and sole (B) for different groups of years. The legal minimum landing size (MLS) is indicated

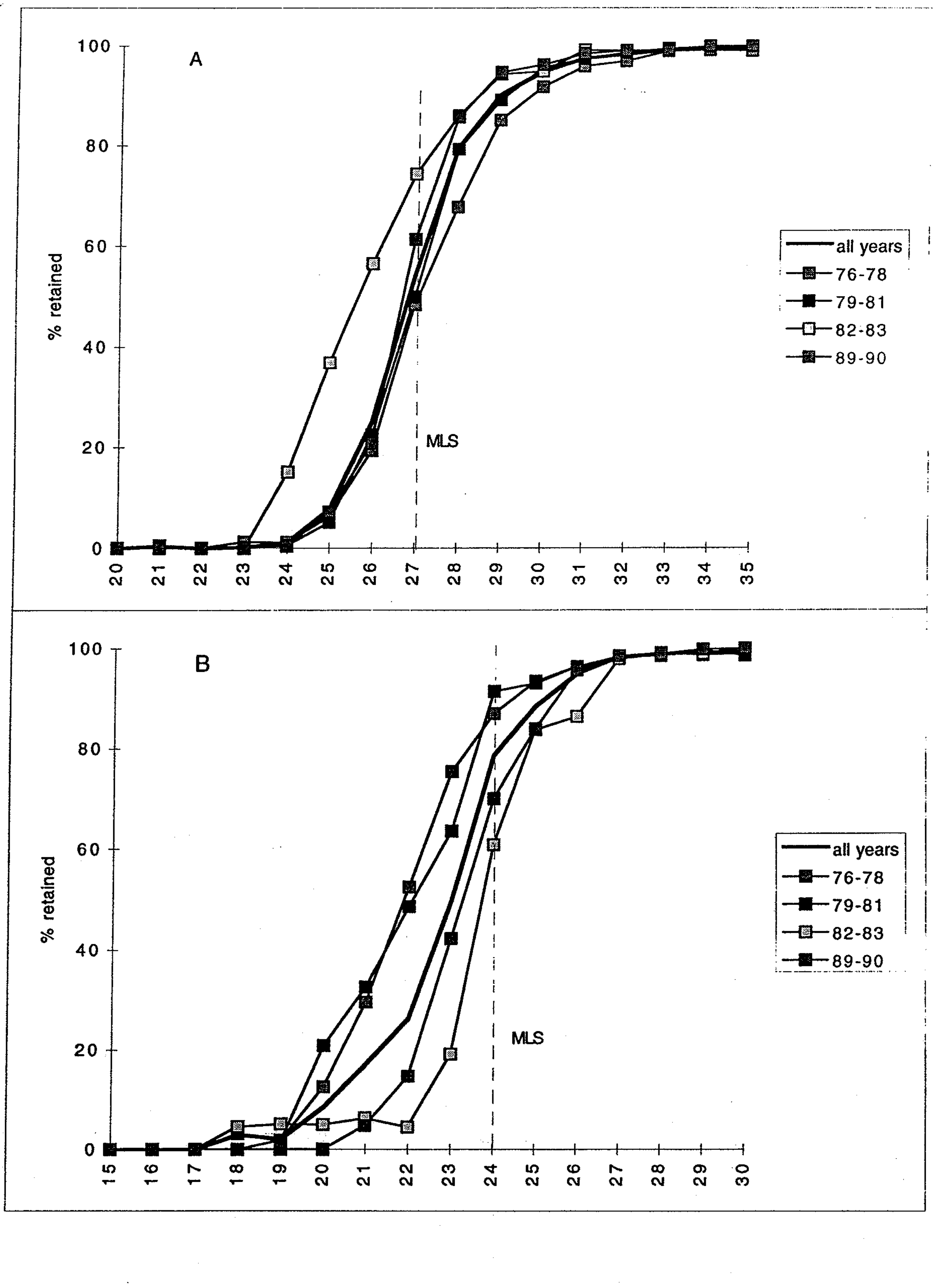


Figure 7 Confidence limits of the percentage retained for selected size classes of sole (A) aand plaice (B) for different groups of years

