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Analysis of discarding in the Dutch beamtrawl fleet

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Samenvatting

Een van de drie werkpakketten van het F-project, werkpakket “F1”, richt zich op de verbetering van de toestandsbeoordeling. Dit rapport “A3” vormt het derde onderdeel van werkpakket F1 en onderzoekt het overboord zetten van gevangen vissen of bodemdieren, ook wel discarden genoemd, door de Nederlandse boomkorvloot. Met name het discarden van schol in de Noordzee staat in de belangstelling, omdat veel jong schollen worden gevangen en gediscard in deze visserij. Het lijkt erop dat in de laatste jaren een stijging plaats heeft gevonden in de hoeveelheid scholdiscards, evenals een verplaatsing van jonge schol naar dieper water verder uit de kust. Dit rapport geeft een overzicht van de resultaten uit onderzoeken uitgevoerd door het Nederlands Instituut voor Visserijonderzoek naar het discarden door de Nederlandse boomkorvisserij en naar de overleving van discards. Daarnaast wordt onderzocht of gedurende de periode 1985-2002 verschuivingen hebben plaatsgevonden in de verspreiding van jonge schol over de Noordzee. Bovendien wordt het effect van discards op de bestandsschattingen van schol onderzocht. Hiertoe worden eerst de aantallen discards geschat met behulp van een model. Vervolgens worden bestandschattingen met elkaar vergeleken die met en zonder discards zijn berekend.

Discardsbemonstering onderzoek
Vanaf het einde van de jaren ’60 zijn gedurende verschillende perioden discards bemonsterd aan boord van Nederlandse boomkorschepen. Dit rapport geeft een overzicht van verschillende onderzoeken naar discards die in het verleden zijn uitgevoerd: gedurende 1969-1970 door De Veen en Rodenburg (1971), in 1975 door De Veen et al. (1975) en gedurende 1976-1983 en 1989-1990 door Van Beek et al. (1998). Daarnaast worden resultaten van het huidige onderzoek naar discards dat loopt vanaf de tweede helft van 1999 gegeven. Voor 2003 worden voorlopige resultaten getoond, omdat de gegevens nog niet beschikbaar zijn voor alle reizen. Bemonstering van discards in de recente periode vond met name plaats aan boord van boomkorschepen met motorvermogen groter dan 300 PK, vissend met 80 mm.

In de laatste jaren zijn de aantallen scholdiscards die per uur gevangen werden gestegen in vergelijking met de jaren ’70 en ’80. Daarnaast is het ook discardpercentage (aantallen gediscarde vissen ten opzichte van de aantallen gevangen vissen) gestegen. Vooral voor schol buiten de scholbox is het discardpercentage veel hoger geworden. Het discardpercentage buiten de scholbox was 31% in aantal gedurende 1976-1990 en 74% gedurende 1999-2002. In 2003 was het discardpercentage 84%. In de laatste jaren werd deze stijging waarschijnlijk deels veroorzaakt door een sterke 2001 jaarklasse, die in grote aantallen voorkwam in de discards in 2002 en 2003. Een vergelijking van de omvang van deze 2001 jaarklasse met de sterke 1996 jaarklasse kan nog niet gemaakt worden. De schollen uit de 2001 jaarklasse waren in 2003 pas 2 jaar oud, terwijl de discardbemonstering van de 1996 jaarklasse pas begon in 1999, toen schollen uit deze 1996 jaarklasse al 3 jaar oud waren.

Voor tong is het discardpercentage buiten de scholbox gestegen van 12% gedurende 1976-1990 tot 19% gedurende 1999-2002. Deze stijging werd voornamelijk veroorzaakt door een stijging van de hoeveelheid discards. Voor kabeljauw zijn de hoeveelheden aanlandingen en discards gedaald over 1999-2003 ten opzichte van de periode 1976-1990.

Discardsoverleving onderzoek
Onderzoek naar de overleving van discards aan boord van boomkorschepen zijn verricht door De Veen et al. (1975) gedurende 1972-1975 en door Van Beek et al.(1990) gedurende 1972-1982. Tijdens beide onderzoeken is de mate van beschadiging van gediscarde vissen bepaald aan de hand van uiterlijke beschadigingen van deze vissen. Bovendien is de overleving van gediscarde schol en tong geschat. Dit laatste werd gedaan door vissen, die zouden worden gediscard, in bakken met water te zetten en te kijken hoeveel vissen na verloop van tijd overleefden. Tijdens deze proeven is onder andere de invloed van tijdsduur van de trekken, vistuig, motorvermogen en tijd aan boord onderzocht.

Beide onderzoeken toonden dat de meeste vissen die gediscard werden zwaar beschadigd waren. Het onderzoek van De Veen et al. (1975) liet zien dat zwaarder motorvermogen meer zwaar beschadigde discards en minder licht beschadigde discards opleverde. Van Beek et al. (1990) toonden dat langere trekduur meer zwaar beschadigde discards opleverde.

Wat overleving betreft konden beide onderzoeken niet met elkaar worden vergeleken. De Veen et al. (1975) verrichtten onderzoek met een licht net, terwijl Van Beek et al. (1990) een zwaarder net gebruikten en langere trekken maakten. Beide onderzoeken vonden echter dat de overleving van licht beschadigde vissen hoog was

en dat de overleving afnam voor zwaarder beschadigde vissen. Overleving daalde met langere trekduur en de tijd dat de vissen aan boord waren. Van Beek et al. (1990) schatten de overleving van schol in de boomkorvisserij op maximaal 10%. In de huidige periode is het gemiddelde motorvermogen toegenomen in de boomkorvisserij, hetgeen waarschijnlijk een negatief effect heeft op de overleving van discards.

Verspreiding van schol
Het hogere discardspercentage van schol buiten de scholbox kan worden verklaard doordat kleine schol zich verplaatst heeft naar dieper water gedurende de laatste jaren. Met twee modellen statistische methoden is onderzocht of jonge schol van 0 tot 4 jaar oud tegenwoordig meer in dieper water zit dan vroeger. Hiervoor werden gegevens gebruikt van de Beam Trawl Survey (onderzoek naar visbestanden met een boomkor vistuig) gedurende 1985-2002. Met de eerste methode is gekeken of de aantallen schollen van een bepaalde leeftijd die zich op een bepaalde diepte bevonden over de jaren 1985-2002 zijn verplaatst naar dieper water. Met de tweede methode is onderzocht of de kans dat schol van een bepaalde leeftijd zich op een bepaalde diepte bevond, veranderd is gedurende de periode 1985-2002.

Beide methodes gaven aan dat gedurende de periode 1985-2002 een verschuiving heeft plaatsgevonden in de verspreiding van schol in de Noordzee naar dieper water verder uit de kust. De eerste methode liet een verandering zien in aantallen per diepte over de jaren. Elk jaar zijn in verhouding meer vissen naar dieper water getrokken. Alleen bij 0-jarige vissen gaf de statistische methode dit niet aan. Uit de ruwe gegevens kwam wel naar voren dat 0-jarige vissen zich dieper zijn gaan bevinden, maar de verhouding van vissen tussen ondiep en dieper water was niet veranderd. De tweede methode die de kans bepaalde dat schol zich op een bepaalde diepte bevond, gaf ook aan dat jonge schol zich de laatste jaren zich meer in dieper water bevindt.

De verandering in de verspreiding van jonge schol naar dieper water maakt jonge schol meer beschikbaar voor de boomkorvisserij met motorvermogen groter dan 300 PK, die zich buiten de ondiepe kustzone bevindt. De bemonsterde discardreizen van dit vlootsegment lieten zien dat gedurende de laatste jaren kleine schollen gevangen werden buiten de scholbox, die gedurende de jaren ’70 en ’80 alleen maar binnen de scholbox voorkwamen.

Invloed discards op bestandsschattingen
Tot op dit moment is er weinig onderzoek verricht naar het effect van het discarden van schol op de kwaliteit van de bestandsschattingen. Kraak et al. (2002) hebben onderzoek verricht naar het effect van discards op de bestandsschatting. Hierbij werd een vast percentage discards per leeftijd aangenomen over hele periode en in de laatste paar jaar een hoger discardpercentage dan in de voorliggende periode. In werkelijkheid zal de hoeveelheid discards van jaar tot jaar verschillen door verschil in omvang van een jaarklasse en door verschil in groei. Bij vissen met een langzame groei duurt het langer voordat ze mogen worden aangeland en deze zullen daarom meer worden gediscard.

Met een wiskundig model werd het effect van veranderingen in de hoeveelheid discards per jaar op de bestandsschatting onderzocht aan de hand van lengtegegevens van schol per leeftijd en jaar. Deze lengtegegevens waren afkomstig van twee afzonderlijke surveys (BTS en SNS) en van otolietenterugberekeningen. Dit zijn berekening van de leeftijd van vissen aan de hand van groeiringen op gehoorsteentjes, die zich in de hersenen van vissen bevinden. Omdat deze gegevens alleen voor 1 kwartaal beschikbaar waren en voor het model voor alle 4 de kwartalen nodig waren, werden de lengtes in andere kwartalen geschat, door aan te nemen dat er rechtlijnige groei is tussen kwartaal 1 en 3 (warmere perioden) en geen groei tussen kwartaal 3 en 1 (koudere perioden). Met de gemiddelde lengte en een variatie rond deze lengte werd per kwartaal en leeftijd het percentage vissen van een bepaalde leeftijd die een bepaalde lengte hadden berekend. Vervolgens werd hieruit het percentage vissen berekend dat in visnetten achter zouden blijven door gebruik te maken van selectiegegevens uit de literatuur. Hierbij werden twee selectiepatronen nagebootst, een visserij met 60 mm en met 80 mm maaswijdte. Hierna werd, aan de hand van gegevens van het uitsorteren van de vangst aan boord van de bemonsterde discardreizen, bepaald welk deel van de vangst zou worden gediscard en zou worden aangeland. Aantallen discards per kwartaal werden vervolgens geschat door de aantallen aanlandingen per kwartaal te vermenigvuldigen met de factor discards ten opzichte van aanlandingen, die met het model was berekend. De aantallen discards werden per jaar en leeftijd opgeteld, en vervolgens opgeteld bij de aantallen aangelande schol. De zo verkregen aantallen werden dan gebruikt als vangstgegevens in de bestandsschattingen.

Vergelijking van door het model geschatte discardspercentages met observaties uit de discardreizen van de laatste paar jaren lieten zien dat otolietenterugberekeningen lagere schattingen van het percentage discards gaven, terwijl surveys hogere schattingen opleverden. Het discardspercentage was lager wanneer aangenomen werd dat 80 mm maaswijdte werd gebruikt in vergelijking met 60 mm maaswijdte.

Met op deze wijze geschatte discards meegenomen in de bestandsschatting zijn de populatieaantallen en visserijsterfte voor de jongste leeftijdgroepen hoger ten opzichte van bestandsschattingen zonder geschatte discards. Ook resulteert het meenemen van geschatte discards in hogere recruitment schattingen en hogere schattingen van de paaibiomassa. De paaibiomassa werd met discardschattingen gebaseerd op otolietenterugberekeningen gemiddeld 1.5 (tussen 1.0-2.3) keer hoger geschat dan in een bestandsschatting zonder discards. Met discardschattingen gebaseerd op de BTS werd de paaibiomassa 2.3 (tussen 1.7-4.0) keer hoger en de SNS 2.0 (tussen 1.5-2.6) keer hoger geschat dan zonder discards in de bestandsschatting. Wanneer discards mee worden genomen in de bestandsschatting en de discards zijn niet geschat als vast patroon maar gebaseerd op biologische gegevens als groei, heeft met name een periode van hoge recruitment, langzame groei en hoge discardpercentages het grootste effect op de uitkomst van de bestandsschatting.

In het onderzoek naar het effect van het meenemen van discardschattingen op de bestandsschatting werd schol van 1 jaar oud niet meegenomen, omdat er vaak geen aanlandingen van deze leeftijdgroep waren. Met het model konden dan geen discards worden berekend. Dit is een ernstige tekortkoming van het model, omdat deze 1-jarigen een belangrijk deel van de discards vormen.

Summary

This report “A3” covers third item in work package 1 of the F-project; the investigation of discarding in the Dutch beam trawl fleet. There is concern by the scientific community about the discarding (returning of fish/bottom dwelling animals caught back to the sea) of North Sea plaice by the Dutch beam trawl fleet, since many juveniles are caught and discarded in this fishery. There are indications that in recent years there has been an increase in discarding of plaice, as well as a change in spatial distribution of juvenile plaice towards deeper, more offshore areas. This report summarizes discard studies conducted by The Netherlands Institute for Fisheries Research, investigates changes in spatial distribution of plaice and investigates the effect of discards on the stock assessment.

Discards have been estimated at various times during the late 1960’s. This report will summarize results from Dutch discard sampling programmes performed in the past, the current discard sampling programme, and results from discard mortality studies. In recent years, the discard percentage as well as absolute numbers of plaice discarded have increased compared to the 1970s and ‘80s. This increase was probably caused by a strong 2001 year class, dominating the discard fraction. Comparisons with the 1996 year class can not be made at this moment, since sampling of this year class started in 1999, when the fish were already 3 years old. However, the high discard percentages recently observed for the 2001 year class will lead to large proportions of this yearclass discarded.

A linear and a logistic model, both used to describing the abundance of plaice over the water depth between 1985 and 2002, showed that during the last decade the spatial distribution of plaice has shifted towards deeper, more offshore areas. Observations from discards on beam trawl vessels showed that in recent discard trips small plaice were caught outside the plaice box, while during the 1970s and ‘80s plaice were only caught inside the plaice box. This change in spatial distribution to deeper water could make plaice at length in the discard phase more vulnerable to the fishing fleet.

To date there has been little investigation of the impact of discarding of plaice on the quality of stock assessments. In a simulation study the effects of discards on the stock assessment of plaice are investigated. Therefore simulated populations were constructed, derived from mean length at age data obtained from otolith back-calculations and from two distinct surveys. Selection ogives and discarding (sorting) ogives were derived from the literature and used to estimate discards proportions at age, given the simulated populations. Quarterly catch at age numbers were then calculated from the quarterly landings at age using these discard proportions at age. Compared to the (scanty) observer trips, otolith back-calculations gave smaller estimates of proportions discards and the surveys larger.

With discards included in the assessment, stock numbers and fishing mortality increased on the youngest ages. This resulted in higher recruitment to the population and to increased estimates of spawning stock biomass. The perception of stock trends could be markedly different with the inclusion of discards, especially in periods of high recruitment and associated low growth and high discard rates. In this study, 1-group plaice could not be included in the analysis because the landings of this age group were often zero. This is a serious shortcoming because the 1-group is an important part of the discards.

Introduction

The F-project is a 4-year research project with the objective to improve the mutual understanding between fishermen, scientists and fisheries managers, by stimulating communication and collaboration between fishermen and fisheries scientists. The results of the annual stock assessments of plaice and sole by ICES have raised serious criticism on the transparency of the methodology, the quality of the input data and the quality of the stock assessment models used. One of the three working packages of the F-project, F1, is concerned with the improvement of stock assessment of plaice and sole. Product A3 within this working package, investigates the amount of discarding in the Dutch beam trawl fleet and the effects of discarding on the stock assessment of plaice.

The ecology of fish, management policies and economics often combine to increase the amount of discarding. The main reasons for discarding fish have been highlighted as:

- commercial species below the minimum legal landing size
- over-quota fish, which is not allowed to be landed when this results to exceeding legal quota
- species with no commercial value
- poor quality of fish (Van Beek, 1998)

Most of the fish that are discarded do not survive the catching and sorting process (Saila, 1983; Van Beek et al., 1989, 1990; Dingsor, 2001), resulting in a loss of future fish production and hence profits for the fishing industry (Saila, 1983; Allen et al., 2001). A major beneficiary of discarding, the seabirds, also ensure that few fish survive the process (Garthe and Huppop, 1994; Garthe et al., 1996; Reeves and Furness, 2002).

The Dutch beam trawl fishery is one of the main fisheries on flatfish in the North Sea. It targets sole (*Solea solea*) and plaice (*Pleuronectes platessa*) (Pastoors et al., 2000; ICES, 2002b). There are indications that in recent years the plaice stock has been subjected to increased discarding (ICES, 1999, 2003a). Discarding is affected by:

- differences in growth rate of fish, influencing the period fish are susceptible to discarding (ICES, 2002b, 2003b)
- decline of the biomass of larger fish, thereby increasing the proportion discarded (Pastoors et al., 2000; ICES, 2002b)
- shift in the distribution of smaller fish to deeper water (ICES, 1999), making them more susceptible to commercial fishing (Pastoors et al., 2000)

During 1969-1970 (De Veen and Rodenburg, 1971), 1975 (De Veen et al., 1975), 1976-1983 and 1989-1990 (Van Beek, 1998) trips were made by observers from the Netherlands Institute of Fisheries Research onboard commercial beam trawl vessels to monitor discards. From 1999 onwards discarding practices of the Dutch beam trawl fleet in the North Sea have been monitored, first within EC project CEC 98/097 (Anon., 2002), together with the United Kingdom, Norway, Sweden, Denmark, Germany and Belgium. From 2002 onwards discards data are collected under the Data Collection Regulation (EC., 2000, 2001; ICES, 2003a). During these discard trips information about the quantity and composition of fish landings and discards and the quantity of benthic invertebrates in the discarded part of the catch were collected. To assess the mortality of discarded fish, discard mortality studies were carried out in the past.

This report will give an overview of the results from the studies mentioned above:

- Discard sampling programmes performed in the past
- Current discard sampling programme
- Discard mortality studies

Discard sampling in the 1970s and ’80s showed that highest discard rates of juvenile plaice were observed in the nursery grounds along the Dutch coast. To reduce discarding in the nursery grounds, an area between 53ºN and 57ºN, called the “plaice box”, was closed to fishing for trawlers with more than 300 hp engine power in the second and third quarter since 1989 and for the whole year since 1995. It was expected that at the same rate of exploitation the introduction of the plaice box would enhance recruitment, yield and spawning stock biomass (ICES, 1987). Since 1989 however, yield and spawning stock biomass have declined (Pastoors et al., 2000; ICES, 2003b). In recent years discard rates outside the plaice box have increased up to 75%-80% (Netherlands Institute for Fisheries Research, unpub. data). ICES (1999) reported that since 1995 the relative abundance of all age groups of plaice in the shallow waters of the German part of the box has declined and large concentrations of 2-3 year old plaice were observed towards the western limit of the box. Catch of smaller juvenile plaice in recent discard trips indicate that the distribution of juvenile plaice shifted from the shallow coastal areas towards deeper offshore areas. In this report the shift in distribution of juvenile plaice will be investigated using survey data.

Within the ICES community there has been growing concern about the impact of un-assessed discarding of fish on the quality of the stock assessments and the resultant management advice (Casey, 1993; Alverson et al., 1994; Dingsor, 2001; ICES, 2002a). The annual variability in the discarding of fish may cause problems for fish stock assessments and subsequent advice. To date there has been little investigation of the impact of variable discarding on the quality of stock assessments. When discarded fish are not accounted for in stock assessments, fishing mortality on the younger age classes may be underestimated (Dingsor, 2001) and this may affect the estimates of spawning stock biomass (SSB) and recruitment (Casey, 1993). A constant bias (Pope, 1988) would result in the re-scaling of our perception of the biomass series (Dingsor, 2001; ICES, 2002b) and the yield per recruit curve (Casey, 1993), which is fine if the stock is managed on the basis of relative trends and dynamics. However a constant bias would cause problems if the fisheries was managed using absolutes, e.g. catch limits relating to biomass reference points, and both management scenarios (trends and absolutes) would be in trouble with if the bias varied greatly or had a trend.

The temporal coverage of the sampling programmes was not comprehensive enough to derive estimates of discards for the whole assessment time series. The impact of discarding rates can however be investigated through discard simulation. To assess the potential impact of discarding on the stock assessment of plaice, a simulated population can be constructed, which is subjected to a theoretical catching process, which discriminates between landings and discards. The main assumption is that variability in annual and cohort growth rates affects the potential to be selected by the fishery and the potential to be discarded. It is expected that the variability in growth will cause a variable bias in the stock assessment of North Sea plaice.

Chapter 2 describes the discard sampling programmes that were carried out during 1969-1970, 1975 and 1976-1990 as well as the recent programme during 1999-2003. Chapter 3 gives a description of two discard mortality studies carried out during 1972-1975 and 1972-1982. In chapter 4 changes in spatial distribution of juvenile plaice is analysed using two different models. In chapter 5 the impact of discarding on the stock assessment of plaice is assessed, using a simulated population and a theoretical catching process. In chapter 6 the results are discussed and conclusions are presented in chapter 7.

2. Historic discard programmes

In the period 1969-2003 discards have been measured onboard Dutch vessels in different discard programmes. This chapter summarizes results from these programmes that were carried out between October 1969 and October 1970 (De Veen and Rodenburg, 1971), the first half of 1975 (De Veen et al., 1975) and between 1976 and 1990 (Van Beek, 1998), as well as from the recent programme during 1999-2003. Each paragraph first gives an introduction to the sampling programme, and then an overview of the results. The last paragraph gives a summary of numbers of plaice and sole landed and discarded for the different periods.

2.1 Discard programme 1969-1970

2.1.1 Introduction

In 1966/67 the large 1963 plaice year-class recruited to the fishery. This unexpected rise in landings of small fish soon spoilt the market and most of these fish ended in fishmeal factories. This resulted in an increase in minimum landing size from 25 cm to 27 cm in the second half of 1968. Plaice of larger size were however still discarded in great amounts. A study of discarding was made in which length compositions and quantities of fish caught, landed and discarded were determined on board during 11 trips throughout the period 1969 to October 1970 (Figure 2.1). The trips were made on board of beamtrawlers and ottertrawlers. The total number of fish discarded by the fleet was estimated by raising the numbers per fishing hour to the total number of fishing hours of the fleet.