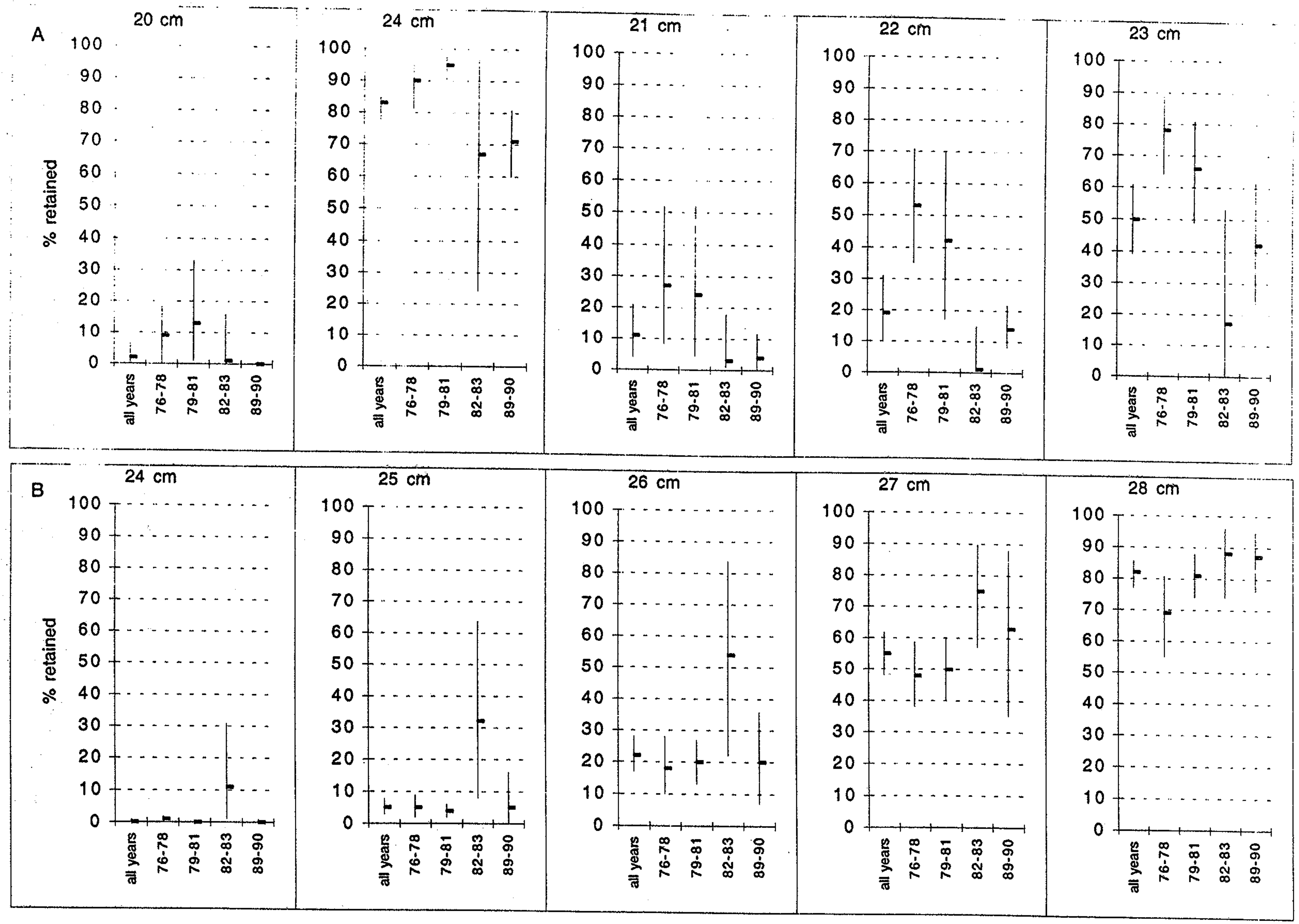


Figure 8 Relationship between landings, fish discards and debris (kg/fh) and mean horse power of the sampled vessels during the four periods distinguihed

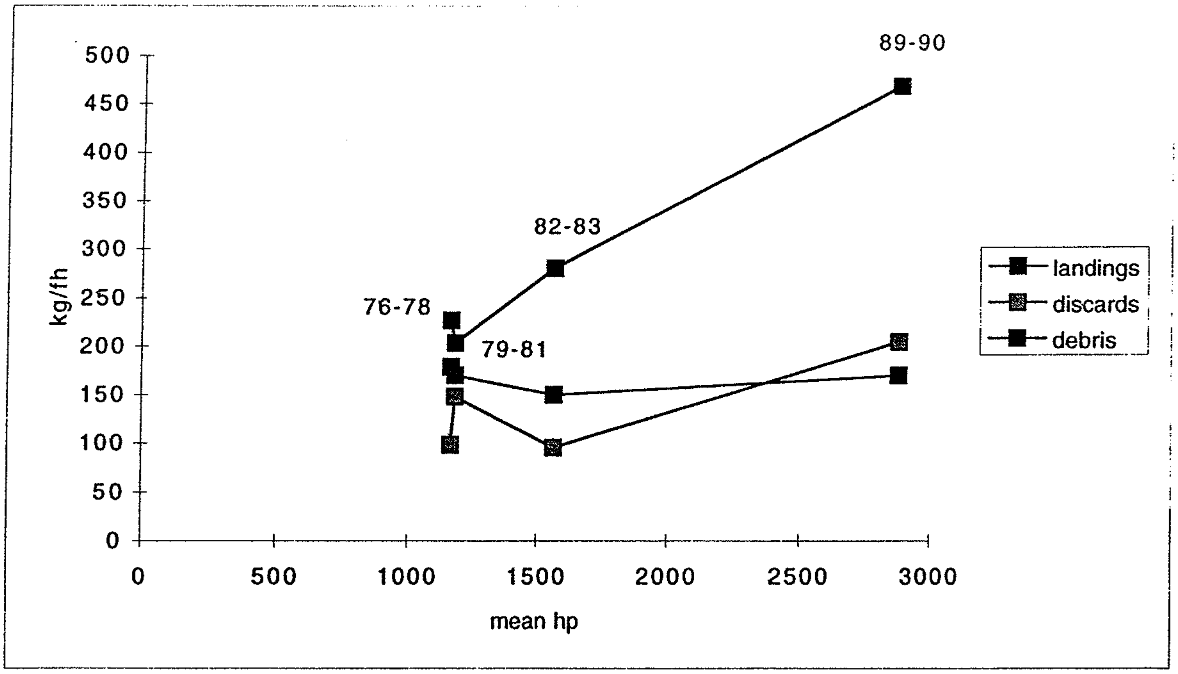


Figure 9 Number of vessels N (open symbols) and mean horse power hp (open symbols) of the demersal trawl fleet, excluding shrimpers <261 hp (based on data from LEI-DLO)