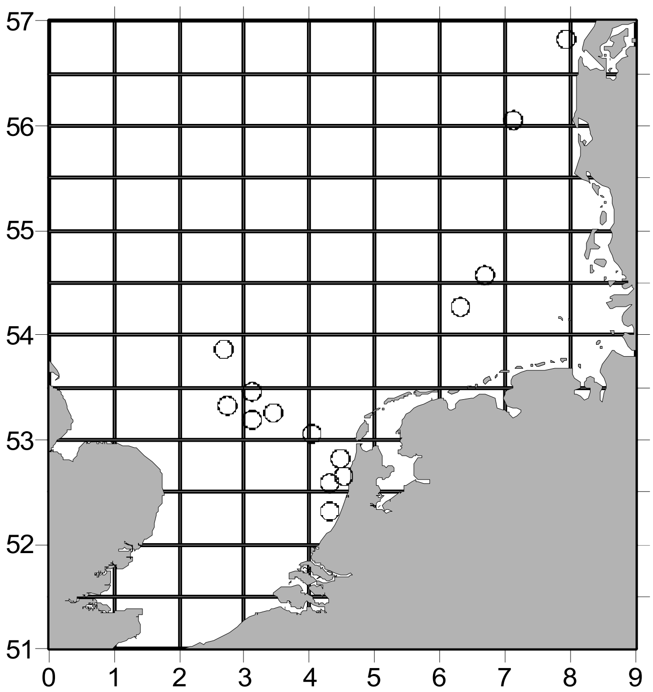

Figure 2.1. Overview of the positions visited during the trips made between October 1969 and October 1970.

2.1.2 Results

For plaice the sorting ogive began at 25 cm and the 50% retention length (length at which 50% of the fish caught was kept onboard) was 28 cm (Figure 2.2). On average 40% by numbers and 23% by weight of legal sized plaice were discarded at sea. Thus the total landings in 1969 and 1970 of 39 and 46 thousand tons equate to nominal catches of 48 and 57 thousand tons.
In 1969 a total of 32 million legal sized plaice were caught and discarded, in 1970 a total of 40.7 million. The number of undersized plaice (below 25 cm, the international minimum landing size in those years) discarded during the period October 1969 - October 1970 was estimated at 131 million. The sorting ogives of plaice by the smaller and less powerful boats fishing inshore were narrower than the ogives by the larger vessels operating in deeper water (Figure 2.3).

For sole the sorting ogive ends at about the minimum size of 24 cm as could be expected for a species for which a large market demand exists. One should expect a knife-edge selection at 24 cm, because all sole are measured onboard before landing. In practise fishermen kept sole from 21 cm and longer onboard and selected landings when gutting the fish. The number of undersized sole (below 24 cm, the international minimum landing size) discarded during the period October 1969 - October 1970 was estimated at 65.7 million.

For cod the sorting ogive started at 30 cm and the 50% retention length was 33 cm (Figure 2.4). For whiting discarding of legal sized fish was greater than for plaice and cod, with the 50% retention length of 32 cm, which was 5 cm more than the minimum landing size. A large 1967 yearclass was partly responsible, whereas in addition whiting was kept onboard in case the total catch of other species was small.

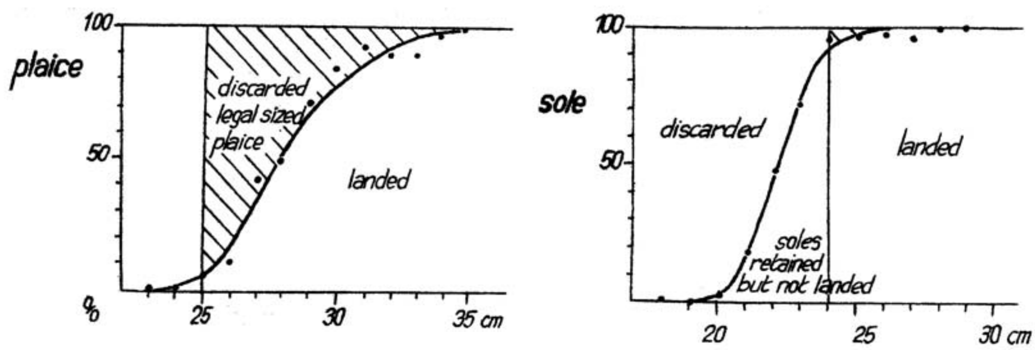

Figure 2.2. Sorting ogive for plaice and sole.

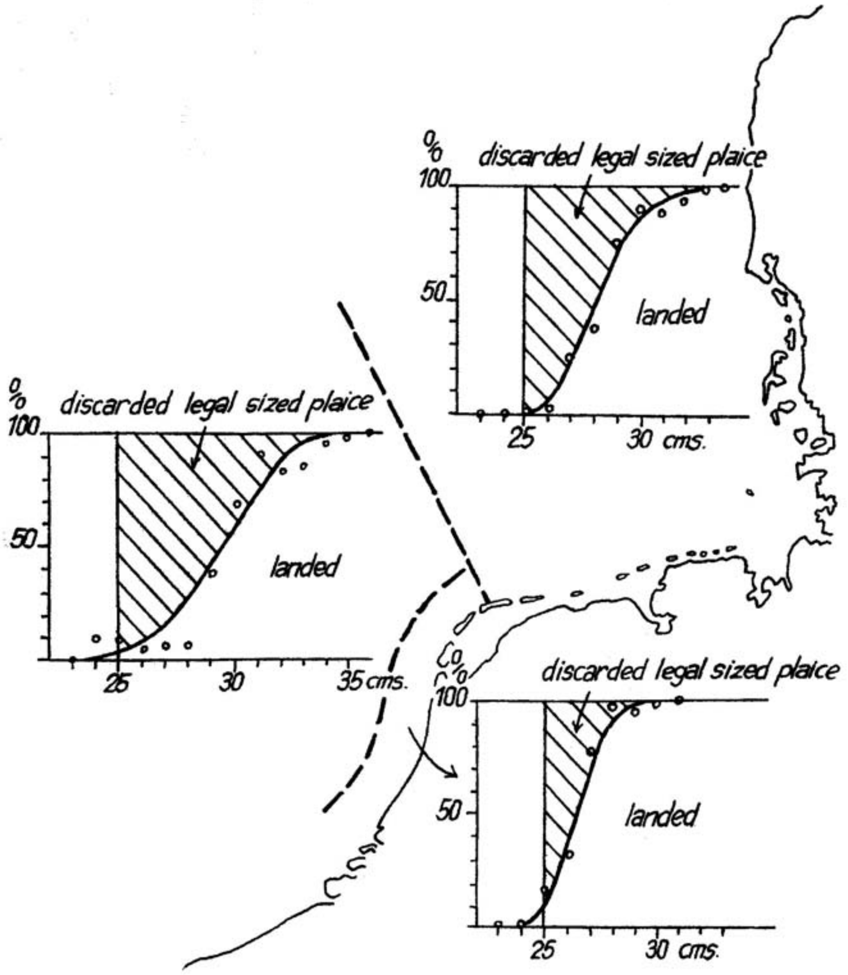

Figure 2.3. Sorting ogive for plaice in different areas.

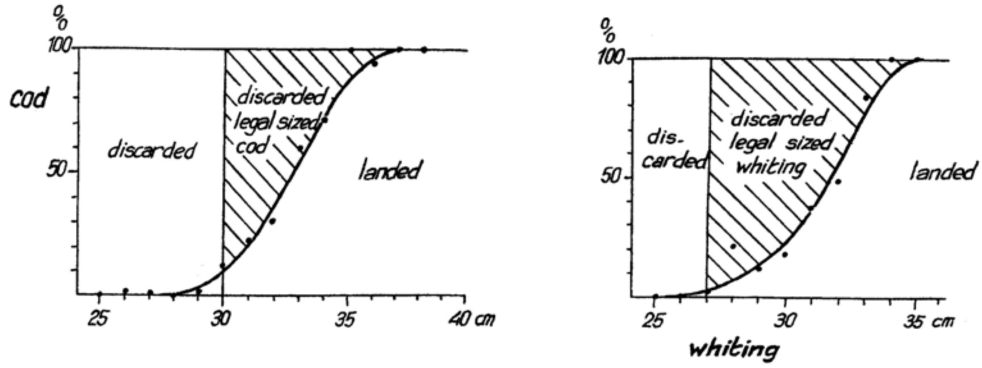

Figure 2.4. Sorting ogive for cod and whiting.

2.2 Discard programme 1975

2.2.1 Introduction

A resolution of the Statistics Committee urged countries to initiate or continue research into the collection of data on discards, especially of species under quota regulation. Therefore discard data were collected during 12 trips in the first half of 1975 onboard a number of flatfish beam trawlers with engine power ranging from 240 – 1350 HP (Figure 2.5). During each trip the length distribution of discarded and landed fish was estimated by sampling a limited number of hauls. By raising these data to the total amount of discards and kept fish during the whole cruise the total length distribution of all discards for the whole trip was be constructed. The total number of fish discarded by the fleet was estimated by raising the numbers per 100 fishing hours to the total number of fishing hours of the fleet.

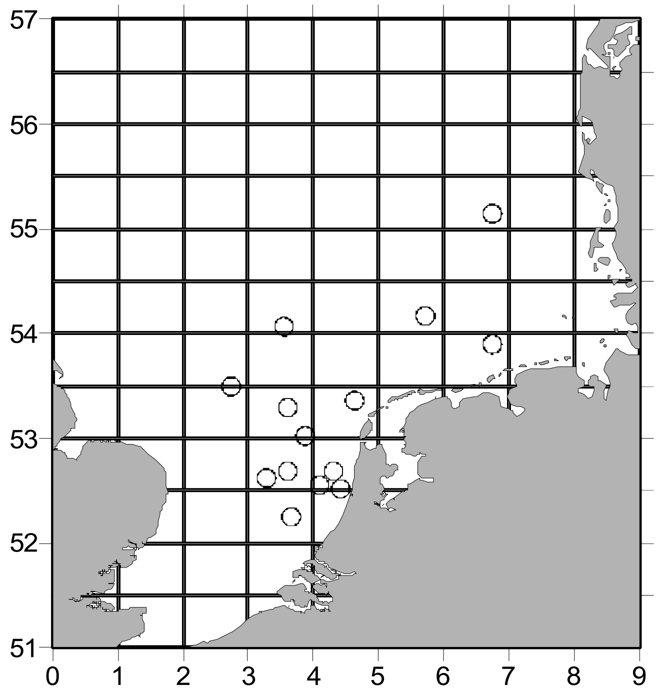

Figure 2.5. Overview of the positions visited during the trips made in the first half of 1975. During some trips, vessels fished at more than one location.

2.2.2 Results

The number of plaice discarded per hour was 130 (Table 2.1). The total number of plaice discarded by the entire fleet over 1975 was estimated at 110.8 million. The sorting ogive started at 25 cm and the 50% retention length was 27 cm.

Plaice was discarded in higher numbers per hour inside the 12 miles zone compared to outside this zone (Figure 2.6). Inside the 12 mile-zone plaice was discarded at 12 cm and larger with the peak in length-frequency distribution at 22 cm. Outside the 12 mile-zone zone plaice was discarded at 15 cm and larger with the peak at 25-26 cm. The peak in the length frequency distribution was at 24 cm for all areas combined.

About 12 sole were discarded per hour. The total number discarded was estimated around 10.4 million. The 50% retention length was about 22 cm, 2 cm below the legal minimum size of 24 cm. Sole was discarded between 15 and 26 cm both inside and outside the 12 mile- zone. The peak in the length frequency distribution was around 21 cm for all areas combined.

Table 2.1. Number of discards per hour and estimated total number of discards per species during the first half of 1975.

Species	Number discards per hour	Annual number ($*10^6$) of discards

Plaice	130	110.8
Sole	12	10.4
Dab	32	274.2
Cod	3	23.3
Whiting	2	19.3
Turbot	0.93	0.79
Brill	0.13	0.11

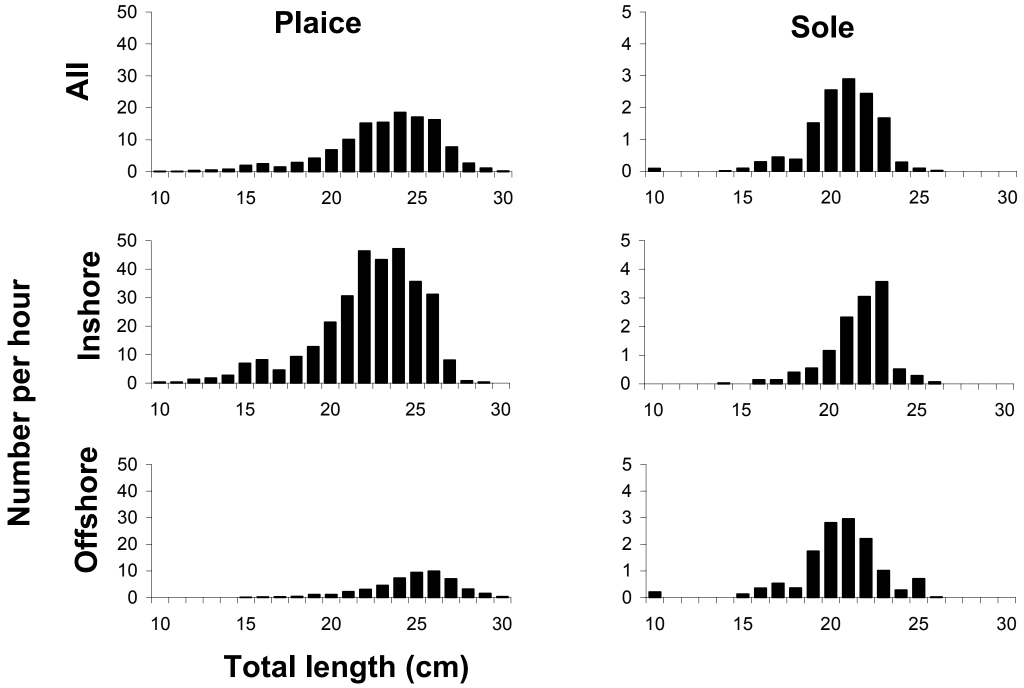

Figure 2.6. Number of discards per hour per length class for plaice and sole, for all areas combined, inside (inshore) and outside (offshore) the 12 miles zone**.**

Dab was discarded at lengths between 10 and 27 cm, with the peak in the length frequency distribution at 17 cm (Figure 2.7). Cod and whiting were discarded in smaller numbers. Cod was mainly discarded between 15 and 25 cm with the peak in length frequency distribution around 21 cm, while whiting was discarded over a wider range of 10-32 cm.

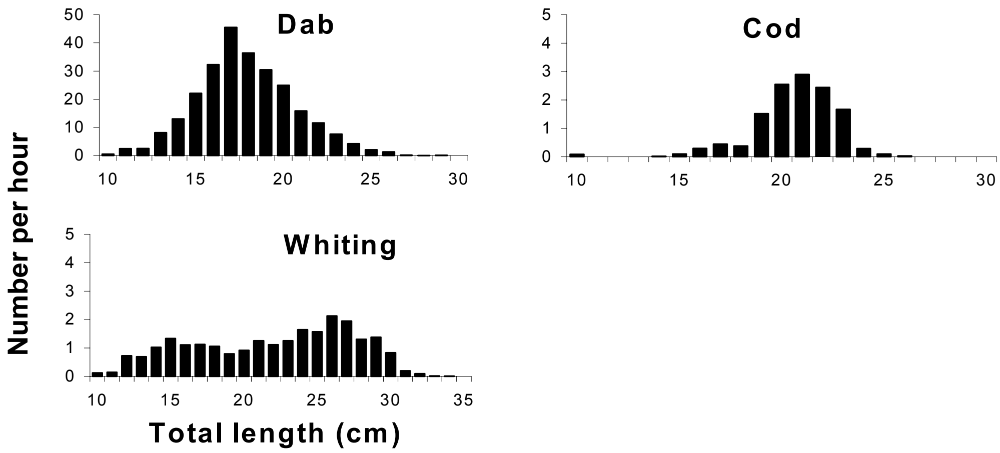

Figure 2.7. Number of discards per hour per length class for dab, cod and whiting.

2.3 Discard programme 1976-1990

2.3.1 Introduction

During the period 1976 to 1990, 51 trips were made by observers on board commercial beamtrawlers inside and outside the plaice box (Figure 2.8). Most trips were carried out in the first and last quarter of the year. The trips were not evenly spread out over the whole period and during 1984-1988 no trips were made at all. 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. 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. Landings were measured several times per day but not by haul. From the landings sub-samples of 10 or 20 kg were weighed and length distributions were recorded by species. As fish sorting procedures on board had developed in the eighties by the introduction of conveyor-belt systems, the standard procedure could no longer be 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 at 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 fish discards and non-fish discards, was estimated by subtracting the volume of landings from the estimated total catch. In a single case, landings were measured in the fish market.

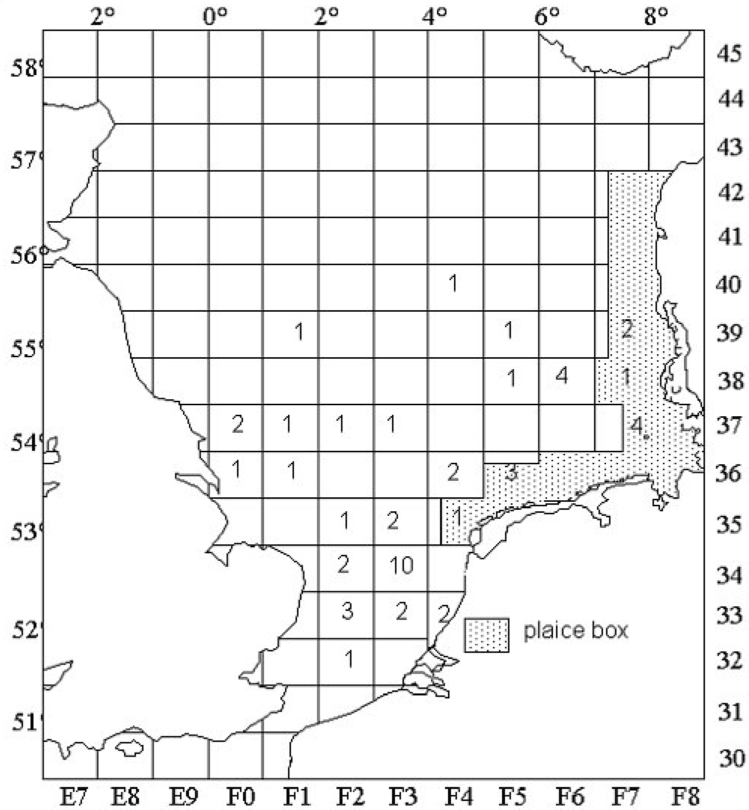

Figure 2.8. Spatial distribution of discards trips, classified according to main ICES rectangles and the location of the plaice box.

2.3.2. Results

On average landings accounted for 31% of the total catch and discards for 25% (Figure 2.9). The remaining part was non-fish discards (e.g. invertebrates). The average weight of the landings per fishing hour over all trips was 125 kg/hour (Table 2.2), while the average weight of the fish discards was 137 kg/hour. Average weight of landings per hour was lower inside the plaice box than outside, but the average weight of fish discards was much higher. The weight of fish and non-fish discards per hour was higher in 1989-1990 compared to the preceding periods, while the weight of the landings remained about the same.

Table 2.2. Number of trips and weight of the landings and discards over 4 periods, over all years and for inside and outside the plaice box.

	1976-1978	1979-1981	1982-1983	1989-1990	All years	Inside box	Outside box
Number trips	12	27	6	6	51	11	40
Landings (kg/hr)	167	159	140	159	158	125	168
Fish discards (kg/hr)	98	148	96	205	137	252	105
Non-fish discards (kg/hr)	227	203	280	468	249	289	238

In the second and third quarter discard rates were significantly higher ($P<0.05$) than in the other two quarters and originate both from higher discards and lower landings (Table 2.3), probably related to changes in distribution of the fleet and fish. Higher landings in quarter 1 were caused by fisheries on spawning aggregations and in quarter 4 by recruitment of new year classes.

Table 2.3. Comparison of estimates of average quantities of fish and non-fish discards in weight by quarter. Total discard weight (kiloton) were estimated from fleet landings (left) and fleet effort (right).

	Quarter 1	Quarter 2	Quarter 3	Quarter 4
Number trips	15	9	11	16
Landings (kg/hr)	198	109	94	194
Fish discards (kg/hr)	94	172	183	126
Non-fish discards (kg/hr)	218	270	298	232
Fish discards (kiloton)	13/13	32/31	34/33	19/19
Non-fish discards (kiloton)	30/29	50/49	55/54	36/34

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 2.8). 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. Only 2% consisted of sole while other species contributed 18% in weight or 14% in numbers to the discarded fish fraction.

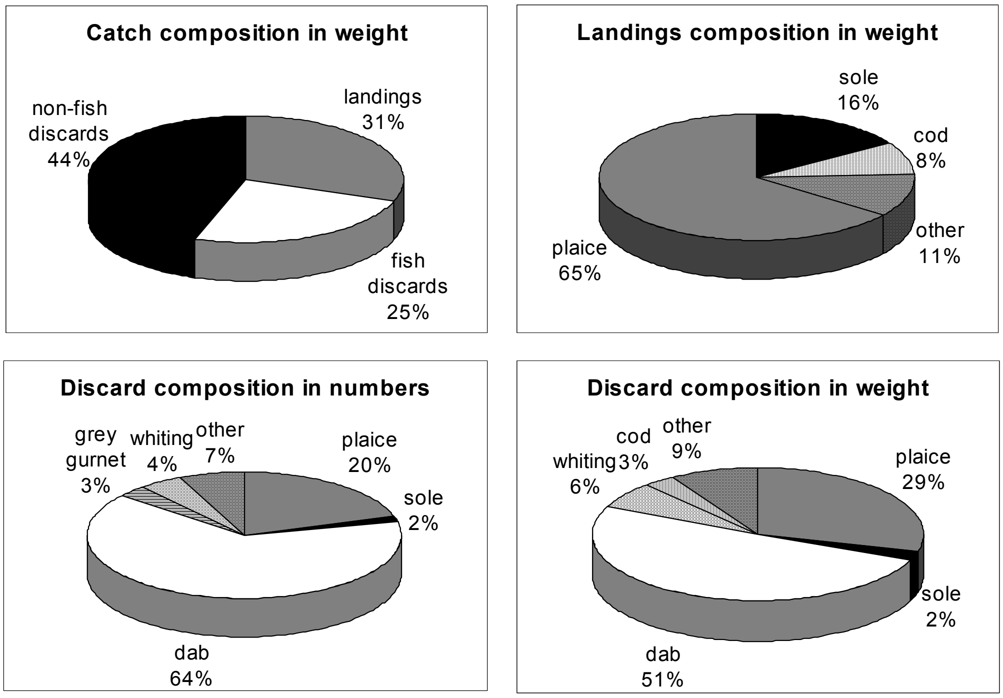

Figure 2.9. Composition of the catch over all trips**.**

From the main target species, plaice and sole, 51% and 16% of the numbers caught or 27% and 10% in weight were discarded (Table II.1 in Appendix II) over all trips. The discard percentage of plaice varied between 20%-61% in number and 13%-35% in weight during 1976-1978, 1979-1981, 1982-1983 and 1989-1990 (Table 2.4), while for sole it varied between 8%-29% in number and 5%-21% in weight (Table 2.5).

Table 2.4. Plaice landed (L) and discarded (D) per hour and percentage discarded (%D) over 1976-1978, 1979-1981, 1982-1983, 1989-1990 and 1976-1990.

		Number			Weight		
Period	**N trips**	**L**	**D**	**%D**	**L**	**D**	**%D**
1976-1978	12	275	121	31%	116	23	17%
1979-1981	27	283	445	61%	100	53	35%
1982-1983	6	298	75	20%	91	14	13%
1989-1990	6	392	330	46%	104	46	31%
1976-1990	51	296	312	51%	111	40	27%

Table 2.5. Sole landed (L) and discarded (D) per hour and percentage discarded (%D) over 1976-1978, 1979-1981, 1982-1983, 1989-1990 and 1976-1990**.**

		Number			Weight		
Period	**N trips**	**L**	**D**	**%D**	**L**	**D**	**%D**
1976-1978	12	85	8	8%	19	1	5%
1979-1981	27	104	13	11%	24	2	8%
1982-1983	6	126	52	29%	25	6	19%
1989-1990	6	286	83	22%	44	12	21%
1976-1990	51	124	24	16%	26	3	10%

The absolute amount of discards as well as the percentage of discards within the plaice box was higher than outside the plaice box for both species (Figure 2.10). The percentage of plaice discards within the plaice box was 78% compared to 31% outside the plaice box.
Outside the plaice box, plaice were caught from 15 cm and longer with the highest numbers discarded at 25 cm, while inside the plaice box also smaller fish were caught. For sole the discard percentages inside and outside the plaice box were 21% and 12% respectively. Sole were caught both inside and outside the plaice box from 17 cm and longer.

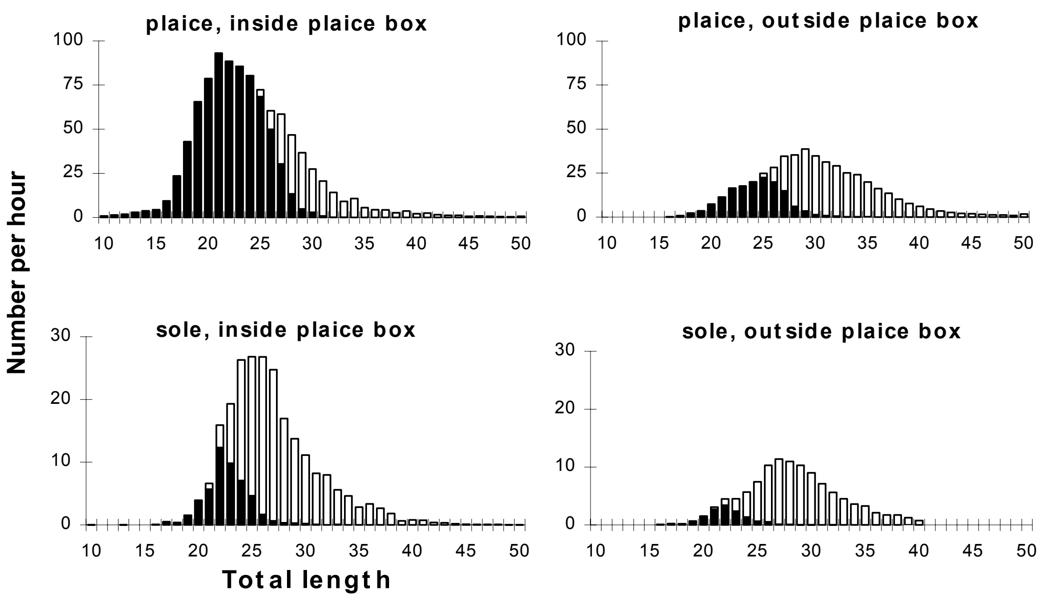

Figure 2.10. Length frequency distribution of plaice and sole caught inside and outside the plaice box. Discards are black bars, landings white bars.

Dab, the most abundant species in the catch, was discarded 98% in numbers or 92% in weight (Table II.1). Dab were discarded from 8 cm and longer with the highest numbers discarded around 17 cm (Figure 2.10). Cod was discarded 59% in numbers or 22% in weight, while whiting was discarded 89% in numbers or 68% in weight (Table II.1). The majority of cod and whiting was discarded between 20 and 30 cm (Figure 2.11).

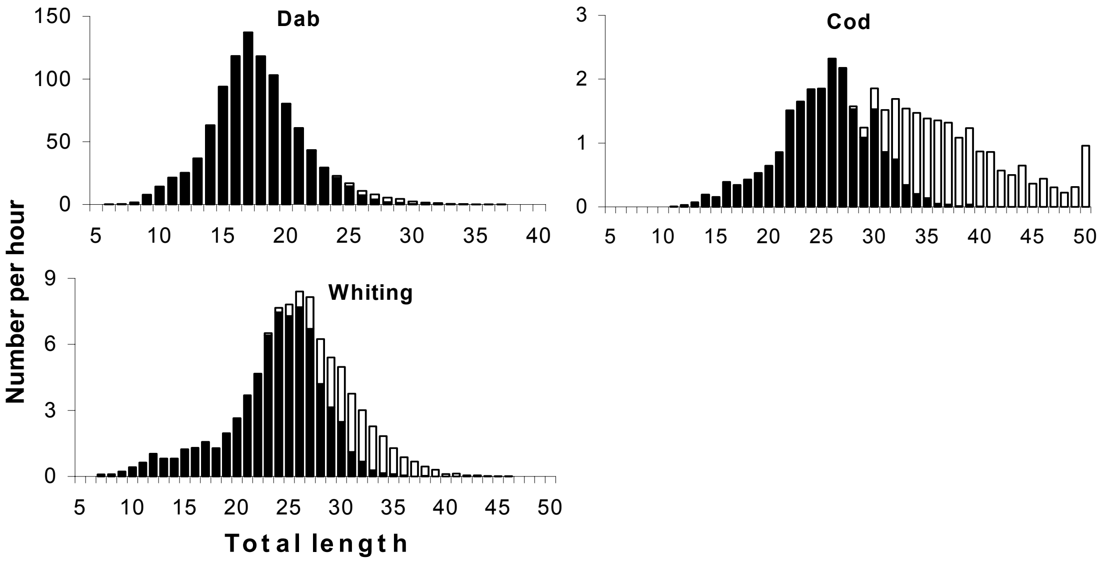

Figure 2.11. Length frequency distribution of dab, cod and whiting. Discards are black bars, landings white bars.

In most periods the 50% retention length for plaice was 27 cm, which was the minimum landing size for plaice (Figure 2.12). Except for the period 1982-83 the ogives for the different periods are similar. The ogive for the period 1982-83 suggested that in that period a larger proportion of smaller plaice was retained. The difference with all other periods for selected lengths of 24-26 cm was significant (p<0.05). However, the difference was mainly determined by 1 vessel. When this vessel was excluded from the analysis the difference disappeared. The sorting ogives also indicated that the retention of plaice from 27 cm and longer increased over time. The sorting ogives for sole showed a change in selection behaviour between the first two periods and the last two periods, when a smaller proportion of undersized soles was kept onboard compared to the first two periods. The difference was significant (p<0.05) for length groups between 20-24 cm.

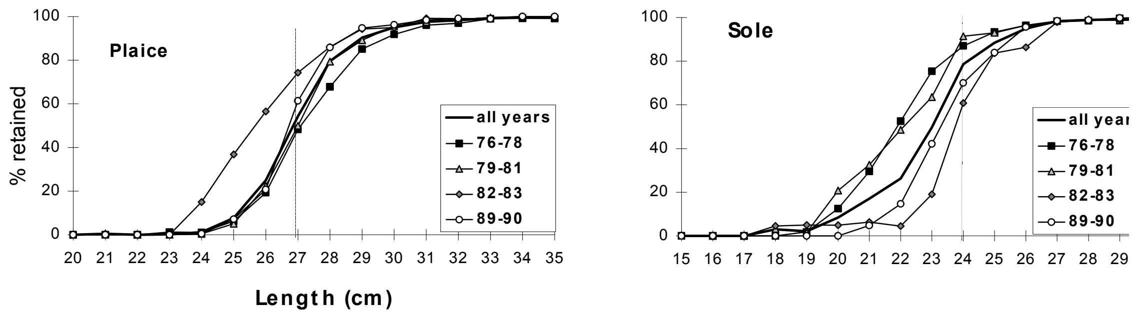

Figure 2.12. Weighted means of the percentage of the catch remained onboard by length of plaice and sole for different group of years.

2.4 Recent discard programmes 1999-2003

From 1999 onwards discarding practices of the Dutch beam trawl fleet in the North Sea has been monitored, first within EC project EC 98/097 (Anon., 2002), together with the United Kingdom, Norway, Sweden, Denmark, Germany and Belgium. From 2002 onwards discards data are collected under the Data Collection Regulation (EC., 2000, 2001; ICES, 2003a). The first paragraph describes in summary the sampling programme and methodology used. The raising procedures used are described in Appendix A. The second and third paragraph shows results over 1999-2002 and preliminary results over 2003. At this point not all data was available from the trips made in 2003.

2.4.1. Introduction

Between 1999-2002 a total of 26 trips were sampled on beam trawl vessels with engine power larger than 300 HP, fishing with 80 mm cod-end mesh size. Also 3 trips on eurocutters with engine power of 300 HP were sampled. Discard data over 2003 were available for 8 trips on large vessels and 1 trip on a eurocutter. For a trip, two observers went on board a vessel, sampling discards and landings from at least 60% of the hauls (Van Beek, 2001). Selection of the vessels was quasi-random and based on co-operative sampling (ICES, 2000). This means that co-operation of a skipper with the project was on a voluntarily basis. In advance it was not known which fishing grounds would be visited. Some ICES rectangles were sampled more frequently while other rectangles were not sampled at all (Figure 2.13). For each sampled haul, a sub-sample of the discards was measured. All fish were counted and measured. Benthic invertebrates were only counted. Total and sampled volume of discards was recorded. A sub-sample of the fish landed was measured, and total and sampled landings weight was recorded. If possible, otoliths were collected from the major discarded fish species (plaice, sole, dab, cod, whiting) for age readings. All data were entered into a computer program on haul basis and later transported into the central database. Sampled numbers of fish per haul were raised to numbers at length and at age for both discards and landings. Different raising procedures were used for discards and landings because different sources of information were available for these catch components. For the landings the total landed weight per species was available, while such data was not available for discards. Therefore discards were raised with the estimated haul volume (see Appendix I.1).

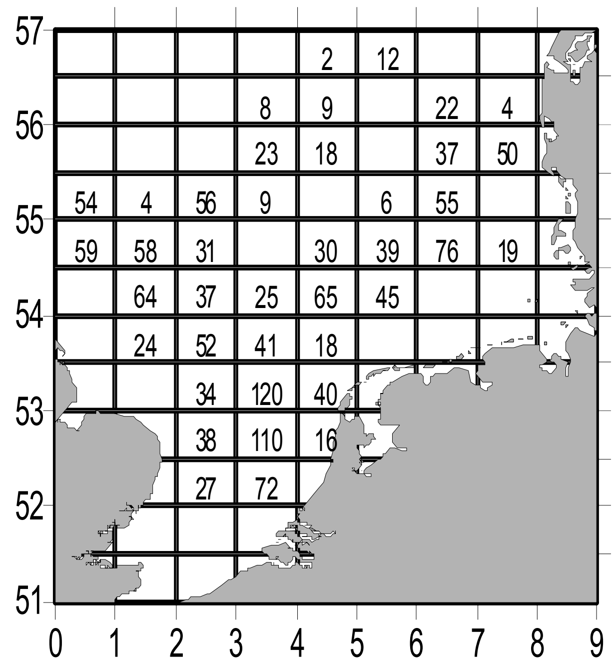

Figure 2.13. Total hours sampled for discards per ICES rectangle over 1999-2002.

2.4.2. Results 1999-2002

The average total weight of all discard combined varied per year between 34438 kg for 2002 and 40889 kg for 2000 (Table 2.6).

Table 2.6. Mean and variance per year over the total weight (kg) of all discards per trip in 1999-2002.

	1999	2000	2001	2002
Number of trips	3	13	4	6
Mean weight (tonnes) over trips	40	41	36	23
CV (standard deviation/mean)	50%	54%	33%	17%

Of all fish species dab was discarded the most for both the large vessels (on average 934-2192 per hour) and the eurocutters (351-403 per hour), followed by plaice (Table II.2, II.3). The discard percentage for plaice was 74% in number (varied between 55% to 77% on a yearly basis) and 47% in weight (between 29% to 52%) for large vessels (Table 2.7). In 2001 and 2002 more plaice was discarded than in 1999 and 2000. For eurocutters, the discard percentage was 82% in number and 52% in weight in 2000. For 2001 the amount of plaice landed was low during the sampled hauls (1 kg per hour), resulting in a discard percentage in weight of 90%.

Table 2.7. Average number and weight (kg) per hour landed (L) and discarded (D) and percentage discarded (%D) per year for plaice caught with beam trawl vessels >300 HP (TB) and eurocutters (Euro) in 1999-2002.

		Number			Weight (kg)		
Gear	**Year**	**L**	**D**	**%D**	**L**	**D**	**%D**
TB	1999	143	176	55	42	17	29
TB	2000	197	530	73	51	41	45
TB	2001	371	1023	73	80	91	53
TB	2002	241	825	77	63	67	51
TB	**Average**	**220**	**627**	**74**	**57**	**51**	**47**
Euro	2000	45	207	82	12	13	52
Euro	2001	not meas.	193		1	10	90
Euro	**Average**	**45**	**202**	**82**	**8**	**12**	**60**

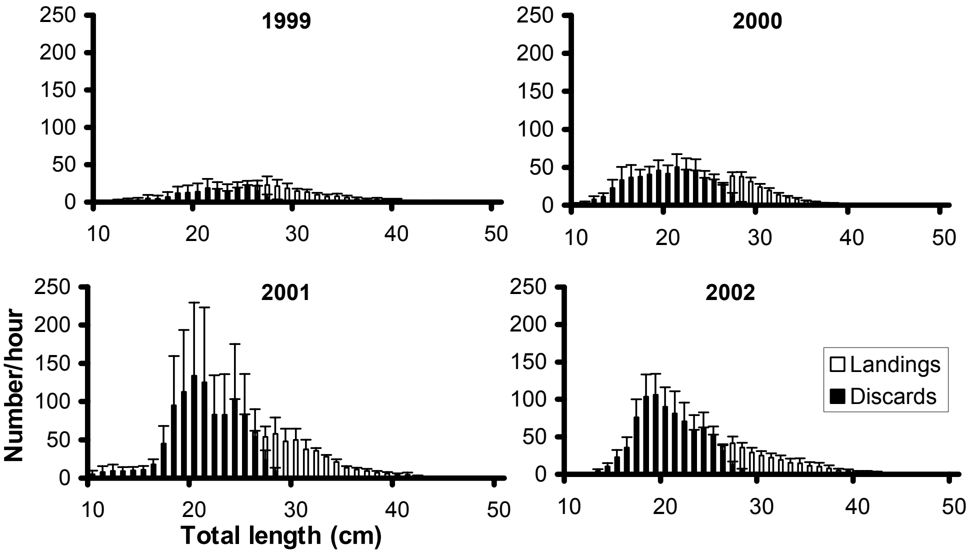

Figure 2.14. Length frequency distribution of plaice in 1999-2002, caught with beam trawl vessel >300 HP. Vertical bars show weighted standard deviation.

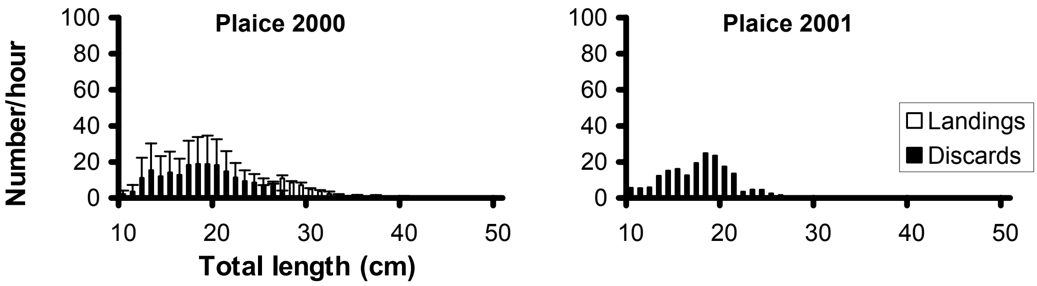

Figure 2.15. Length frequency distribution of plaice in 2000-2001, caught with eurocutters. Vertical bars show weighted standard deviation.

Plaice was discarded from 10 cm and longer (Figure 2.14). In 2001 and 2002, most plaice was discarded around 19-20 cm for large vessels, while in 1999 most plaice were discarded at 25 cm. For eurocutters most plaice was discarded between 15 and 20 cm (Figure 2.15). At 26 cm most plaice was still discarded, while at 27 cm at least 50% of the plaice was landed (Figure 2.16). At 28 cm more than 80% of the plaice is landed.

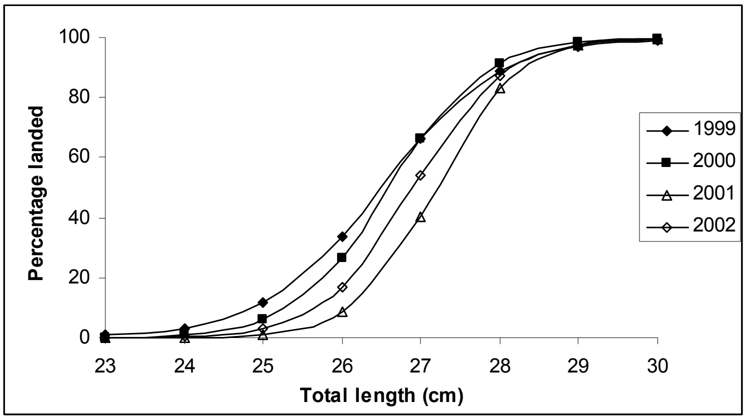

Figure 2.16. Sorting ogive for plaice over 1999-2002 for beam trawlers >300 HP.

Most plaice discards were between age 1 and 3 during 1999-2002 and no discards were observed after age 5 (Table 2.8). The effect of the strong 1996 year class was apparent with high numbers still being discarded and landed at age 5 in 2001 and landed at age 6 in 2002. In 2002 most discards were of age 1, indicating a large 2001 yearclass being vulnerable to the fishery.

Table 2.8. Number of plaice landed (LAND) and discarded (DIS) per hour for ages 0 to 10 in 1999-2002.

year		0	1	2	3	4	5	6	7	8	9	10
1999	DIS	1	56	77	41	1	0	0	0	0	0	0
1999	LAND	0	1	16	72	25	13	6	2	3	2	3
2000	DIS	3	147	252	60	70	0	0	0	0	0	0
2000	LAND	0	6	29	48	85	13	8	2	3	1	1
2001	DIS	1	43	559	264	87	71	0	0	0	0	0
2001	LAND	0	0	3	67	70	198	8	17	2	1	4
2002	DIS	0	392	299	118	14	2	0	0	0	0	0
2002	LAND	0	3	33	69	46	26	55	5	2	1	2

For sole the average discard percentage was 19% in number (varied between 12% to 31% on a yearly basis) and 9% in weight (varied between 5% to 13%) for large vessels (Table 2.9). In 2002 more sole was discarded than in the previous years. For eurocutters the discard percentage varied between 30% and 32% in numbers and 10% and 13% in weight.

Table 2.9. Average number and weight (kg) per hour landed (L) and discarded (D) and percentage discarded (%D) per year for sole caught with beam trawl vessels >300 HP (TB) and eurocutters (Euro) in 1999-2002.

		Number			Weight (kg)		
Gear	**Year**	**L**	**D**	**%D**	**L**	**D**	**%D**
TB	1999	110	15	12	31	2	5
TB	2000	90	25	22	22	2	10
TB	2001	84	12	13	17	1	6
TB	2002	124	31	20	18	3	13
TB	**Average**	**98**	**24**	**19**	**21**	**2**	**9**
Euro	2000	57	26	32	13	1	10
Euro	2001	103	44	30	27	4	13
Euro	**Average**	**73**	**33**	**31**	**18**	**2**	**12**

For large vessels most sole was discarded between 20 and 23 cm (Figure 2.17). Hardly any sole with lengths smaller than 15 cm was caught in the large vessels sampled. In 2000 also smaller sole was discarded in the eurocutters sampled (Figure 2.18).