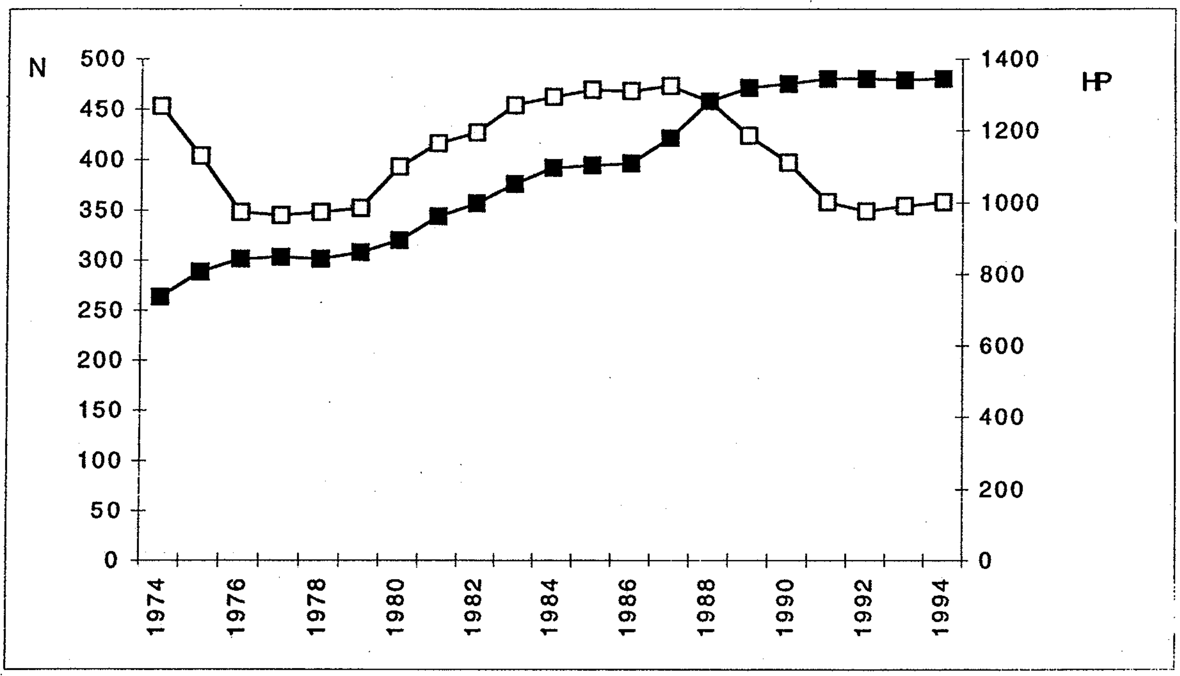


Table 1 Summary table of trip, gear, discards and landings information for individual discard trips

trip number	date	engine hp	# ICES rectangle	mesh size SB	mesh size BB	beam length	n tickler chains shoe	n tickler chains rope	speed (knots)	depth meter	number hauls	number fh	hours at sea	sampled hauls	discards fh	@ nos box disc/haul	sampled landings kg plaice	sampled landings kg sole	sampled landings kg other	landings in kg per 100 fishing hours (fh) (landed weight) plaice	sole	dab	whiting	cod	turbot	brill	other
p1-1	Oct-76	1015	39F5	75.0	75.0	10	10	4	5.5	42	33	82.5	115	23	57.5	14	+	+	+	11150	900	25	50	1330	600	130	130
p1-2	Nov-76	1500	39F1	102.1	118.6	10	8	7	6		41	64.3	109	36	59.0	24	600	10	546	16065	460	1050	60	1800	1370	70	1544
p1-3	Jan-77	1240	36F0	74.7	74.9	10	12	7	6	45	23	47.5	112	23	47.5	19	570	280	263	14888	2300	670	42	442	190	35	216
p1-4	Nov-77	1015	36F1	77.5	82.9	10	11	5		45	39	74.0	108	36	68.0	15	666	400	127	19390	2340	410	0	60	370	220	180
p1-5	Feb-78	1235	36F4	73.5	76.1	10	13	10	5	44	36	81.2	90	35	79.0	15	240	150	180	16500	1530	0	0	1120	790	0	444
p1-6	Mar-78	1300	38F5	73.0	74.0	12	12	10	5.5	42	21	55.2	87	20	52.7	15	200	120	310	30600	1935	0	0	1700	150	50	0
p1-7	Apr-78	600	37F7*	74.9	73.5	11	12	10	5	20	35	70.1	96	26	52.1	11	200	200	100	1710	1884	530	160	1590	117	11	17
p1-8	May-78	700	36F5*	71.0	76.0	10	10			22	38	72.5	101	28	53.5	9	190	173	280	2760	1760	125	0	2630	366	75	0
p1-9	Jul-78	930	35F3	71.8	72.8	10	20	4	4.5	26	33	73.5	94	28	62.0	14	193	185	274	2231	1653	190	150	156	255	65	14
p1-10	Aug-78	1760	34F3	66.4	80.9	10	13	4		34	33	68.5	95	24	50.0	12.5	210	146	466	9375	2400	1360	1600	3050	555	145	345
p1-11	Sep-78	1240	37F7*	75.7	75.7	10	11	3	5	40	27	48.4	91	20	36.2	33	110	80	160	1940	3247	0	0	3433	410	0	0
p1-12	Nov-78	1500	36F5	78.2	79.0	12	12	10	6	24	39	78.6	94	31	60.3	12.5	280	130	400	12620	2640	0	0	2950	1810	210	413
p2-13	Jan-79	900	34F3	-	-	9	10	4			32	67.8	87	24	50.0	24	200	100	460	5881	5970	149	1075	3791	395	224	112
p2-14	Feb-79	1350	34F3	-	-	10	8	8	6.5	35	16	33.8	105	11	23.3	7	60	70	100	3703	6400	0	237	2222	592	0	770
p2-15	Mar-79	1240	37F1	77.3	76.3		10	9	6	50	22	35.8	90	17	27.1	14	180	110	120	18448	14513	307	30	3907	195	519	2453
p2-16	Apr-79	960	40F4	-	-	10	10	8	6	40	29	63.3	108	23	49.0	9	460	80	100	21502	443	613	0	0	637	248	0
p2-17	May-79	1235	38F7*	-	-	10	12	8	6.5	27	47	60.8	100	34	44.3	15	360	170	280	7398	1972	658	145	513	493	82	0
p2-18	Jun-79	1000	34F3	86.1	83.4	9.5	10	10	6	30	18	39.8	81	18	39.8	5	360	70	150	4374	742	594	866	685	0	0	264
p2-19	Aug-79	2000	39F7*	80.9	81.8	10	12	10		22	52	53.7	91	25	26.3	17.4	155	54	244	2104	2907	31	22	56	932	186	115
p2-20	Sep-79	1235	32F2	81.5	86.5	9	9	4	6	35	30	59.3	80	19	39.6	11	380	120	325	6076	844	473	540	2700	350	72	202
p2-21	Nov-79	1240	38F6	-	-	12.5	9	5	5	40	27	64.6	96	23	54.5	17	70	67	250	18092	2209	294	1129	4185	476	82	193
p2-22	Jan-80	1200	34F3	77.1	79.2	12	10	5		37	33	71.3	90	25	55.4	14	76	78	634	7972	2077	167	670	4829	633	156	167
p2-23	Feb-80	1000	34F3	-	-	10	10	5	6	30	35	74.3	96	27	58.2	8	+	90	490	11731	807	2314	1588	1399	304	69	1507