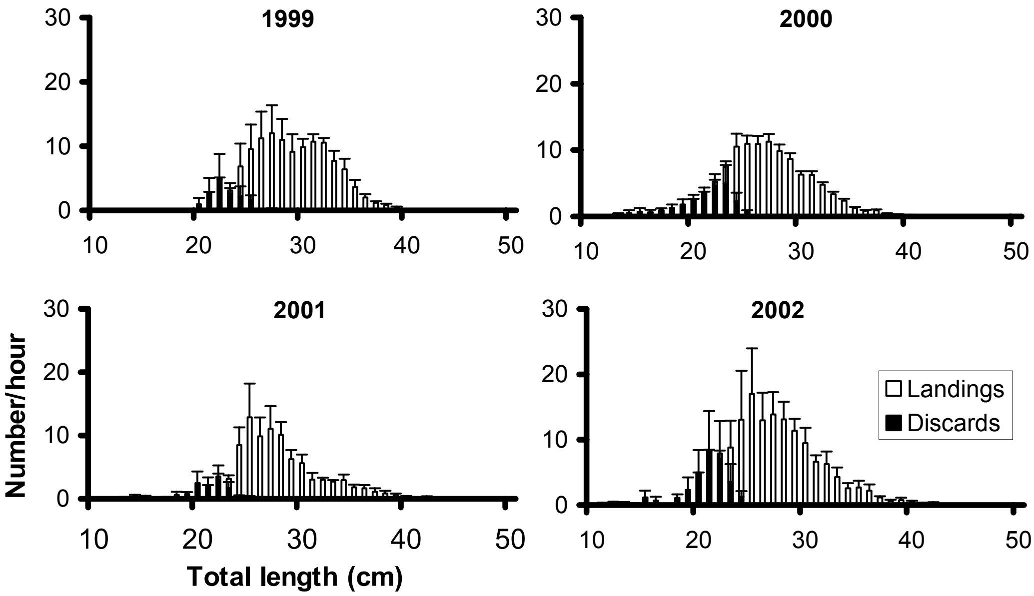

Figure 2.17. Length frequency distribution of sole in 1999-2002, caught with beam trawl vessel >300 HP. Vertical bars show weighted standard deviation.

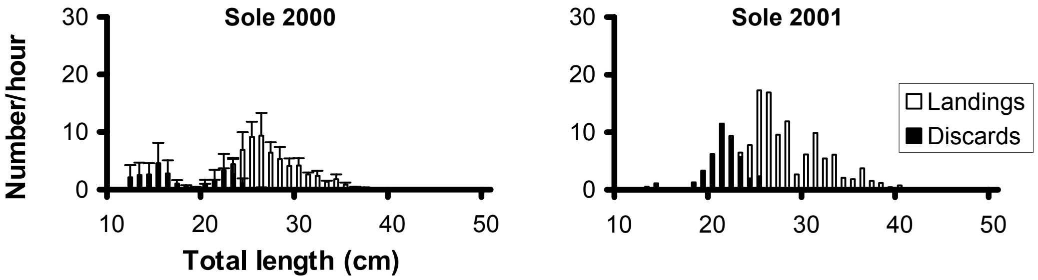

Figure 2.18. Length frequency distribution of sole in 2000-2001, caught with eurocutters. Vertical bars show weighted standard deviation.

More than 50% of the sole were landed at minimum landing size and during 2000-2002 more than 95% was landed at 28 cm. In 1999 82% of the sole was landed at 28 cm (Figure 2.19).

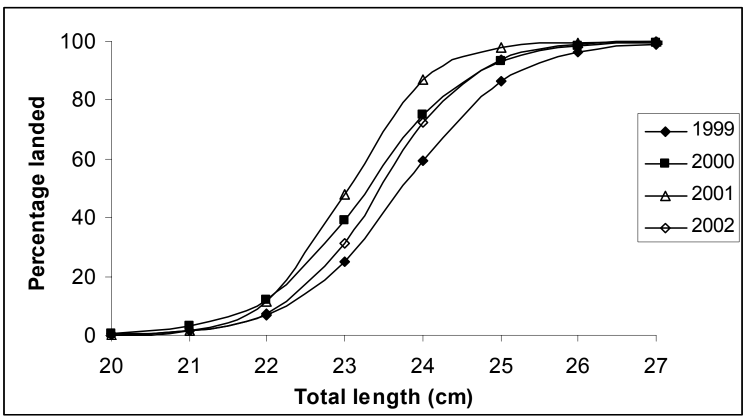

Figure 2.19. Sorting ogive for sole over 1999-2002 for beam trawlers >300 HP.

For dab the discard percentage in weight varied between 84% and 89% for large vessels and 78% and 99% for eurocutters (Table 2.10). The discard percentage for cod varied between 5% and 42% for large vessels and 45% and 47% for eurocutters. The weight of cod discarded per hour varied between <1 and 2 kg. For whiting the discard percentage varied between 72% and 87% for large vessels and 76% to 90% for eurocutters. The weight of whiting landed per hour was 1 kg or less.

Table 2.10. Average weight (kg) per hour landed (L) and discarded (D) and percentage discarded (%D) per year for dab, cod and whiting caught with beam trawl vessels >300 HP (TB) and eurocutters (Euro) in 1999-2002.

		Dab			Cod			Whiting		
Gear	**Year**	**L**	**D**	**%D**	**L**	**D**	**%D**	**L**	**D**	**%D**
TB	1999	13	108	89	3	<1	17	<1	5	87
TB	2000	7	48	87	4	1	21	1	8	84
TB	2001	11	93	89	2	<1	5	1	4	72
TB	2002	11	57	84	3	2	42	1	7	85
TB	**Average**	**9**	**63**	**87**	**4**	**1**	**24**	**1**	**7**	**83**
Euro	2000	4	14	78	<1	<1	47	<1	<1	76
Euro	2001	<1	20	99	<1	<1	45	<1	1	90
Euro	**Average**	**3**	**16**	**86**	**<1**	**<1**	**52**	**<1**	**<1**	**83**

2.4.3. Preliminary results 2003

Of all fish species dab was discarded most in number per hour (1071) followed by plaice (959) (Appendix II: Table II.4). In the eurocutter trip, plaice was discarded more in number per hour (334) than dab (238) (Table II.5).

The average percentage of plaice discarded by large vessels was 84% in number and 59% in weight, which was higher than the previous years (Table 2.11). The discard percentage for sole also increased compared to the previous years, both in number and in weight. For dab and whiting the discard percentage in weight did not increase. For eurocutters the discard percentage in weight was 70% for plaice and 22% for sole (Table 2.12). Both whiting and cod were caught in low numbers.

Table 2.11. Average number and weight (kg) per hour landed (L) and discarded (D) and percentage discarded (%D) for plaice, sole, dab, cod and whiting caught with beam trawl vessels >300 in 2003.

	Number			Weight		
	L	**D**	**%D**	**L**	**D**	**%D**
Plaice	184	959	84	47	69	59
Sole	88	32	27	19	3	14
Dab	60	1071	95	8	58	88
Cod	<1	<1	41	<1	<1	6
Whiting	2	32	94	<1	2	80

Table 2.12. Average number and weight (kg) per hour landed (L) and discarded (D) and percentage discarded (%D) for plaice, sole, dab, cod and whiting caught with a eurocutter in 2003.

	Number			Weight		
	L	**D**	**%D**	**L**	**D**	**%D**
Plaice	26	334	93	8	19	70
Sole	38	29	43	8	2	22
Dab	6	238	97	1	10	88
Cod	<1	0	0	<1	0	0
Whiting		3		<1	<1	77

For large vessels, large proportions of plaice were discarded from 13 cm to the minimum landing size with the largest numbers being discarded at 18-19 cm (Figure 2.20). For the eurocutter two peaks were visible: around 14-15 cm and at 20 cm. Most discarding of sole occured between 19 and 24 cm.

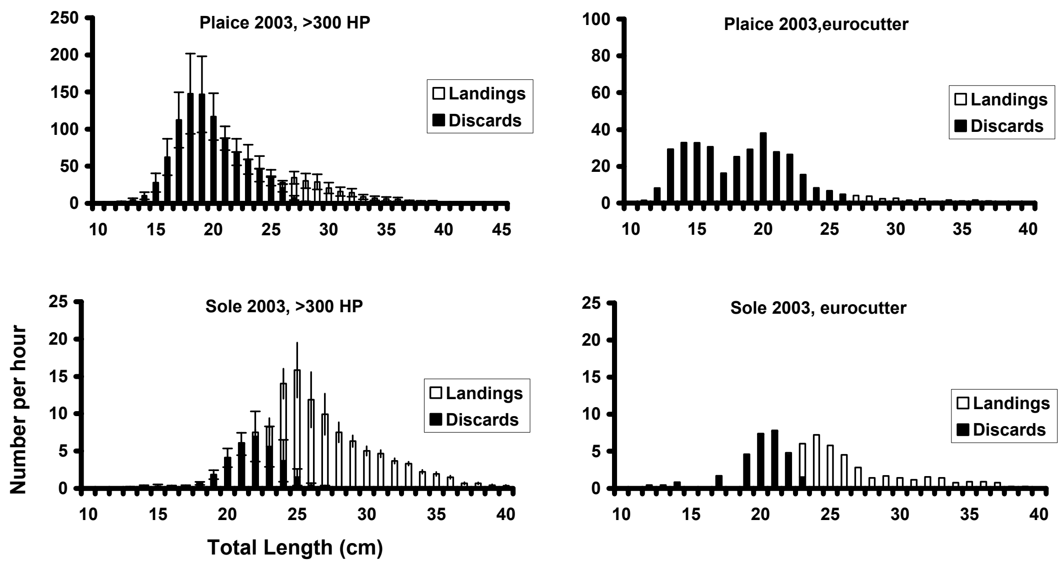

Figure 2.20. Length frequency distribution of plaice and sole in 2003, caught with large vessels and eurocutters. Vertical bars show weighted standard deviation.

2.5 Overview

The percentage of plaice discarded increased in recent years compared to the 1970s and '80s (Table 2.13), especially for vessels fishing outside the plaice box. During 1976-1990 the discard percentage outside the plaice box was on average 31% in number, while during 1999-2002 this was 74%. This increase was caused by a decrease in landings and an increase in discards. Percentage discards also increased for vessels fishing in the plaice box. Before the implementation of the plaice box, large vessels were allowed to fish within this area, resulting in higher numbers of discards than in recent years. The discard percentage inside the plaice box was on average 79% in number during 1976-1990 (Van Beek, 1998). During 1999-2002 the numbers discarded inside the plaice box were lower because of the engine power limitation, while discard percentages were higher with average 82% in number over 1999-2002.

Table 2.13. Summary table of average number and weight (kg) per hour landed (L) and discarded (D) and percentage discarded (%D) for plaice per period.

	plaice		Number			Weight		
Period	box	gear	L	D	%D	L	D	%D
1969-1970		all			40			23
1975		all		130				
1976-1990		all	296	315	51	111	40	27
1976-1990	inside	all	219	754	78			
1976-1990	outside	all	332	148	31			
1999-2002	inside	<300 HP	45	202	82	8	12	60
1999-2002	outside	>300 HP	220	627	74	57	51	47
2003	inside	<300 HP	26	334	93	8	19	70
2003	outside	>300 HP	184	959	84	47	69	59

The percentage of sole discarded did not show a large trend over time (Table 2.14) as seen for plaice, but also increased. During 1976-1990 the discard percentage was on average 21% in number for vessels within the plaice box and 12% for vessels outside the plaice box. During 1999-2002 the discard percentage inside the plaice box was 31% in number during 1999-2002, while outside the plaice box this was 19%. The increase in discard percentage outside the plaice box was caused by an increase in discards.

Table 2.14. Summary table of average number and weight (kg) per hour landed (L) and discarded (D) and percentage discarded (%D) for sole per period.

	plaice		Number			Weight		
Period	box	gear	L	D	%D	L	D	%D
1969-1970		all						
1975		all		12				
1976-1990		all	124	24	16	26	3	10
1976-1990	inside	all	186	49	21			
1976-1990	outside	all	98	14	12			
1999-2002	inside	<300 HP	73	33	31	18	2	12
1999-2002	outside	>300 HP	98	24	19	21	2	9
2003	inside	<300 HP	38	29	43	8	2	22
2003	outside	>300 HP	88	32	27	19	3	14

In recent period the weight of cod and whiting caught per hour decreased compared to the period 1976-1990 (Table 2.15). Because of the low weight of cod caught, discard percentages in recent years are more variable, resulting in discards percentages in weight of 24% in 1999-2002 and 6% in 2003 for large vessels. The number of whiting landings and discards also decreased in recent period compared to 1976-1990.

Table 2.15. Summary table of average weight (kg) per hour landed (L) and discarded (D) and percentage discarded (%D) for cod and whiting per period.

	plaice			Cod			Whiting	
Period	**box**	**gear**	**L**	**D**	**%D**	**L**	**D**	**%D**
1976-1990		all	15	4	22	4	9	68
1999-2002	inside	<300 HP	<1	<1	52	<1	<1	83
1999-2002	outside	>300 HP	4	1	24	1	7	83
2003	inside	<300 HP	<1	0	0	<1	<1	77
2003	outside	>300 HP	<1	<1	6	<1	2	80

3 Discard mortality studies

During 1972-1975 and 1972-1982 the mortality of fish discard has been assessed during different discard mortality studies. This chapter summarizes results of these studies carried out by De Veen et al. (1975), who focussed on survival of plaice and sole from mainly 20 minutes hauls onboard a research vessel, and by Van Beek et al. (1990), who focussed on survival of plaice and sole onboard commercial vessels. Each paragraph first gives an introduction to the project, and then an overview of the results, describing the degree of damage of the discards, as well as discard mortality.

3.1 Discard mortality study 1972-1975

3.1.1 Introduction

For this study the degree of damage and the survival of plaice and sole discards was assessed. These experiments were performed in November 1972, April-May 1973 and January-February 1975 onboard the research vessel “Tridens”. Plaice and sole were graded according to apparent damage into 6 categories, from completely healthy and undamaged to dead (Table 3.1). Plaice, graded by stage of damage and duration of haul were put in separate tanks for four days, and their survival was examined twice a day. In February 1975 survival studies were initiated on total mortality of net and exposure on deck together. After hauls of 20 minutes, the catch was left onboard for 20 and 40 minutes and thereafter placed in separate tanks.

Table 3.1. Description of the 6 damage categories

Category	Lively	Description
A	fish lively	Mucus layer intact, no visible damage to skin
B	fish lively	Mucus layer not more intact, slight scratches on skin
C	fish not so lively	Mucus layer partly removed, loss of scales near tail
D	fish sluggish	Mucus layer mostly removed, many scales missing
E	fish sluggish	Mucus layer lost, most scales missing
F	fish dead	

3.1.2 Results

Degree of damage
Most plaice were categorized as category B and C, while category F fish was not abundant (Figure 3.1). There was a slight decrease in the average degree of damage as fish increased in length. The influence of more engine power on the degree of damage was visible for plaice caught with vessels >1000 HP with more plaice categorized as E and F and less as A and B (Figure 3.2). Cutters with large engine power are able to drag heavier beamtrawls with more chains and fish with higher speeds, resulting in heavier damaged fish.
Sole caught with vessels up to 500 HP were mainly categorized as B and C (Figure 3.3). The influence of more engine power was also visible for sole, with more fish categorized as D, E and F.

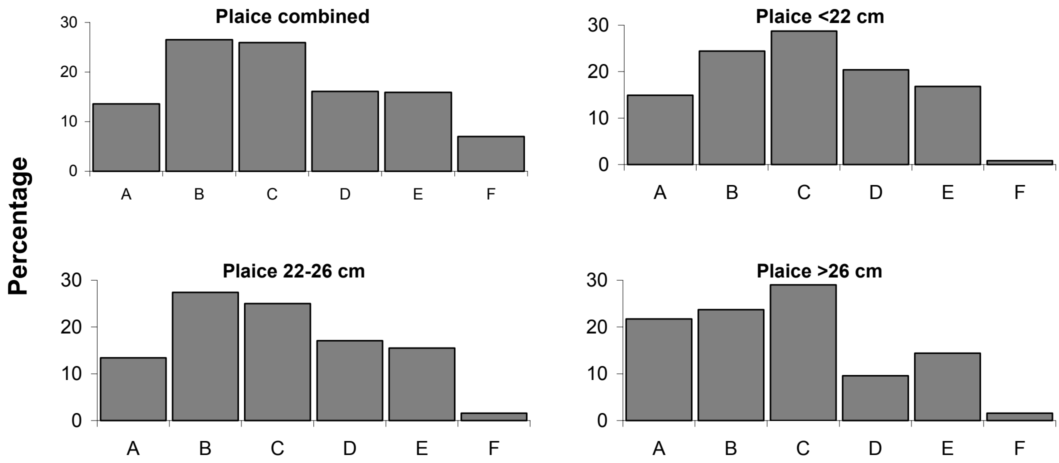

Figure 3.1. Relative frequency per damage stage for plaice for all length combined, smaller than 22 cm, 22-26 cm and larger than 26 cm.

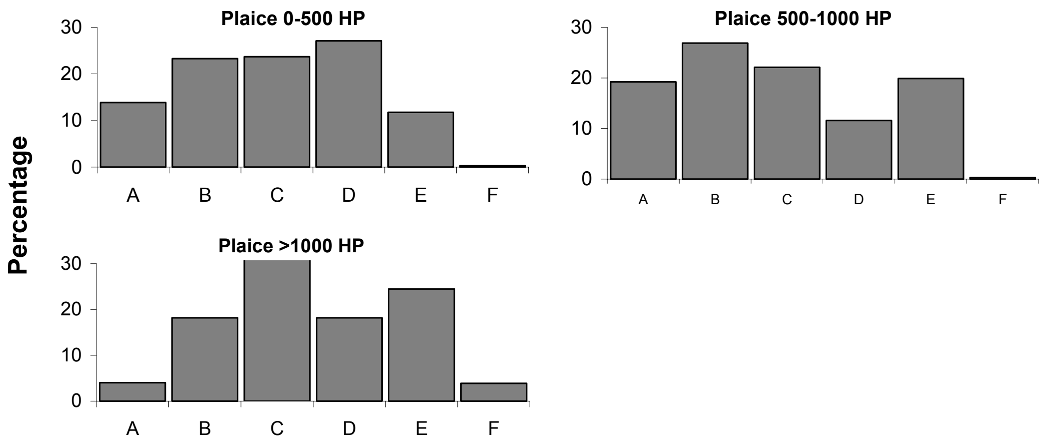

Figure 3.2. Relative frequency per damage stage for plaice for vessels with an engine power between 0-500 HP, 500-1000 HP and larger than 100 HP.

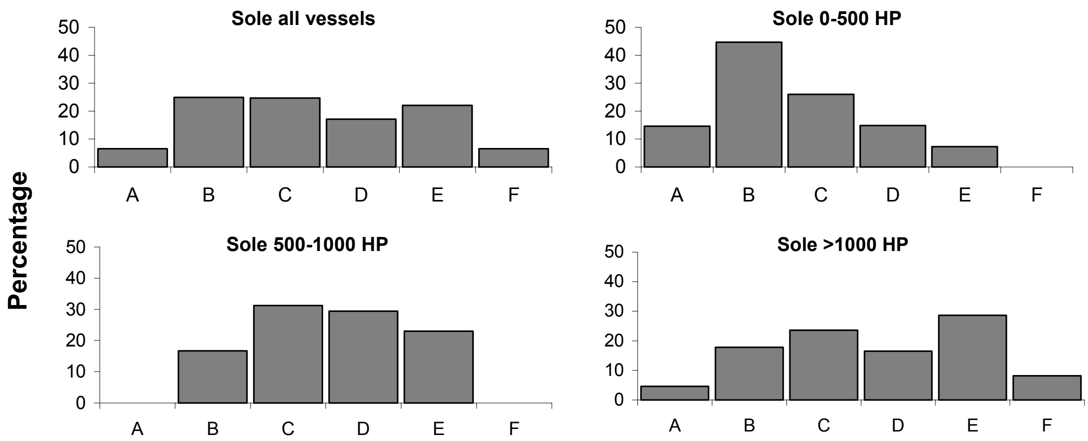

Figure 3.3. Relative frequency per damage stage for sole caught with all vessels, for vessels with an engine power between 0-500 HP, 500-1000 HP and larger than 1000 HP.

Discard mortality

Mortality increased with increasing degree of damage for both North Sea plaice and Irish Sea sole (Figure 3.4). All category A type plaice survived, while all category E died after three days with a haul duration of 20 minutes. The survival of category A type sole was around 95%, while for category E 14% survived.

Haul duration negatively affects survival. The average survival of plaice after three days was around 50% for 20 minute hauls, but decreased with longer haul duration (Figure 3.5).

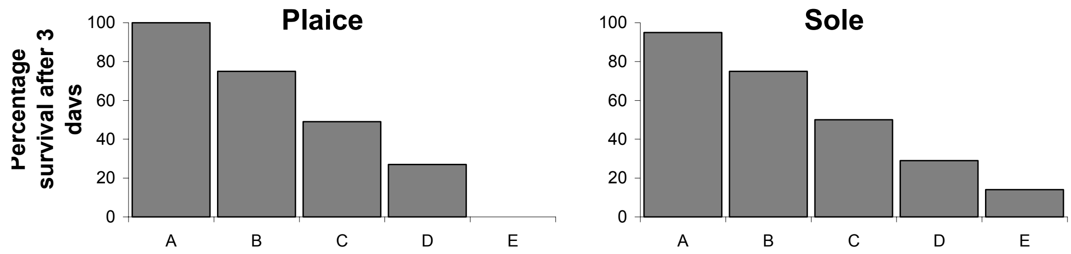

Figure 3.4. Percentage survival per damage stage for North Sea plaice and Irish Sea sole after 3 days, with 20 minute hauls.