p2-24	Mar-80	1310	34F3	77.2	77.0	10	10	5	6	26	37	73.7	92	27	55.0	12	150	260	320	3475	1575	1357	0	0	375	110	0
p2-25	Apr-80	1240	38F6	70.0	67.4	12	6	12	6	37	38	70.2	101	26	48.9	24	220	130	270	6760	2377	950	700	915	300	50	0
p2-26	Aug-80	1240	37F7*	67.5	68.0	12	6	12		35	37	47.3	71	16	18.4	18	152	108	230	2455	3160	850	0	1690	816	60	0
p2-27	Aug-80	1270	34F2	-	-	9	9	mat	6	37	39	64.2	94	24	40.8	26	368	120	630	7667	1246	1000	1500	685	570	115	40
p2-28	Nov-80	1235	36F4	71.2	70.4	11	13	8	6	18	20	33.3	47	9	14.3	18	220	110	224	36000	240	0	0	4800	300	60	0
p2-29	Nov-80	1000	33F3	-	-	10	9	4	5.5	30	30	65.8	76	22	48.1	8.5	160	50	163	12167	608	425	243	1575	85	290	0
p2-30	Dec-80	1240	38F6	69.0	73.0	12	6	12	6	38	24	58.3	97	16	38.8	13	140	50	150	13047	790	210	300	360	500	75	1530
p2-31	Jan-81	1350	34F3	83.0	79.0	10	8	8	5	30	41	84.3	109	29	61.8	15.8	210	100	396	11620	1280	545	1700	1540	195	290	95
p2-32	Feb-81	1000	34F3	80.0	80.0	9.5	10	5	5.5	31	6	13.3	23	6	13.3	8	130	8	50	11478	300	1525	0	0	400	200	3600
p2-33	Mar-81	1500	37F0	-	-	10	8	8	6	53	41	72.3	116	31	54.0	16	280	120	193	11333	1708	458	83	286	165	90	0
p2-34	Jun-81	1500	39F7*	6.9	7.8	14	11	11	5.5	20	44	53.8	87	22	27.4	25	235	78	280	11014	2233	430	350	2050	400	120	515
p2-35	Jul-81	270	33F4	75.0	75.0	6	4	0		18	10	10.0	15	9	9.0	7.2	9	40	10	700	1970	50	0	20	162	253	1020
p2-36	Jul-81	340	33F4	-	-	7.5	1	0		16	15	10.4	13	15	10.4	8	18	40	26	693	2275	1664	208	0	0	0	0
p2-37	Oct-81	1700	37F0			-	12	12	5	54	32	67.4	89	15	30.8	21	178	70	95	8160	1187	0	0	0	325	85	0
p2-38	Oct-81	1235	33F2	-	-	10	10	5	5.5	40	31	72.8	91	24	56.3	13.3	180	88	500	12436	2090	950	600	1264	67	153	45
p2-39	Nov-81	1200	36F5*	-	-	12	12	10	5.5	30	47	70.3	95	35	51.4	16.7	220	110	224	13665	2107	200	440	220	400	200	0
p3-40	Feb-82	1015	37F2	-	-	10	8	4	5	70	33	68.9	116	27	56.8	7	+	+	+	10450	1829	0	0	769	327	22	0
p3-41	Sep-82	1235	34F2	85.0	85.0	10	10	5	5.5	40	42	75.1	97	19	34.6	22.5	+	60	176	4794	1598	905	506	333	310	173	289
p3-42	Oct-82	1235	33F2	85.0	85.0	10	10	5	5.5	40	40	82.0	97	30	57.8	20	+	40	170	5457	1944	488	232	989	154	171	0
p3-43	Dec-82	2000	38F6	80.0	80.0	16	8	12	5.5	35	30	67.5	105	21	46.3	20	80	50	170	20741	1926	473	254	419	336	108	0
p3-44	Dec-82	1235	33F2	-	-	10	10	5	5.5	40	34	70.3	92	14	29.6	26	124	32	150	6700	2628	565	1621	1375	252	266	327
p3-45	Nov-83	2700	35F2	-	-	14	12	9	6.5	30	37	76.8	99	21	43.5	17.5	+	220	200	6567	4952	575	520	417	541	709	43
p4-46	Sep-89	1800	35F4	-	-	12	12	10	6.5	29	50	69.0	93	28	39.0	26	100	100	100	4347	8693	29	0	0	202	0	0
p4-47	Oct-89	4446	8F1/37F3	100.0	100.0	12	12	10	7.5	30	41	56.3	90	25	35.0	13.2	240	75	20	20836	1183	480	0	+	+	+	300
p4-48	Feb-90	2496	33F2/3	85.0	85.0	12	-	-	6	36	38	81.3	100	17	35.0	22	203	114	83	20923	4123	492	+	+	+	+	1046
p4-49	Mar-90	3760	37F7	100.0	100.0	12	11	11	6	35	35	50.7	76	21	30.4	31	55	75	205	10248	7538	0	236	315	472	118	394
p4-50	May-90	3000	34F3	82.0	82.0	12	13	8	6	32	44	85.0	100	30	58.0	19.5	130	90	244	3529	2588	141	94	0	400	141	894
p4-51	Jun-90	1800	35F3	80.0	80.0	12	11	8	6	30	45	72.6	92	27	41.8	41	107	119	108	2738	2291	0	112	0	224	28	0

*: plaice box; +: unknown or included in other; -: not measured; @: boxes of approximately 40 kg containing discarded fish, invertebrates and debris; #: main rectangle

Table 2 Prevalence of species in catches, landings and discards of 51 sampling trips Average condition factor (c) and fresh gutted weight conversion factor (f) used in the calculations are also given.

scientific name	English name	occuring in catch	landings	discards	c	f
Pleuronectes platessa	plaice	51	51	50	0.0108	1.07
Solea solea	sole	51	51	41	0.0096	1.04
Limanda limanda	dab	51	43	51	0.0106	1.13
Scophthalmus maximus	turbot	50	49	11	0.0100	1.11
Scophthalmus rhombus	brill	47	46	13	0.0100	1.11
Microstomus kitt	lemon sole	21	8	20	0.0100	1.11
Platichthys flesus	flounder	22	6	22	0.0109	1.11
Hypochlossus platessoides	long rough dab	18	0	18	0.0100	
Glyptocephalus cynoglossus	witch	1	0	1	0.0100	
Arnoglossus laterna	scaldfish	34	0	34	0.0100	
Buglossidum luteum	solenette	35	0	35	0.0064	
Gadus morhua	cod	48	42	44	0.0101	1.16
Merlangius merlangus	whiting	51	36	51	0.0081	1.14
Melanogrammus aeglefinus	haddock	16	8	11	0.0100	1.17
Trisopterus luscus	bib	34	7	33	0.0100	1.14
Trisopterus minutus	poor cod	27	0	27	0.0100	
Clupea harengus	herring	7	0	7	0.0100	
Clupea sprattus	sprat	6	0	6	0.0100	
Alosa fallax	twaite shad	3	0	3	0.0100	
Scomber scombrus	mackerel	6	0	6	0.0078	
Trachurus trachurus	horse mackerel	20	1	19	0.0080	1.00
Lophius piscatorius	monk	8	1	7	0.0100	1.22
Eutrigla gurnardus	grey gurnard	44	4	44	0.0075	1.00
Trigla lucerna	tub gurnard	19	9	16	0.0075	1.00
Ammodytidae	sandeel	26	0	26	0.0100	
Hyperophlus lanceolatus	gt sandeel	4	0	4	0.0100	
Callionyumus lyra	dragonet	41	0	41	0.0075	
Agonus cataphractus	hooknose	34	0	34	0.0075	
Trachurus vipera	lesser weever	17	0	17	0.0100	
Rhinonemus cimbrius	four-bearded rockling	2	0	2	0.0100	
Myoxocephalus scorpius	bull rout	2	0	2	0.0100	
Mullus surmuletus	red mullet	2	0	2	0.0100	
Scyliorhinus canicula	dogfish	3	0	3	0.0100	
Squalus acanthias	spurdog	2	1	1	0.0100	1.00
Mustelus asterias	starry smooth-hound	2	0	2	0.0100	
Raja clavata	roker/thornback ray	10	1	9	0.0050	
Raja spec.	rays not identified	3	2	2	0.0050	1.00

Table 3 Average numbers and weight landed and discarded by species per 100 fh average percentage discarde and standard deviation thereof for all discard trips combined.
Landed weight is corrected by a fresh gutted correction factor (see Table 2)

	numbers/100 fh				weight/100 fh			
species	landed	discarded	% discarded	sd %	landed	discarded	% discarded	sd %
plaice	29575	31166	51	13	11046	4019	27	11
sole	12384	2447	16	5	2618	276	10	3
dab	2258	100496	98	3	563	6930	92	4
turbot	334	47	12	11	454	19	4	7
brill	190	49	21	13	150	13	8	9
lemon sole	72	182	72	21	32	22	41	31
flounder	398	1409	78	9	163	406	71	17
long rough dab	0	252	100		0	26	100	
witch	0	1	100		0	0	100	
scaldfish	0	694	100		0	21	100	
solenette	0	805	100		0	5	100	
cod	1511	2158	59	20	1498	411	22	23
whiting	1526	7021	82	11	412	884	68	13
haddock	136	49	27	46	60	6	9	47
bib	54	825	94	10	22	95	81	62
poor cod	0	283	100		0	15	100	
herring	0	97	100		0	3	100	
sprat	0	104	100		0	2	100	
twaite shad	0	11	100		0	1	100	
mackerel	0	6	100		0	2	100	
horse mackerel	+	150			2	32	94	12
monk	+	7			34	1	4	28
grey gurnard	13	4651	99.7	2	3	335	99	2
tub gurnard	124	153	55	88	37	14	27	38
sandeel	0	187	100		0	12	100	
gt sandeel	0	17	100		0	2	100	
dragonet	0	1783	100		0	94	100	
hooknose	0	455	100		0	12	100	
lesser weever	0	393	100		0	6	100	
four-bearded rockling	0	8	100		0	1	100	
bull rout	0	10	100		0	1	100	
red mullet	0	6	100		0	0	100	
dogfish	0	2	100		0	1	100	
spurdog	2	1	27	80	8	0	5	80
starry smooth-hound	0	3	100		0	1	100	
roker/thornback ray	0.2	112	100	23	0.3	22	99	23
rays not identified	12	5	28	57	34	2	5	57
all species	48588	156042	76		17136	13694	44	

Table 4 Comparison of estimates of average quantities of discarded fish and debris in weight obtained by quarterly and annual raising, based on 51 trips in the period 1976-1990. The correction factor, ΣQ/annual, is applied to production estimates in Table 5.