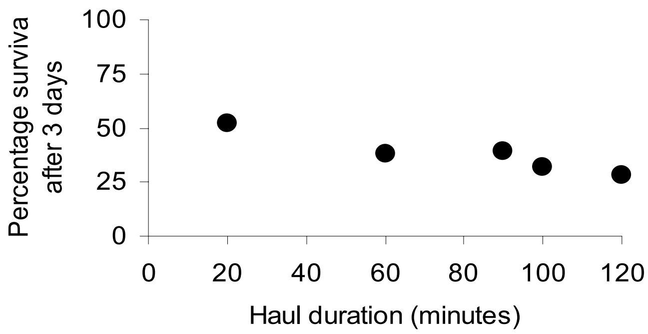

Figure 3.5. Average percentage survival for North Sea plaice after 3 days, for different haul duration.

Survival at the end of the third day was less for hauls of 40 minutes than for hauls of 20 minutes, with sole surviving less than plaice (Table 3.2). Sole survival is very low in case of exposure of 20 minutes and all sole died after an exposure of 40 minutes on deck. Mortality in commercial fishing with hauls of 2 hours will be higher than in the 20 minute hauls of the experiment performed.

Table 3.2. Percentage survival per damage stage for plaice and sole after 3 days, with 20 minute hauls and 20 or 40 minutes exposure on deck.

	Deck exposure	A	B	C	D	E
plaice	20 min	100	89	52	10	0
	40 min	100	57	7	0	0
sole	20 min	14	11	0	0	0
	40 min	0	0	0	0	0

3.2 Discard mortality study 1972-1982

3.2.1 Introduction

For this study survival experiments with plaice and sole discards were carried out onboard commercial beam trawl vessels operating under normal commercial conditions between 1972 and 1982. Additional experiments were carried out with plaice caught with an otter trawl on research vessel "Tridens". Discards were sorted from the catch and their condition classified into 4 categories (Table 3.3). From each of the damage categories a random sample was taken and placed in plastic tanks. If conditions permitted, the experiments were checked every 12 hours and the dead fish were recorded and removed. The experiment was terminated when all fish had died or at the end of the cruise. Survival experiments were initiated with discards from catches that varied in gear used, number of chains and haul duration (between 15 and 120 minutes). In addition the effect of increasing processing speed on the survival of plaice discards was examined on the survival by comparing discard mortality of plaice processed on deck and with a sorting device. Furthermore the survival of sole escaping through the meshes was estimated.

Table 3.3. Description of the 6 damage categories.

Category	Lively	Description
A	Fish lively	No visible signs of loss of scales or mucus
B	Fish less lively	Mucus layer 20% affected, some scales missing
C	Fish sluggish	Mucus layer 50% affected, areas without scales
D	Fish sluggish	Mucus layer >50% affected, many areas without scales

3.2.2 Results

Degree of damage

The degree of damage increased with increasing haul duration for both plaice and sole. For plaice the average degree of damage was worse in the beamtrawl than in the ottertrawl (Figure 3.6). After 120 minute hauls most fish were categorized as D for both plaice and sole caught with a beam trawl (Figure 3.6, Figure 3.7)

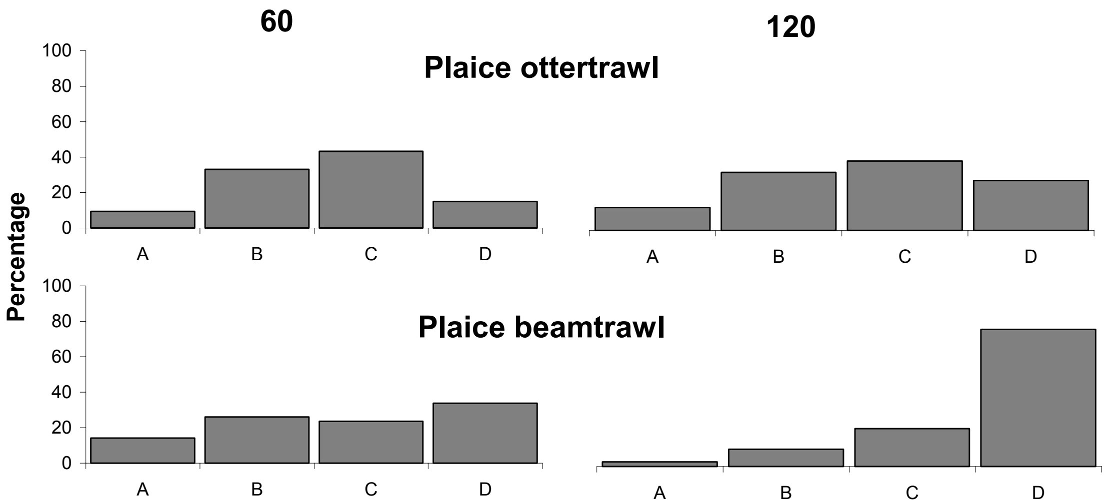

Figure 3.6. Relative frequency per damage stage for plaice caught with ottertrawls and beamtrawls for 60 and 120 minute hauls.

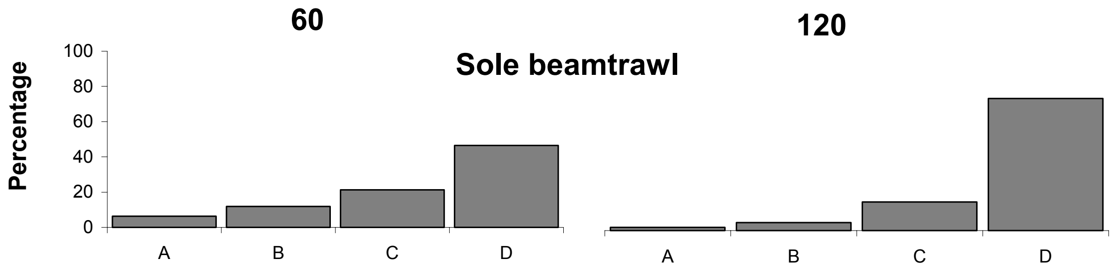

Figure 3.7. Relative frequency per damage stage for sole caught with beamtrawls for 60 and 120 minute hauls.

Discard mortality

The average overall survival for all damage categories of both plaice and sole discards was estimated at 10% (Figure 3.8, left two figures), which was a maximum estimate, because it is likely that in the experiments not all fish died within the experimental period. Estimates varied between 0% and 50% for plaice and 4% and 40% for sole.

Discard survival was higher in 60 minute hauls than in 120 minute hauls, the relation being significant for sole ($p<0.05$) and marginally significant for plaice ($0.05<p<0.10$) (Figure 3.8, right two figures). Survival increased at lower water temperatures.

Survival of plaice was lower in the beamtrawl than in the ottertrawl (Figure 3.9). The method of processing catch onboard did not affect the survival of plaice discards in 120 minute hauls. Pairwise comparison of experiments from 60 minute hauls showed no difference between conveyer belt and traditional processing in one experiment, but substantially higher survival occurred with conveyor belt processing in two other experiments.

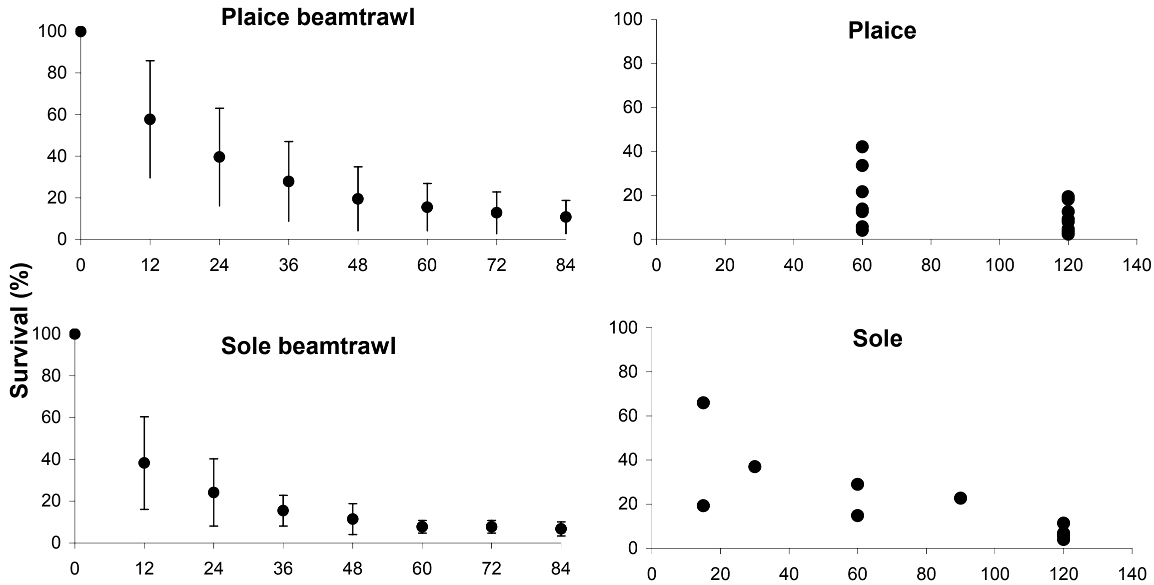

Figure 3.8. Relative frequency of survival (%) per 12 hours for plaice and sole discards caught with beamtrawls for 120 minute hauls (left two figures) and survival (%) of plaice and sole discards after 84 hours in experimental holding tanks in relation with haul duration (right two figures). Vertical bars on left two figures indicate the standard deviations.

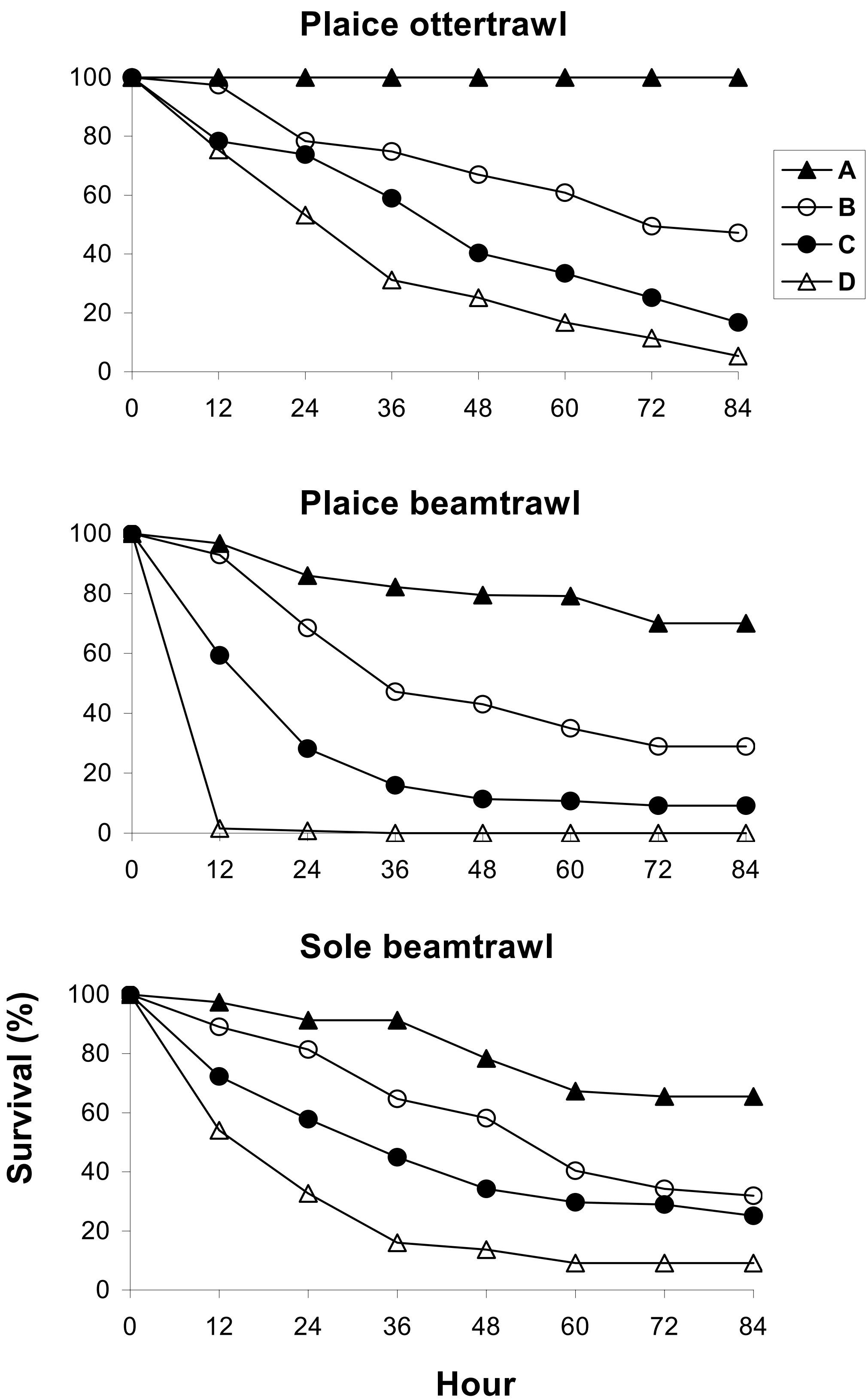

Figure 3.9. Relative frequency of survival (%) per 12 hours for plaice caught with ottertrawls and beamtrawls and sole caught with beamtrawls per damage stage for 60 and 120 minute hauls combined.

Survival of soles escaped through the mesh.
The survival of sole escaping through the mesh was estimated at 60%. Survival of soles escaping decreased with increasing haul duration (Figure 3.10). As the decreased survival at longer haul durations may be caused by prolonged stay of the escaped soles in the cod-end cover, the survival was extrapolated to a haul duration of 0 minutes. Visual inspection of sole caught halfway through the meshes showed some loss of scales. Inspection of the sole used in the survival experiments that died also showed loss of scales. The estimated survival of 60% therefore seems a reasonable, but necessarily crude estimate.

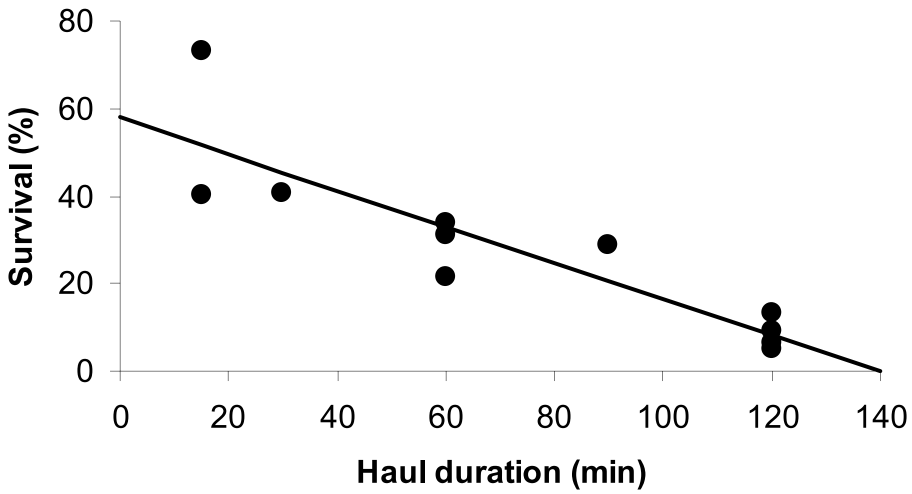

Figure 3.10. Survival (%) after 84 hours of sole escaped through the meshes and collected in a cod-end cover of a beam trawl in relation to haul duration. the extrapolated survival at a haul duration of 0 minutes is estimated at 60%.

3.3 Overview

Results from mortality experiments by De Veen et al. (1975) and Van Beek et al. (1990) both showed that most of the fish discarded were heavy damaged (Figure 3.11). Van Beek et al. (1990) divided the degree of damage into four categories, while De Veen et al (1975) used six, splitting the heavy damage category D into three distinct categories; D, E and F (Table 3.1). De Veen et al. (1975) showed that increased engine power lead to more heavy damaged fish and less lightly damage fish, while Van Beek showed that more heavy damaged fish was also caused by longer haul duration. Because the data from both studies were not available for the same haul duration and engine power, direct comparisons between both studies cannot be made.

Direct comparison of both studies for survival of plaice cannot be made, since De Veen et al. (1975) did experiments onboard of a research vessel using a light net, while Van Beek et al. (1990) used heavier gear with more chains and longer haul duration. However all studies found high survival for category A damaged fish, and decreasing survival for heavier damaged fish (Figure 3.12). Survival of plaice discards decreased drastically with deck exposure of 40 minutes compared to 20 minutes (De Veen et al. 1975). Survival was lower for plaice discard in beamtrawls than in ottertrawls (Van Beek et al. 1990).

In both studies survival decreased with increasing haul duration (Figure 3.13). Again direct comparison between both studies could be made, because of differences in fishing gear.

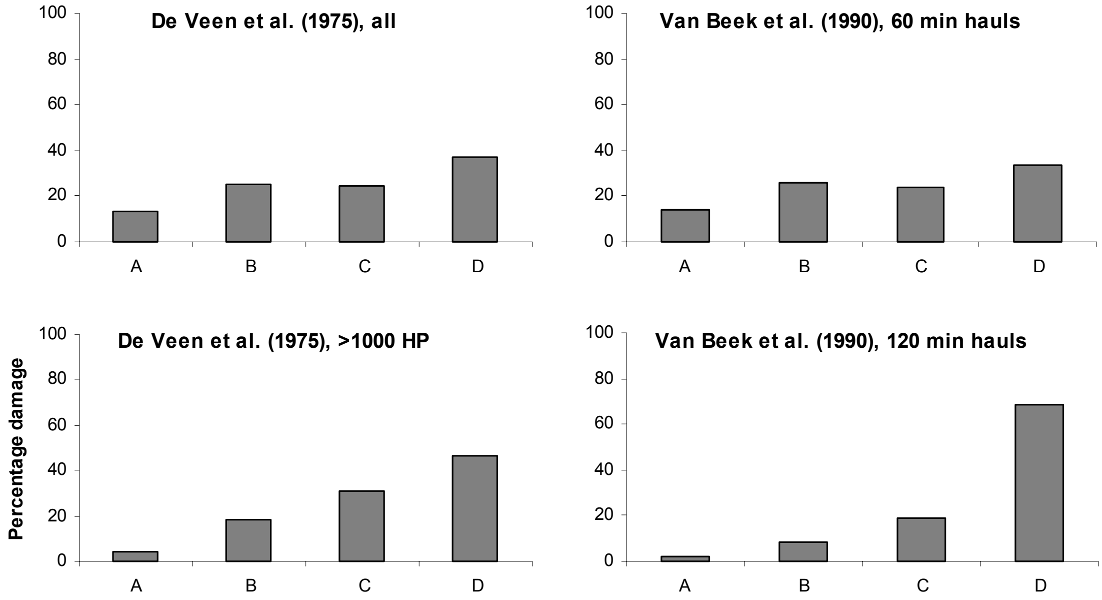

Figure 3.11. Degree of damage from De Veen et al. (1975) for all observations and for large beam trawl vessels with engine power >1000 HP, and from Van Beek et al. (1990) for 60 minute and 120 minute hauls.

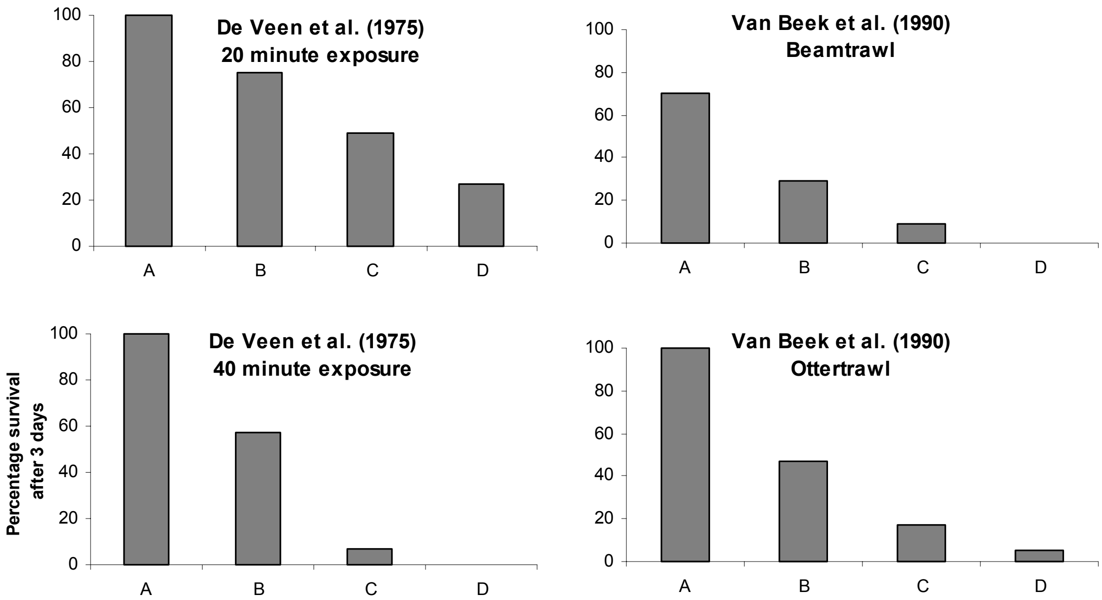

Figure 3.12. Percentage survival after 3 days from De Veen et al. (1975) for 20 minute hauls and 20 and 40 minute deck exposure, and from Van Beek et al. (1990) for beamtrawl and ottertrawl vessels.

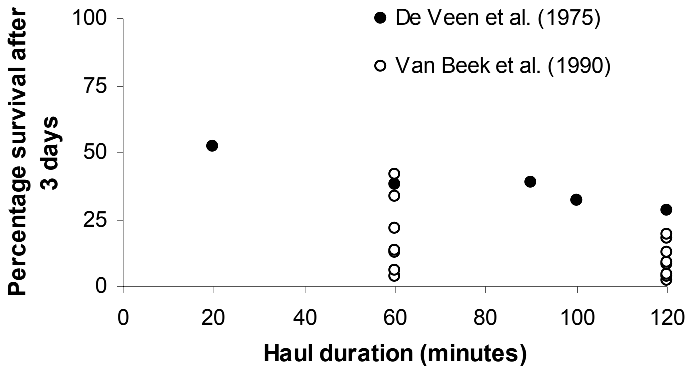

Figure 3.13. Percentage survival after 3 days for different haul durations from De Veen et al. (1975) with a research vessel, and from Van Beek et al. (1990) with commercials vessels.

4. Changes in spatial distribution of plaice

In this chapter changes in the distribution of juvenile plaice from shallow coastal towards deeper offshore areas are investigated. The abundance of juvenile plaice is modelled using two models, depending on year and water depth.

4.1 Introduction

To investigate changes in the distribution of plaice, estimates of plaice abundance in the North Sea were obtained from survey data. The BTS (Beam Trawl Survey) has been conducted from 1985 onwards to monitor demersal stocks in the North Sea. The survey is conducted in August and September and uses a pair of 8-m beam trawls with 40 mm stretched mesh cod-ends. Each year the same ICES rectangles are fished with, depending on the rectangle, 1-4 hauls. Within the ICES rectangles the positions of the stations are chosen on a pseudo-random basis taking unfishable areas into account. From the survey data numbers at age per hour are calculated for each haul and year. For each haul the water depth was known. Two separate models were used to model the abundance of plaice, a linear and a logistic model. Both models investigate changes in abundance of plaice by water depths. The difference between both of the models is that the linear model investigates changes in actual numbers (log-transformed) by water depth, whereas the logistic model investigates changes over the years in the chance that plaice were caught at a water depth. This chance is expressed as a number between 0 (no fish at that water depth) to 1 (fish were caught at that water depth in all the hauls).

The linear model (Neter et al., 1996) describes the abundance of plaice, thereby correcting for differences between years and distribution over water depths. To meet certain criteria of this analysis (normal distribution, equal variance) the number at age per hour were first log-transformed:

$$\text{Log(Abundance)} = \text{Ln(Number at age per hour)} \qquad (1)$$

Afterwards the abundance was modelled with year taken as a class variable and water depth as a continues variable. The interaction term of year*water_depth was also taken as a continuous variable:

$$\text{Log(Abundance)} \sim \text{year}_i + \text{water depth}_j + \text{year*water depth}_j \qquad (2)$$

Significant effects of "Year*water depth" indicate that changes occurred in the abundance of plaice over the water depth over the years. In a graph of log abundance (y-axis) plotted against water depth (x-axis) these changes in abundance over the years are shown as changes in the steepness of the slope of the relationship. The variable "year" explains differences in the abundance between different years, mainly caused by differences between year classes. The variable "water depth" explains the relationship between abundance and water depth: for juvenile plaice, numbers decrease with increasing water depth.

The logistic model describes the chance that plaice of a certain age is found at a depth in a year. Therefore for all depths in a year it was indicated if plaice of a certain age was found at that depth (p=1) or not (p=0). This fraction was transformed with a logit transformation (Allison, 1999):

$$\text{Logit(p)}=\text{Ln(p/(1-p))} \qquad (3)$$

This transformed p was modelled depending on year and water depth:

$$\text{Logit(p)} \sim \text{water depth}_j + \text{year*water depth}_j \qquad (4)$$

4.2 Results

From visual inspection of the distribution of plaice over the North Sea over the period 1985 to 2002 (Appendix III: Figure III.1 to III.4) plaice appears to have moved towards deeper offshore areas. Age 0 (Figure III.1) and age 1 plaice (Figure III.2) were mainly distributed along the shallow coastal areas. However in recent years both age groups seems to appear more offshore. Age 2 (Figure III.3) and age 3 (Figure III.4) were distributed more offshore. It appears that in recent years less plaice of these two age groups are distributed along the coastal zone.

For the linear model, the term “year*water depth” was highly significant (P<0.0001, Table 4.1) for age 1 to age 4 (Figure 4.1). This means that there was a change in abundance of plaice over water depths in time, with plaice moving towards deeper water over the years. It can be seen for example, that during the late ’80 the log abundance of age 3 plaice slowly decreased with increasing water depth, while from the ’90 onwards the log abundance increased with increasing water depth. This increase in abundance with increasing water depth was highest for recent years.
For age 0 the “year*water depth” was not significant, because the direction of the slopes of the modeled relationship between log abundance and water depth did not change over the years. However age 0 plaice were caught in deeper water during recent years, mainly between 20 and 30m, then in the late ‘80s, when most age 0 plaice were caught between 15 and 25m (Figure 4.2).

For the logit model, the change in proportion of age 0 and 1 plaice with depth per year was highly significant (P<0.0001, Table 4.1), borderline significant for age 2 (0.10>=P>0.05) and significant for age 3 (0.05>=P>0.01) and age 4 (p<0.01, Table 4.1). For age 0 and 1 plaice more fish appeared in deeper water depth in recent years (Figure 4.3). Age 2 plaice were found over the entire depth range during all years, so changes in abundance of this age group were not apparent in this analysis. Changes were however apparent for age 3 and 4 with lower proportions of plaice distributed in the shallow areas during recent years compared to the mid 1980’s and early 1990’s.

Table 4.1. Significance of the year*water depth effect for each age. If a term was significant, the distribution of plaice over the water depth have changed over the years (change in de slope of the lines showing the relationships between log abundance and water depth).

Age	Linear model	Logit model
0	N.S.	<0.0001
1	<0.0001	<0.0001
2	<0.0001	0.0676
3	<0.0001	0.0199
4	0.0001	0.0013

highly significant=P<0.01
significant=0.05>=P>0.01
borderline significant=0.10>=P>0.05
not significant= N.S.

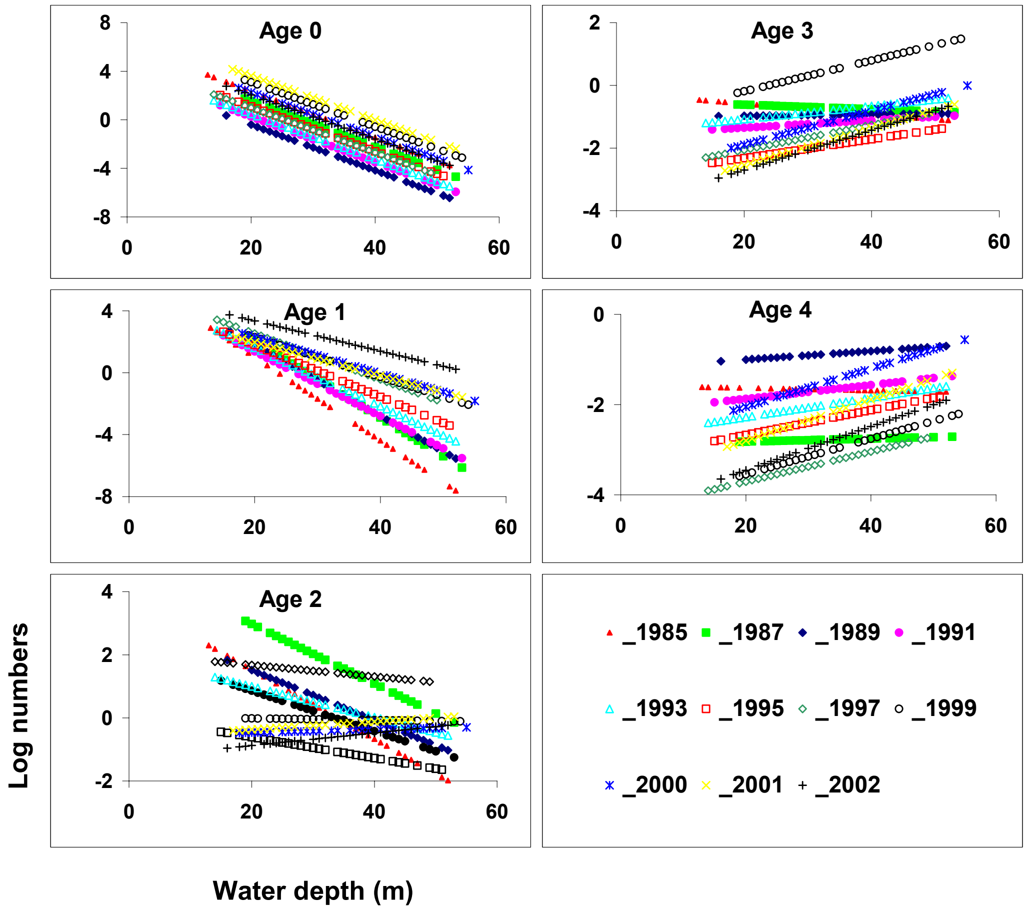

Figure 4.1. Linear model. Modelled abundance of plaice (expressed as log numbers per hour) against water depth (m) per year for ages 0 to 4. For display purposes only uneven years between 1985 and 1999 were presented.

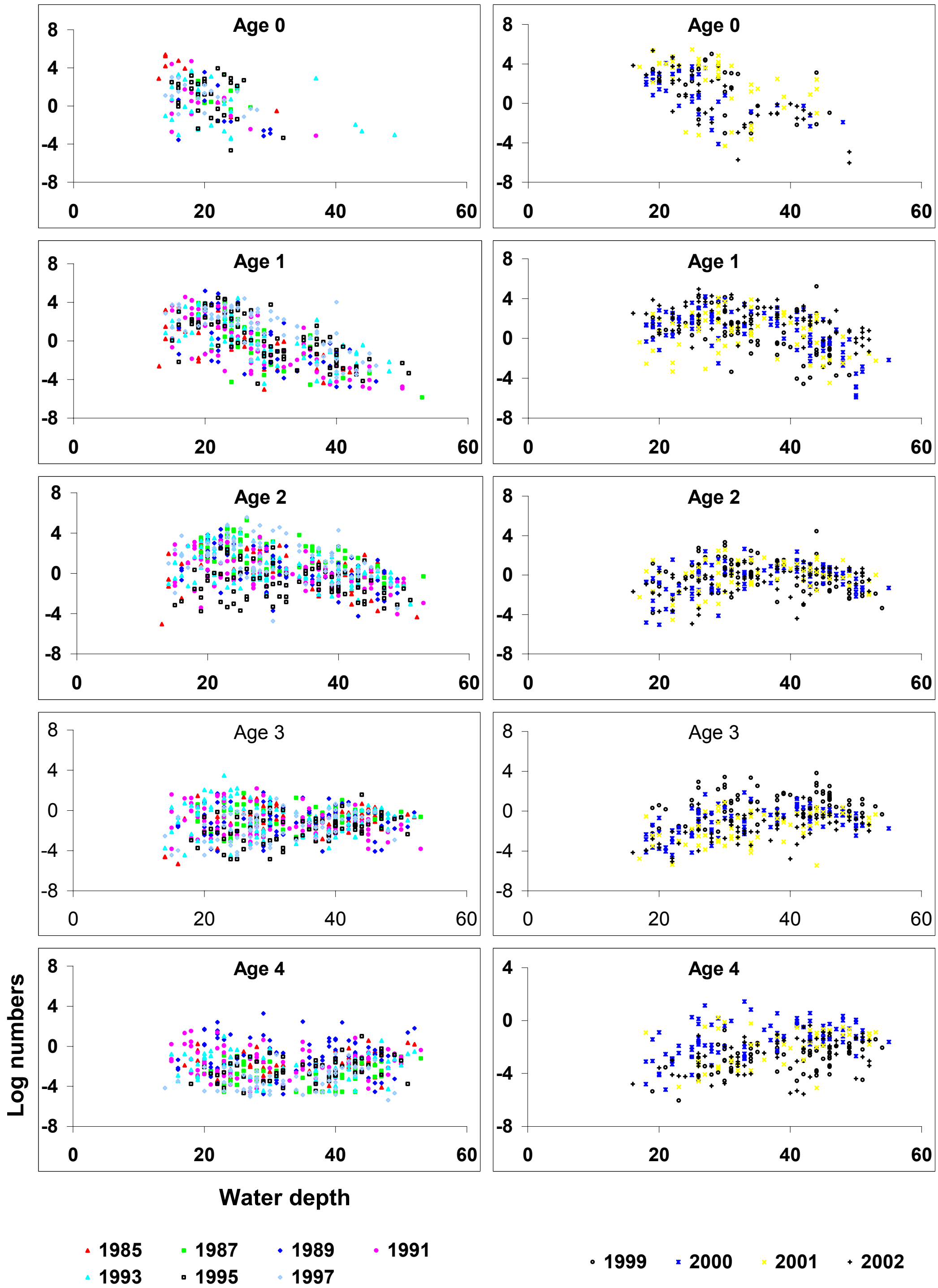

Figure 4.2. Abundance of plaice (expressed as log numbers per hour) against water depth (m) per year for ages 0 to 4. For display purposes only uneven years between 1985 and 1997 were presented in left figures.

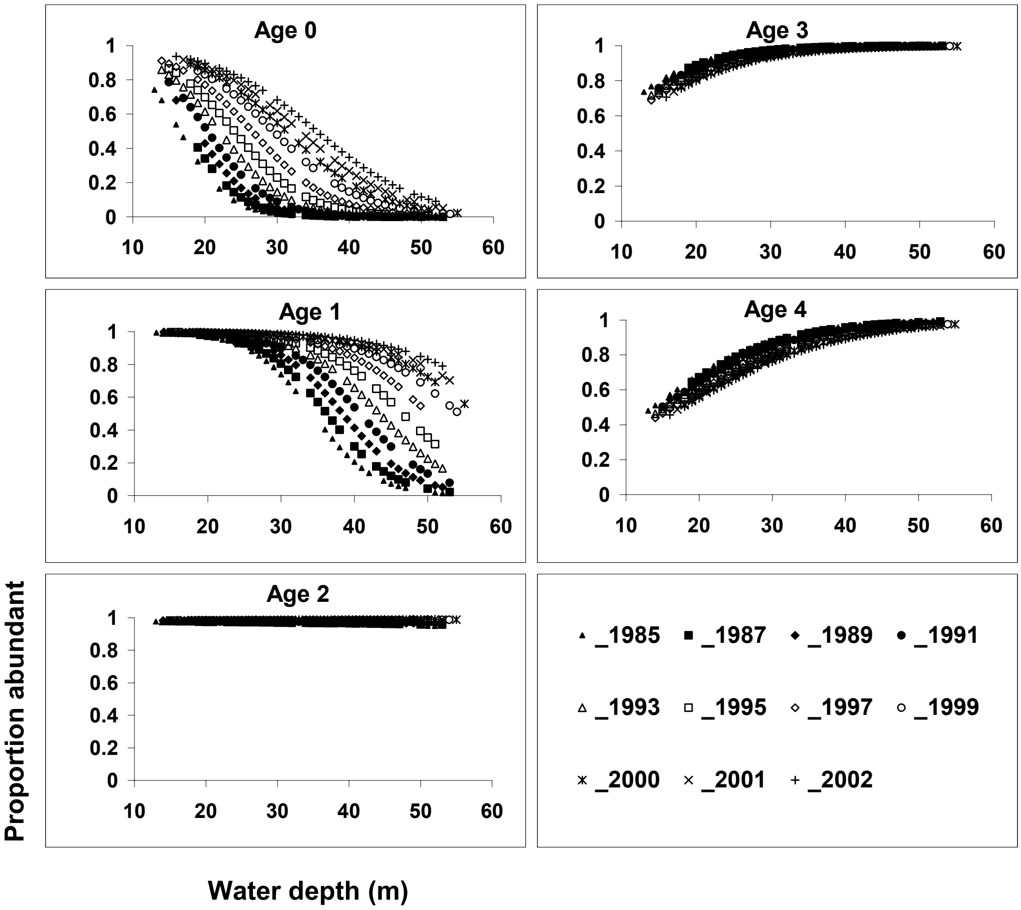

Figure 4.3. Logit model. Proportion of plaice abundant against water depth (m) per year for ages 0 to 4. For display purposes only uneven years between 1985 and 1999 were presented.

5. Effects of plaice discards on stock assessment

5.1 Introduction

Because of the gaps in the time series of discard information from the sampled discard trips (see chapter 2), actual observations can momentarily not be used in the stock assessment for North Sea plaice. However the effect of discards on the stock assessment can be investigated using a constant discard rate based on fixed discard patterns of juvenile plaice, or using models that simulate variable discard rates.

In a recent “quick-scan” calculation for North Sea plaice, the impact of a simple constant discard rate on the assessment was investigated (Kraak et al., 2002). Using XSA (Darby and Flatman, 1994) and the same model setting as the ACFM assessment (ICES, 2002b), the catch was increased by a factor 2 to account for discarding (i.e. discards were thought to be 50% of the actual catch, based on Van Beek (1998)). This extra catch in numbers was re-distributed between ages 1 to 5 in fixed proportions derived from recent discards sampling. The resulting assessment showed that the mean F over ages 2 to 10 increased by approximately 25% compared to the ACFM assessment, as did the estimates of SSB and recruitment (in agreement with Casey (1993)). Adjusting catch for the last 3 recent years by a factor of 2.5 (i.e. discards were 80% of the actual catch), to account for this higher discarding, increased the mean F again in the final years, as did the estimates of SSB and recruitment, although the effect of the 3 years higher discarding in the input data went back seven years in the assessment.

This chapter describes the effect of a variable discard rate on the stock assessment of North Sea plaice. For this analysis a model based on growth information, selectivity parameters and landings information was used, which estimates discards numbers at age from landings numbers at age.

5.2 Material and methods

To investigate the effect of a variable discard rate on the stock assessment of North Sea plaice, quarterly catch at age numbers were calculated from quarterly landings at age numbers using discard proportions at age. These discard proportions at age were estimated from a simulated population based on a normal distribution, a selection ogive and a sorting ogive (Casey, 1993; ICES, 1999). This chapter describes the methods used in summary, while appendix I.2 describes the methods in more detail.

Discard proportions were derived from a simulated population. To create this population, data on mean length at age per quarter were used from either (1) back-calculations of otoliths collected from commercial landing or (2) research vessel survey data (BTS and SNS). Since data were only available for one quarter (1^{st} quarter for otolith or 3^{rd} quarter for survey data), mean length at age for the other quarters were calculated assuming linear growth between quarter 1 and quarter 3 and no growth between quarter 3 and quarter 1 the next year (Figure 5.1).

To calculate the abundance in percentage of a length class within an age group per quarter, a normal distribution was used, using the mean length per quarter and an average standard deviation per age group (Figure 5.2).

From the simulated population the proportion of fish caught was estimated from a selection ogive (Figure 5.3), which was based on selection experiments (Appendix I.2). In the analysis, both a selection ogive for a 60 mm as for an 80 mm mesh size were explored. The proportion of fish discarded or landed was calculated using a sorting ogive, which was derived from onboard observations (Appendix I.2).

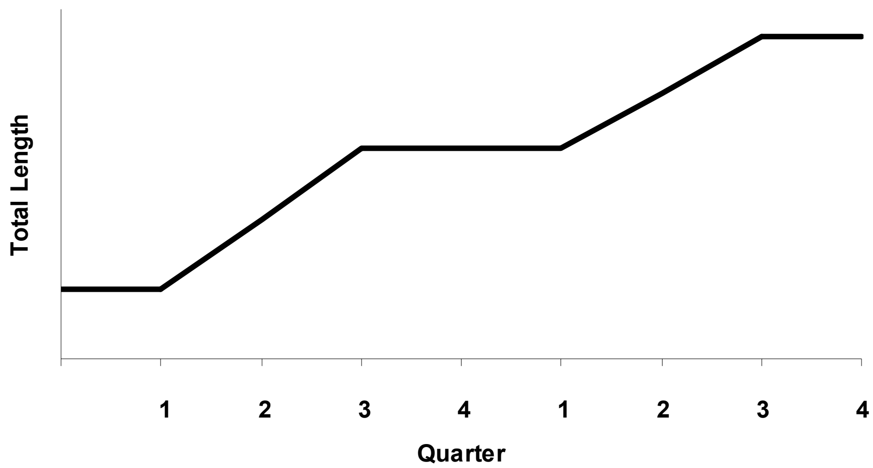

Figure 5.1. Modelled growth in a year. During the 1st and 3rd quarter linear growth is assumed, while during the 3rd and 1st quarter there was no growth.

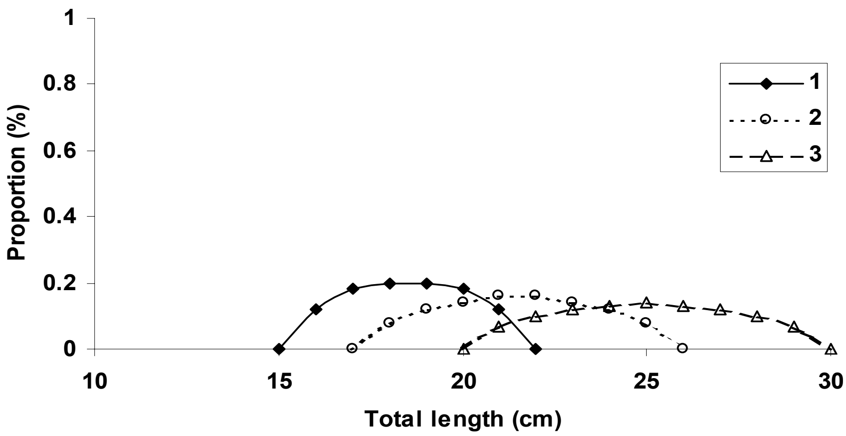

Figure 5.2. Fictive modelled population in a quarter and year. With the normal distribution the proportion of a length class within an age class is calculated.