	period	Q 1	Q 2	Q 3	Q 4	ΣQ	annual	corr factor
a	number of discard trips	15	9	11	16		51	
b	landings (kg/fh)	198	109	94	194		158	
c	fish discards (kg/fh)	94	172	183	126		137	
d	debris discards (kg/fh)	218	270	298	232		249	
e	ratio fish discards	.32	.61	.66	.39		.46	
f	ratio debris discards	.52	.71	.76	.55		.62	
g	average landings fleet (kt.)	28	20	18	30		95	
h	average fh fleet ('000)	135	179	179	147		641	
i	fish discards (kt.)	13	32	34	19	98	82	1.195
j	fish discards (kt.)	13	31	33	19	95	88	1.080
k	debris discards (kt.)	30	50	55	36	172	152	1.132
l	debris discards (kt.)	29	49	54	34	166	160	1.038

b: landed weight
e: ratio fish discards over total fish in weight c/(b+c)
f: ratio debris over landings + debris in weight d/(b+d)
g: Dutch beam trawl fleet, provided by LEI-DLO, landed weight
h: Dutch beam trawl fleet, provided by CBS
i: estimated from landings as g*e/(1-e)
j: estimated from FH as h*c
k: estimated from landings as g*f/(1-f)
l: estimated from FH as h*d

Table 5 Estimates of annual fish and debris discards by the Dutch beam trawl fleet in selected periods between 1976-1990 (rows i-l), based on sampled data (rows a-f) and fleet statistics (rows g-h). Estimates were derived using 2 different methods:
1) by raising the observed ratio of discards/fh (c, d) to the total fishing hours (h) and
2) by applying the ratio discards/discards+landings in the samples (e, f) to the total landings of the fleet (g).
95% Confidence limits are given in brackets. Values corrected for quarterly bias in the sampling, estimated in Table 4, are given in italics. Legends for rows are the same as in Table 4

	period	1976-1978	1979-1981	1982-1983	1989-1990	all years	plaice box	excl plaice box
a	number of discard trips	12	27	6	6	51	11	40
b	landings kg/fh	167 (118-216)	159 (125-193)	140 (96-184)	159 (91-226)	158 (136-181)	125 (93-156)	168 (141-195)
c	fish discards kg/fh	98 (77-120)	148 (94-202)	96 (60-131)	205 (146-264)	137 (106-168)	252 (165-338)	105 (81-130)
d	debris discards kg/fh	227 (138-315)	203 (155-252)	280 (198-352)	468 (279-657)	249 (203-295)	289 (169-409)	238 (190-287)
e	ratio fish discards	.37 (.27-.47)	.48 (.37-.59)	.40 (.26-.55)	.57 (.37-.75)	.46 (.39-.53)	.68 (.56-.79)	.38 (.32-.44)
f	ratio debris discards	.58 (.46-.70)	.56(.46-.65)	.67 (.52-.81)	.76 (.58-.91)	.62 (.55-.68)	.71 (.62-.79)	.59 (.51-.66)
g	average annual landings fleet (kt.)	89	88	105	112	95	15 1)	80 1)
h	average annual fh fleet ('000)	693	632	609	617 2)	641	141 3)	500 3)
i	fish discards (kt.) method 2	51 (32-79) *61 (38-95)*	81 (66-126) *97 (79-150)*	70 (36-131) *84 (43-156)*	147 (67-341) *176 (80-407)*	82 (62-107) *97 (74-127)*	38 (23-67) *46 (28-80)*	48 (36-61) *58 (43-73)*
j	fish discards (kt.) method 1	68 (53-83) *74 (57-90)*	94 (60-128) *101 (64-138)*	58 (37-80) *63 (40-86)*	126 (90-163) *137 (97-176)*	88 (68-108) *95 (73-116)*	39 (25-52) *42 (27-56)*	51 (39-63) *55 (43-68)*
k	debris discards (kt.) method 2	124 (75-209) *140 (85-236)*	109 (74-164) *124 (84-185)*	215 (112-447) *243 (127-506)*	361 (153-1102) *408 (173+1248)*	152 (118-199) *173 (133-226)*	43 (29-67) *49 (33-76)*	111 (81-152) *125 (92-173)*
l	debris discards (kt.) method 1	157 (96-218) *163 (100-127)*	128 (98-159) *134 (102-166)*	171 (120-221) *177 (125-230)*	289 (172-406) *301 (179-422)*	160 (130-189) *166 (135-196)*	44 (26-63) *46 (27-65)*	116 (92-139) *120 (96-145)*

1) ratio estimated from national landings statistics 1974-1976 (plaice, sole, cod, whiting)
2) estimated from relation fishing hours fishing days
3) estimated from effort distribution in 1974-1976