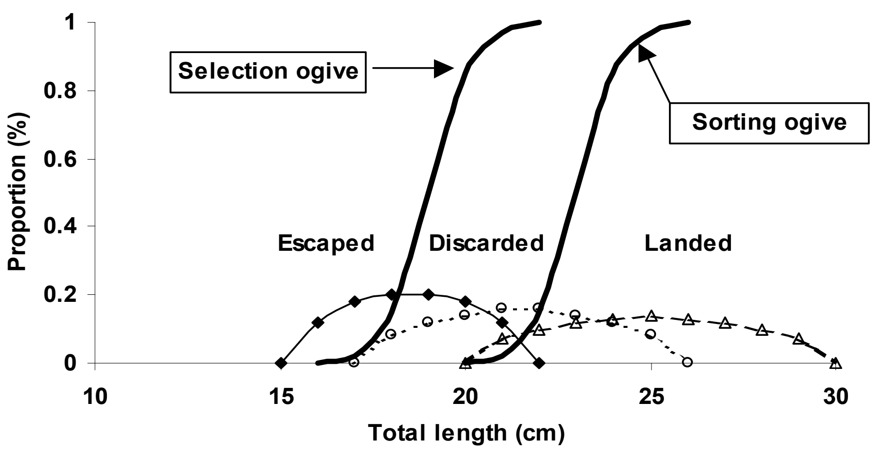

Figure 5.3. Selection and sorting ogive. The selection ogive divides the population in a part that escaped the nets and a part that is caught. The sorting ogive divides the caught part into a landed and a discarded part.

The ratio of the sum of all the catch proportions (landings and discards) to the sum of all the landings proportions was calculated per age, quarter and year. Official catch numbers at age per quarter (which are only landings) were corrected to total numbers of landings and discards at age per quarter. These numbers were summed per year and used as catch input for the stock assessment models.

5.3 Results

Modelling growth and discard proportions
The observed mean length at age fitted the predicted mean length at age well, especially for young ages (Figure 5.4). Mean lengths obtained from survey data were in general lower than the mean lengths obtained from back-calculations (Appendix IV: Figure IV.1). Furthermore, the discrepancies between the back-calculated mean lengths and the survey derived mean length increased substantially with age. Observed mean length from otolith back-calculations showed a significant increase over the whole time series (1962-1996) for age 1-5. Both surveys as well as the otolith back-calculations showed a decrease in mean length at age for the strong 1996 yearclass.

The higher mean length at age estimates from otolith back-calculations resulted in proportion discards (Tables IV.1 to IV.8), which were lower compared to survey based length estimates from age 2, quarter 3 onwards (Figure IV.2a and IV.2b). For comparison of otolith back-calculations with the BTS, the overall difference in proportion was very significant in all cases (paired t-tests performed on averages of yearly quarters[1]: $p<<0.001$ for all ages 2-6 and both mesh sizes). Similarly, the discard proportions estimated from the otolith back-calculations were much lower ($p<<0.001$) than those estimated from the SNS except for age 2 with 80 mm mesh size ($p=0.1$).

The estimated discard proportions based on a selection ogive with 80 mm mesh size were lower than those with 60 mm mesh size when considering the estimates from otolith back-calculations and from the SNS. This difference was very significant ($p<<0.001$) in all cases, except at the ages 4, 5 and 6 for the otolith estimates where the statistical test could not be performed. For BTS estimates, the discard proportion with 80 mm were significantly lower ($p<0.001$) than those with 60 mm for age 2, whereas there was no significant difference ($p=0.46$) between mesh size at age 3. The proportion discards was significantly higher with 80 mm ($p<0.01$) than with 60 mm at ages 4, 5 and 6.

[1] Data are arcsine square root transformed. This is a usual treatment to normalise proportions.

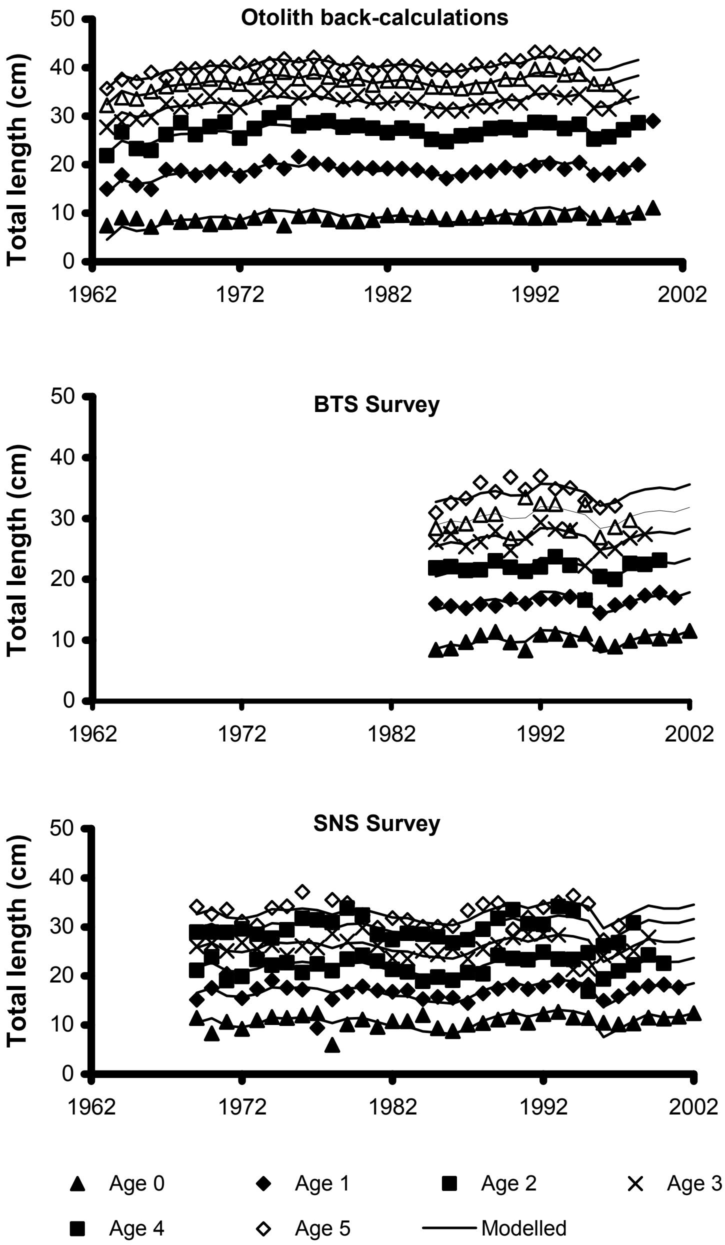

Figure 5.4. Observed and predicted mean length (cm) for age 0-5 plaice per yearclass, estimated from growth signals of otolith back-calculations (quarter 1, top), BTS survey (quarter 3, middle) and SNS survey (quarter 3, bottom).

Stock assessment

Mean fishing mortality (Fbar) on the youngest ages in the analysis, age 2 and 3 (Figure IV.3a, Table IV.9), was higher with discards included in the catch numbers (Figure 5.5). This was to be expected because the model assumes that more fish of age 2 and 3 are vulnerable to the fishing gear. With discards included and assuming an 80 mm mesh size fishery, the mean fishing mortality was on average 1.51 times higher (range 1.04-2.34 over 1963-2002) for estimates from otolith back-calculations, 2.25 times higher (range 1.68-4.00 over 1985-2002) for BTS estimates and 1.95 times higher (range 1.46-2.57 over 1969-2002) (Figure 5.5). The absolute juvenile fishing mortality was higher using survey data to reconstruct discards than otolith back-calculations (Figure IV.3a). When assuming a 60 mm fishery the juvenile fishing mortality was higher for otolith back-calculations before the mid 1980's, but lower in recent period compared to survey estimates. Fishing mortality in the mid 1990's was estimated to be as high as in the early 1980's. In the late 1990's, fishing mortality showed a sharp decrease and a strong increase again from 2000 onwards.

For many years age 1 fish were not reported in the landings. Therefore the approach could not be used for that age since the discard proportion cannot be applied to a non-existing landing. All age 1 fish were excluded from the assessments. The number of fish recruiting to the population at age 2 (Figure IV.3a, Table IV.10) was higher with discards included in the catch data (Figure 5.5). The recruitment was most sensitive to the assumption of a 60 mm mesh size. During the 1980's several strong year classes were observed in all three approaches, but most apparent with otolith back-calculations. In the 1990's only the strong 1996 yearclass stands out, but numbers recruiting were lower compared to the 1980's. With discards included and assuming an 80 mm mesh size fishery, the recruitment on age 2 was on average 4.34 times higher (range 1.32-12.5 over 1963-2002) for estimates from otolith back-calculations, 2.76 times higher (range 1.94-4.75 over 1985-2002) for BTS estimates and 2.37 times higher (range 1.82-3.47 over 1969-2002) (Figure 5.5).

Spawning stock biomass (Figure IV.3a, Table IV.11) was also higher when discards were included (Figure 5.5) Again, the sensitivity to including discards was especially noticeable for assumption of a 60 mm fishery, especially for otolith back-calculations. All three approaches showed a decline in spawning stock biomass from the beginning of the 1990's. During that period the influence of discards on the estimated spawning stock biomass also declined, caused by lower discard proportions during this period (Figure IV.2a and IV.2b). With discards included and assuming an 80 mm mesh size fishery, the spawning stock biomass was on average 1.52 times higher (range 1.04-3.51 over 1963-2002) for estimates from otolith back-calculations, 1.56 times higher (range 1.31-2.20 over 1985-2002) for BTS estimates and 1.49 times higher (range 1.19-1.99 over 1969-2002) (Figure 5.5).

Total stock biomass at age was investigated to explore the effects of including discards in more detail (Figure IV.3b). Differences in total biomass were found using each of the three approaches to derive discards estimates. The differences were most striking for years with strong year classes.

With discards included in the assessment, stock numbers and fishing mortality increased on the youngest ages. This resulted in higher recruitment to the population and to increased estimates of spawning stock biomass. The perception of stock trends could be markedly different with the inclusion of discards, especially in periods of high recruitment and associated low growth and high discard rates.

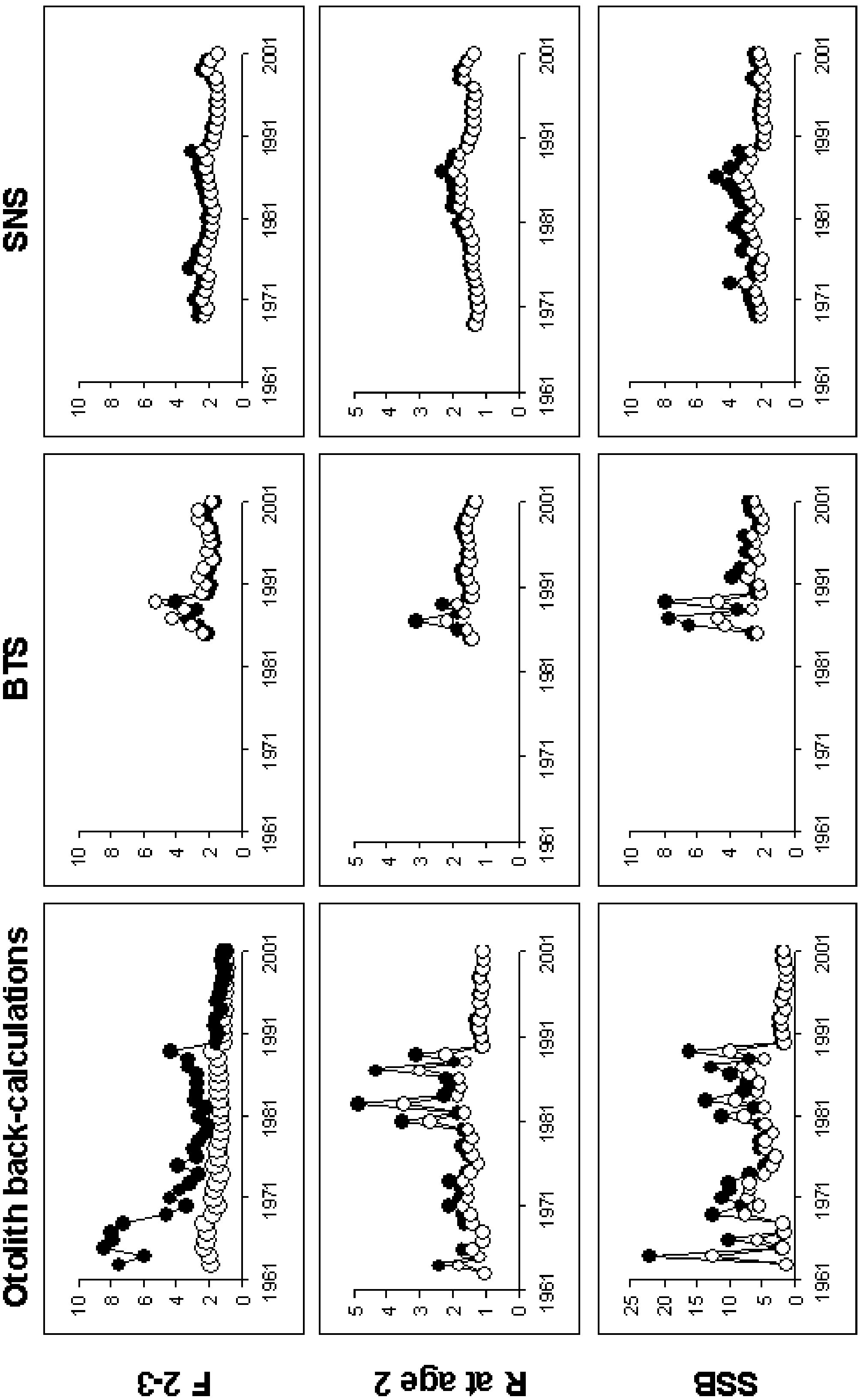

Figure 5.5. Results of F2-3, recruitment at age 2 and SSB from assessments with discards numbers-at-age included for 80 mm (white dots) and 60 mm (black dots) divided by results from assessments with only landings numbers-at-age included, for otolith back-calculations and BTS and SNS surveys.

6. Discussion

6.1 Discard sampling programmes

The percentage of plaice discarded appears to have increased in recent years compared to the 1970s and 80s. This could partly be caused by strong year classes (1996, 2001) in the recent sampling. The 2001 year class appears strong in the discard fraction during the discard trips and was also noticeable in the BTS and in lesser degree in the SNS survey indices. Direct comparisons with the previous strong yearclass (1996) cannot be made because the discard sampling programme only started in 1999 when the 1996 year class was already three years old. The effect of this year class was apparent in fish still being discarded in high numbers at the age of 5. The growth rate of fish from this year class was lower than the growth rate of previous year classes, which extends the period that fish are susceptible to discarding (ICES, 2002b, 2003b). Because of the high mortality rates of discards caught with beam trawls, the fishing mortality on under-sized fish from this year class was high and underestimated in the routine stock assessments that do not account for discards (ICES, 2003b). This may have resulted in a substantial overestimation of the plaice stock (ICES, 2003b).

Changes in plaice discards percentage in the recent period could also be caused by a decrease in landings of plaice, by gear alterations or by changes in fishing efficiency. Landings of plaice varied in weight between 42-81 kg per hour during 1999-2003 while during the 1970s and ‘80s this varied between 104-136 kg per hour. The length-frequency distributions over 1976-1990 showed more landings of larger plaice compared to recent period. Also the mean weight per fish landed showed a decrease in recent period (from 0.36 kg to 0.26 kg per fish landed). Gear-alterations like double cod-ends and liners could also result in a higher discard percentage. These gear alterations decrease the effective mesh size, making small plaice more vulnerable to the trawl. Changes in fishing efficiency could also have an effect on discarding. Since the late ‘70s the fishing speed has increased from 5-6 mile per hour to 7 mile per hour. The width of the beam increased from on average 10 m at the end of the 1970s to 12 m in the ‘80s. As a result the surface fished per hour increased by 30% (Van Beek, 1998). However, there does not appear to be an increase in discarding of sole, which is caught in the same fishery. This suggests that changes in efficiency or gear alterations are unlikely to be the major source for the increase in plaice discards.

Because of the high costs of sampling, it is only possible to sample a limited number of vessels each year. Only for the beam trawl vessels with engine power larger than 300 HP fishing with 80 mm mesh size, most of the North Sea was spatially covered. Coverage in effort of all trips made by the entire fleet was low (0.05%-0.12%). Discard sampling programmes in other countries also have to deal with low fleet coverage. The Scottish discard sampling programme, sampling seines and Demersal trawls, covered 0.1%-0.2% of the fleet annually (Stratoudakis et al., 1998), coverage of the French trawler fleet was 0.8% (Rochet et al., 2002), while the Irish discard sampling programme covered 0.3%, 4.1% and 3.5% of respectively the ottertrawl, beamtrawl, and Scottish seine fleet (Borges et al., 2003). Because of the limited number of trips sampled, variation can change greatly by including or excluding trips. This variation is caused by differences in spatial distribution of small fish in fishing areas, differences in efficiency, and differences in actual mesh size and net geometry. Stratoudakis et al. (1999) stated that high CVs (=standard deviation/mean) could be due to low sampling levels and large variability in discard rates, because of different areas fished and species targeted. Because cooperation with the discard sampling programme is on a voluntary basis, not all segments of the Dutch beam trawl fishery are sampled, possibly leading to a bias in the discard sampling programme. The best way to improve the precision of discard estimates is through increasing the level of sampling activity (Stratoudakis et al., 1999; Allen et al., 2002). Because variation between hauls within a vessel is low, and variation between vessels is larger than between trips made on one vessel, increasing the precision of the data could be enhanced by sampling more vessels instead of sampling more hauls within one vessel.

6.2 Discard mortality studies

The discard mortality studies reported in this report showed that several factors contribute to the mortality of discards during the catching and sorting process. The degree of damage and the survival depend on haul duration, fishing gear, engine power and duration of deck exposure. The survival of plaice decreased with longer haul duration, indicating that mortality factors working in the cod-end are a dominant factor. A survival experiment performed on discards in the Dutch twinrig fishery showed low surviving numbers, which was assumed to be caused by a long haul duration, which was on average two times as long as in the beam trawl fishery. (Van Keeken et al., 2004). Irrespectively of haul duration, Van Beek et al. (1990) concluded that also the number of tickler chains had effect on the survival of discards through inflicting injuries.

Average survival of plaice discards in recent years is not investigated, but assumed to be as low as seen in the discard survival study by Van Beek et al. (1990). Lower survival of plaice in the larger vessels (De Veen et al. 1975) and higher survival of plaice in the ottertrawl (Van Beek et al. 1990) indicate that fishing speed is also an important factor, which amplifies the mechanical damage inflicted during the stay in the trawl. During the 1970's and 80's most larger beam trawl vessels were between 300 and 1500 HP, while in recent years the majority of the large vessels have engine power of 2000 HP, thereby increasing the fishing speed (Van Beek, 1998; Rijnsdorp et al., 2000). Higher fishing speeds and heavy trawls could negatively affect survival.

Some factors that influence the survival of discards on deck have not been considered. Discards may be subjected to mechanical damage from the sorting process, damage from suffocation, from temperature differences and from desiccation. Before the use of conveyor belts, the catch was processed by hand. Van Beek et al. (1990) reported that the survival of discards was higher at haul durations of 6o minutes using conveyor belts, because the catch was kept wet and processed more quickly. However these differences were not found for 120 minute hauls, which is the average haul duration in the modern beam trawl fishery.

6.3 Changes in spatial distribution of plaice

During the last decades, a shift in spatial distribution of plaice towards deeper, more offshore water took place. Two different models were used to investigate changes in the spatial distribution of plaice. A linear model was used to analyse differences in log-transformed numbers over the water depth by year, and a logit model was used to analyse differences in the chance that plaice were abundant at water depths. Both models showed a clear shift of plaice towards deeper more offshore areas for all ages in the discard fraction. The only exception was for age 0 where the linear model was not significant although the raw data for this age does indicate a shift towards deeper water.

In 1989 the plaice-box was installed with the purpose of protecting the under-sized fish from fishing activities (Rijnsdorp and Van Beek, 1991; ICES, 1999). It was assumed that the distribution of plaice would not change over time (ICES, 1987). In a series of special surveys conducted in 1996, 1998 and 1999, there were strong indications however that plaice in the discard size classes were most abundant around the border (depth 25-30 m) of the plaice box (ICES, 1999). There are indications that during 2000-2002 the distribution of plaice shifted even more towards offshore areas compared to the end of the '90s (Figure III.1 to III.4 Appendix). In recent discard trips outside the plaice-box, the size of the smallest plaice caught (10-11 cm) corresponded to those lengths at which plaice was caught inside the plaice box during the 1970s and '80 (Van Beek, 1998). Two other assumptions related to the expected benefits from the plaice box were that all fisheries would be excluded from the plaice box and that no change would occur in growth rates of plaice (ICES, 1987). These assumptions did not stand. Eurocutters with an engine power less than 300 HP are still allowed in the plaice box (ICES, 1999; Pastoors et al., 2000) and this fleet component has increased in number of vessels. The growth rates of year classes between 1989-1994 and the strong 1996 year class showed a decrease, thereby reducing the expected positive effect of the plaice box (ICES, 1999; Pastoors et al., 2000).

6.4 Effects of plaice discards on stock assessment

Modelling growth and discard proportions

The results of the current investigations suggest that accounting for the variable bias caused by inter annual and cohort differences in growth will have an impact on the assessment of North Sea plaice, because it will result in different discarding practices. This in turn will affect the yield per recruit dynamics and hence any management advice based on reference points. The simulations suggests that ignoring discards in the stock assessment process may have a substantial impact under certain conditions while in other situations the impacts are much lower. The largest effects were found in combinations of strong yearclasses (high abundance) with low growth rate (long susceptibility). Whilst these findings are intuitive and follow those of Casey (1993), this is the first simulation to show these effects using a temporally resolved growth model based on field observations of growth.

There are many assumptions in this simulation. One assumption is that growth in plaice varies by year and cohort (i.e. separability exists in growth) which is based on observations that plaice growth is influenced by density, temperature and other factors that combine to give cohort and year effects (Rijnsdorp and Van Beek, 1991; Rijnsdorp and Leeuwen, 1992; Grift et al., 2003) The assumption that growth is linear in quarters 2 and 3 and zero during quarters 4 and 1 is not very realistic, but a simple approximation of the process. Other techniques for describing plaice growth (Grift et al., 2003) are being developed and may be suitable in future developments of this model.

The simulated discard numbers at age are dependent on assumed selection and sorting ogives. The selection ogive is extrapolated from Van Beek et al. (1981, 1983) and Rauck (1980). Rigorous testing of these ogives has not taken place and further investigations, over a range of gears and fishing behaviours, is required. The assumption of 80 mm mesh size is based on the minimum mesh size, but because of the use of gear alterations like double cod-ends and liners, it is questionable if this 80 mm selection ogive gives the actual L_{50} and L_{25} values for plaice. Therefore, the 60 mm mesh selection was included as an alternative scenario in the exercise. The assumption that all discarded fish die appears reasonable, given that the 10% survival rate observed by Van Beek et al. (1990) was only after 84 hours.

The growth models fitted the data reasonably well (Figure 5.4). However 8% of the data points were removed as outliers. Generally, these points were caused by low sampling of certain cohorts in a few years, some of which resulted in estimates of negative growth of a cohort between quarters. A sample size-weighted model could have been constructed to deal with this problem but the simpler method of removal of a few data points was thought preferable to maintain transparency of the methods.

Substantial differences existed between mean length at age obtained from otolith back-calculations and from the lengths measured on the surveys. These differences in mean length at age could be caused by Lee's phenomenon (Lee, 1912), which says that the marketable fish are a biased sample from the total population. Mean length at age from back-calculations were derived from marketable sized fish (above 27 cm), in other words "the survivors". Due to the high fishing pressure on plaice in the North Sea, the first fish that reach the marketable size are the fast growing individuals. Faster growing fish will get through the discard phase faster and will be landed at earlier ages than slow growing fish in the population. These fish may give an overestimation of the mean length at a certain age for the entire population (Lee-effect). The proportion discards, calculated from the mean length derived from otolith back-calculations, are therefore lower from age 3 and older compared to the survey derived estimates. The two survey series show broadly the same trends in length and proportion discarded.

The validity of the model was tested by comparing the estimates of proportions discarded from the model with those from the few available field observations. It appears that the method of back-calculation of growth rates from the otoliths results in an underestimation of discarding of fish younger than 3½ years of age (Figure IV.4). This is probably due to the overestimation of length at age, which was described above. Conversely, the survey method gives an overestimate of discarding in the older fish. This is probably due to the poor catching ability of large fish by surveys. Commercial trawls are required to use 80 mm cod-end mesh size or larger, while surveys use 40 mm cod-end mesh size and fish at slower speed. This could result in lower selection for the larger fish in the surveys (Pope, 1975). Fargo and Workman (1997) also found that mean lengths of four commercial species were significantly greater for the commercial vessel using 150 mm mesh sizes than for a research vessel using 87.5 mm mesh size (Fargo and Workman, 1997).

A major drawback of this approach is that the estimated numbers of discards at age can only be estimated from the available numbers of landings at age. Landings numbers for age 1 were small and during 1963-1968 and 1987-1988 even 0, while discard proportion at age 1 was sometimes very high. Adjusting catches of age 1 plaice for discards could lead to greater instability of the model and were therefore left out of the analysis. However the high proportion of age 1 fish discarded can have great impact on the number of fish recruiting to the population at age 1. The inclusion of age 1 discards in the assessment could potentially have a much larger influence on the assessment and on biological reference points than the study which is described here, which is limited to age 2 and older.

Stock assessment

The inclusion of discards in the assessment of North Sea plaice increases the perceived values of F on young ages, which is similar to reports by Casey (1993) and Dingsor (2001). The increase in $F_{(2\text{-}3)}$ is not constant over all years, thus reflecting the variable bias in the assessment. The coefficient of variation (CV; an indication for the variability in the data) in mean $F_{(2\text{-}3)}$ over the time series was reduced by 2-7% by including discards. The CV in the estimated recruitment time series (age 2) increased. The variability in discarding proportions appears to have little effect on the estimated recruitment after 1991 (Figure IV.3a), suggesting that discarding only plays an important role in biasing the assessment when recruitment is high, e.g. at age 2 in 1965, 1981, 1983 and 1987. Higher recruitment of these strong year classes affects discarding, not only because more young fish are vulnerable to the fishery, but also because slower growth of fish from these strong year classes will extend the discard phase.

Strong year classes also biased the estimates of SSB (Appendix IV: Figure IV.3a), but the adjustment for variable discarding had less effect on the estimates of SSB when recruitment was around average. Closer examination of the numbers at age showed that it were the numbers of age 2 and age 3 fish that were changed by the inclusion of discards (Figure IV.3b). It appears that in terms of describing the basic stock dynamics and considering the role of growth, discarding mainly impacts on our perception during periods of high recruitment.

Preliminary analysis has been carried out regarding the effects of including discards on biological reference points. Recruits per SSB were higher when discards were included. Effect on recruits per SSB was most sensitive to the assumption of a 60 mm fishery. With discards included, recruits per SSB were also more variable, which was caused by the higher recruitment and the higher SSB. The results were similar to findings by Casey (1993) for Irish Sea plaice.

We conclude that this study constitutes a useful exploration of the potential consequences of including discards on the stock assessment of North Sea plaice, a species where discarding may be a serious problem because of the mesh size that is used in the fishery. The approach, which is developed here, has as a major drawback that the discards of the 1-group plaice could not be included, while this age group is a dominant part of the discards. Further work on the inclusion of 1-group discards is imperative. Preferably the modelling approach should be mirrored by direct observations from fishing vessels to validate the model predictions of discards.

7. Conclusions

- In recent years, the plaice discard percentages and absolute discard rates appear to have increased compared to the 1970s and '80s.
- During the last decades a shift in spatial distribution of juvenile plaice took place towards deeper, more offshore waters, resulting in more juvenile plaice becoming vulnerable to the fishing gear.
- Compared to proportion discards from onboard observations, the method of back-calculation of growth rates from the otoliths results in a smaller estimates of discarding of fish younger than 3 years, while the survey method gives a larger estimate of discarding in the older fish.
- Accounting for the variable bias caused by inter annual and cohort differences in growth, has an impact on the assessment of North Sea plaice, because the growth rate affects the discard rate.
- The inclusion of discards in the assessment of North Sea plaice increases the perceived values of F on young ages, and leads to higher recruitment estimates and slightly higher SSB estimates.
- The inclusion of discards in the assessment of North Sea plaice is most important for strong year classes when growth rate is reduced.
- The method used did not account for discards of the 1-group plaice, which is a dominant part of the discards. Further work on the inclusion of 1-group discards is imperative.

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Appendices

Appendix I: Methodology

Appendix I.1: Raising methodology 1999-2003

Appendix I.2: Simulation of discards

Appendix II: Result discard sampling programmes

Appendix III. Changes in spatial distribution of plaice

Appendix IV. Results simulation of discards

Appendix I: Methodology

Appendix I.1: Raising methodology 1999-2003

Table I.1.1. Explanation of the abbreviations used in the formulas in appendix **I.**

	explanation	subscript	explanation
n	sampled number	l	length
N	total number	h	haul
w	sampled weight	o	hour
W	total weight	t	trip
v	sampled discards volume	p	period (either quarter or year)
V	total discards volume	y	year
u	sampled duration	s	species
U	total duration		
wt	sampled landings weight		
WT	total landings weight		
e	sampled fleet effort		
E	total fleet effort		
T	Number of trips		
DN	total discard number		
LN	total landings number		
CN	total catch number (landings and discards combined)		

Raising discards per trip

The sampled number per length and haul were raised per species to total number per length and haul

$$DN_{l,h,s} = \frac{V_h}{v_h} Dn_{l,h,s} \tag{1}$$

where $DN_{l,h,s}$ is the total number discarded at length (l) in haul (h) for species (s), V_h is total volume of haul (h), v_h is sampled volume of haul (h) and $Dn_{l,h,s}$ sampled number discarded at length (l) in haul (h) for species (s).

The total number discarded at length per haul and species was summed over the sampled hauls to obtain the total sampled number discarded at length (l) for species (s) over all sampled hauls (h). The total number discarded ($DN_{l,t,s}$) at length (l) per trip (t) and species (s) was calculated by multiplying the total number discarded ($DN_{l,h,s}$) over all sampled hauls with the ratio of total trip duration *(U_t)* and duration of all sampled hauls *(Σu_h)*:

$$DN_{l,t,s} = \frac{U_t}{\sum u_h} \sum_{h=i}^{h} DN_{l,h,s} \tag{2}$$

The number discarded at length per hour and species ($DN_{l,o,t,s}$) was calculated by dividing the total number at length per trip ($DN_{l,t,s}$) by total trip duration *(U_t)*.

$$DN_{l,o,t,s} = \frac{DN_{l,t,s}}{U_t} \tag{3}$$

The obtained number discarded at length per hour ($DN_{l,o,t,s}$) was summed over length to obtain the number discarded per hour ($DN_{o,t,s}$):

$$DN_{o,t,s} = \sum_{l=i} DN_{l,o,t,s} \tag{4}$$

Discarded weight per hour per species at length was calculated using length-weight relationships:

$$DW_{l,o,t,s} = \sum_{l} \left(\frac{DN_{l,o,t,s} * A_s * l^{Bs}}{U_t} \right) \tag{5}$$

where $DW_{l,o,t,s}$ is the weight per length, per hour and per species, $DN_{l,o,t,s}$ is the number discarded at length, per hour and per species and A_s and B_s species specific constants.

The variance over the total weight of all discards combined per trip $VAR(DW_y)$ was calculated per year (Anon. 2003):

$$Var(DW_y) = \sum_{t} VAR(DW_{t,y}) \tag{6}$$

where $DW_{t,y}$ is the total weight of all discards in a trip.

Second the variance over the total weight per species per trip $VAR(DW_{y,s})$ was calculated per year:

$$Var(DW_{y,s}) = \sum_{t} VAR(DW_{t,y,s}) \tag{7}$$

where $DW_{t,y,s}$ is the total weight of a species discarded in a trip.

Raising landings per trip

The sampled number landed at length per haul and species ($Ln_{l,h,s}$) were summed over all sampled hauls (*h*) to calculate the sampled number at length for the trip ($n_{l,t,s}$). The total number landed at length for the entire trip ($LN_{l,t,s}$) was calculated by multiplying the sampled number at length for the trip ($Ln_{l,t,s}$) with the ratio of total trip weight obtained from auction or VIRIS data ($WT_{t,s}$) to sampled landings weight of the trip ($wt_{t,s}$):

$$LN_{l,t,s} = \frac{WT_{t,s}}{wt_{t,s}} \left(\sum_{h=i}^{h} Ln_{l,h,s} \right) \tag{8}$$

Number landed at length per hour per species ($LN_{l,o,t,s}$) was calculated by dividing total number landed at length per trip ($LN_{l,t,s}$) by the trip duration *(U_t).*

$$LN_{l,o,t,s} = \frac{LN_{l,t,s}}{U_t} \tag{9}$$

The obtained total number at length per hour ($LN_{l,o,t,s}$) was summed to calculate number per hour per species ($LN_{o,t,s}$):

$$LN_{o,t,s} = \sum_{l=i} LN_{l,o,t,s} \tag{10}$$

Total landings weight per hour ($LW_{o,t,s}$) was calculated per species by dividing total landings weight ($WT_{t,s}$) per species by total trip duration (U_t).

$$LW_{o,t,s} = \frac{WT_{t,s}}{U_t} \tag{11}$$

Numbers at length, per quarter and year

The number of discards and landings (*$CN_{l,o,p,s}$*) at length per hour was calculated per quarter/year by summing the total number landings or discards at length per trip (*$CN_{l,t,s}$*) over all trips in that period (p) and then dividing this by the sum of the duration of all trips *(U_t)* in this period:

$$CN_{l,o,p,s} = (\sum_{p} CN_{l,t,s}) / \sum_{p} U_t \qquad (12)$$

Confidence limits around length-frequency distributions show weighted standard deviation (*$VAR(CN_{l,o,p,s})$*):

$$VAR(CN_{l,o,p,s}) = \sqrt{\left[\left(T_t / (T_y - 1)\right) * \frac{\sum_{l} \left[(N_{l,o,t} - N_{l,o,y})^2 * (U_t)^2 \right]}{U_y} \right]} \qquad (13)$$

where T_y is the number of trips per year, $N_{l,o,t}$ the number at length per hour and trip, $N_{l,o,y}$ the number at length per hour and year, U_t trip duration and U_y total duration over all sampled trips in the concerning year (Sokal & Rohlf, 1981).

Total numbers discards or landings (*$CN_{o,p,s}$*) were calculated by summing over length. Trip duration data was excluded from calculation numbers per hour per period if landings were not measured during a trip, but auction records existed for this species.

$$CN_{o,p,s} = \sum_{l=i} CN_{l,o,p,s} \qquad (14)$$

Appendix I.2: Simulation of discards

Landings numbers at age were corrected for discards using a simulated discard proportion at age, which was estimated from a simulated population based on a normal distribution depending on growth information, a selection ogive and a sorting ogive.

Growth estimates

The distribution of length within an age group in a population was described as a normal distribution, using mean and standard deviation of length at age (Sokal and Rohlf, 1981). Estimates of mean and standard deviation of length at age were obtained from two sources: (1) back-calculations of otoliths collected from commercial landing and (2) research vessel surveys.
Back-calculations were carried out on otoliths (n=2,340) collected from 1st quarter (January-March) commercial landings of female plaice from the Southern North Sea between 52˚ and 54˚N and 1˚ and 4˚E (Rijnsdorp and Leeuwen, 1992). Individuals older than 16 years or larger than 60 cm were excluded from the analysis because the relationship between otolith width and body size could only be determined for the length range of 8-60 cm. Examination of separate growth curves of male and female plaice showed growth rates to be similar for ages 1-4 (ICES 1999). To maintain the simplicity of the model, dimorphic growth differences for ages 5 and 6 were not accounted for.
Otolith back-calculations were carried out over the years 1963-2002. This means that growth rates could be estimated up to the 2000 yearclass. The mean lengths of the 2001 yearclass were approximated as the average length over the 3 previous years (1997-1999).
Two research vessel surveys were used as a secondary source of growth information: the Beam Trawl Survey (BTS) and the Sole Net Survey (SNS). Both surveys are carried out in the third quarter of the year. The BTS was initiated in 1985 and is directed at indices of abundance up to age 10. The survey is conducted with a trawl with a 40 mm mesh cod-end and is based on 1-4 pseudo-random hauls per ICES rectangle (Anon., 2003). The Sole Net Survey (SNS) is directed towards the younger flatfish (ages 0-3). This survey was initiated in 1969 and is based on 10 fixed transects (parallel or perpendicular to the coastline) along the Dutch, German and Danish coast. The position of stations within a transect is chosen such that the entire depth-range of the transect is covered (Anon., 2003).

Population estimates

Quarterly populations were simulated using a normal distribution (Sokal and Rohlf, 1981; Casey, 1993):

$$P_{alqy} = \frac{1}{\sigma_{aqy}\sqrt{2\pi}} e^{\left\{-\frac{1}{2}\left[\frac{\left\{L+\frac{1}{2}\right\}-\mu_{qya}}{\sigma_{aqy}}\right]^2\right\}} \quad (15)$$

where P_{al} is proportion of a length group (l) at age (a) in a population per quarter (q) and year (y), μ_{aqy} is mean length at age per quarter (q) and year (y), σ_{aqy} is standard deviation of length at age (a) per quarter (q) and year (y) and L is length group.
Mean length at age was modelled for each year using a GLM (SAS Institute Inc, 1999):

$$\text{Length}_{aj} = \mu + \text{Age}_a + \text{Ycls}_j + \varepsilon_{aj} \quad (16)$$

where $Length_{aj}$ is length at age (a) for yearclass (j), μ is the overall mean of all observations, Age_a is the effect of age (a), $Ycls_j$ is the effect of yearclass (j) and ε_{ijk} is independent $N(0,\sigma^2)$.

The GLM was applied to the back-calculated otolith data and the survey data separately. Observations with residuals of the model larger than 2.5 or smaller than –2.5 were removed to reduce the influence of outliers on the model (on advice of (Manly, 2001). Fish growth was assumed to take place from the beginning of the second quarter to the end of the third quarter. It was further assumed that 50% of the annual growth occurred during the second quarter and 50% during the third quarter. Therefore the mean and standard deviation of length at age *a* in quarter 1 and year *y* were the same as the mean length for age group *a*-1 in quarter 4 and year *y*-1. Estimates of standard deviations for quarter 2 were calculated as average of standard deviations from quarter 1 and quarter 3.

Selection ogive

Selection experiments have been performed by (Van Beek et al., 1981, 1983) and (Rauck, 1980) (Table I.2.1). (Van Beek et al., 1981, 1983) found no significant relationship between mesh size and selection factor. The selection factor was taken as mean over the experiments, which was 2.2. The selection range was calculated as mean over the selection ranges taken from the experiments performed, which was 3.0 cm.

Table I.2.1. Mesh size, selection factor and selection range for North Sea plaice

Author	Year	Mesh size (mm)	Selection factor	Selection range (mm)
Van Beek et al.	1981	90.4	2.1	32
Van Beek et al.	1981	109.1	2.1	35
Van Beek et al.	1981	122.3	2.08	56
Van Beek et al.	1981	137.2	2.19	54
Van Beek et al.	1983	118.4	2.35	26
Van Beek et al.	1983	107.9	2.29	26
Van Beek et al.	1983	121.2	2.31	38
Van Beek et al.	1983	107.9	2.32	30
Van Beek et al.	1983	122.6	2.37	31
Van Beek et al.	1983	107.8	2.27	35
Rauck	1980	62.4	2.16	
Rauck	1980	62.4	1.88	
Rauck	1980	62.4	1.83	
Rauck	1980	62.4	2.15	

For this calculation, selection ranges derived from experiments with mesh size larger then 120 mm were excluded. The L_{50} (length at which 50% of the fish that enters the net is retained by the meshes) was calculated as the mesh size multiplied by the selection factor (Pope, 1975; Wileman, 1991). The L_{25} (length at which 25% of the fish that enters the net is retained by the meshes) was calculated as the L_{50} minus the selection range divided by 2. The L_{50} and L_{25} were calculated for 80 mm and 60 mm mesh size (Table I.2.2). The minimum mesh size, which is allowed for beam trawling in the southern North Sea is 80 mm. The selection characteristics of 60 mm mesh size was explored, because there are indications that liners are regularly used by commercial beam trawlers, which may substantially reduce the effective mesh size. The value of 60 mm was not based on a quantitative analysis of selection experiments but rather as a reasonable guesstimate.

Table I.2.2. L_{50} and L_{25} values for selection ogive

Mesh size	Selection factor	L_{50}	L_{25}
80 mm	2.2	17.4	15.9
60 mm	2.2	13.0	11.5

The proportion of the population in a length group entering the net and are retained by the gear was assumed to be constant over the years. The proportion of fish of a length group within an age group that are retained by the gear was calculated using a selection ogive (Sparre and Venema, 1989)

$$\Pr_l = (1/(1+EXP^{(S1-(S2*l))})) \tag{17}$$

$$S1 = L_{50} * LOG(3)/(L_{50} - L_{25}) \tag{18}$$

$$S2 = S1/L_{50} \tag{19}$$

where Pr_l is proportion of the population in a length group (l) that enter the net and are retained by the gear, L_{50} is length for which the proportion of fish retained is 50% of those at that length that entered the net, L_{25} is length for which the proportion of fish retained is 25% of those at that length that entered the net, and l is length group.

Sorting ogive

Estimates of DL_{50} and DL_{25} were derived from discard sampling trips carried out in 1982-1983 and 1989-1990 (Van Beek, 1998) and 1999-2002 (Netherlands Institute for Fisheries Research unpublished data). No estimates of DL_{50} and DL_{25} were available for the periods before 1982, between 1984-1988 and 1991-1998. No trends were apparent in the DL_{50} and DL_{25} from the years sampled. For all periods, the DL_{50} and DL_{25} values were assumed to be constant and calculated as average over the periods from which the DL_{50} and DL_{25} were available (Table I.2.3). The proportion of fish landed from a length group within an age group that was retained by the net was calculated using a sorting ogive (Sparre and Venema, 1989):

$$Pl_l = (1/(1+EXP^{(S1-(S2*l))})) \tag{20}$$

$$S1 = L_{50} * LOG(3)/(DL_{50} - DL_{25}) \tag{21}$$

$$S2 = S1/DL_{50} \tag{22}$$

where Pl_l is proportion of the population in a length group that were retained and landed, DL_{50} is length for which the proportion of fish discarded is 50% of those at that length that are caught and DL_{25} is length for which the proportion of fish discarded is 25% of those at that length that are caught.

Table I.2.3. DL_{50} and DL_{25} values for sorting ogive

Period	**L50**	**L25**
1982-1983	27.1	25.9
1989-1990	27.2	26.2
1999	26.9	26.1
2000	26.6	25.9
2002	26.8	26.1
Average	27.0	26.0

The proportion of fish caught discarded at length (Pd_l) was calculated as:

$$Pd_l = 1 - Pl_l \tag{23}$$

Catch at age and discards at age

The proportion of the catch of age *a* that is landed (Pl_a), was calculated as:

$$PL_a = \sum_l P_{la} Pr_l Pl_l \tag{24}$$

where P_{la} is the proportion of a length group within age *a* in the population , Pr_l is the proportion of the population in a length group that are retained by the gear and Pl_l is the proportion of the retained fish that are landed

The catch at age (CN_a) were then calculated from the landings at age (LN_a) as:

$$CN_a = LN_a / Pl_a \tag{25}$$

and the discards at age were calculated as:

$$DN_a = CN_a - LN_a \tag{26}$$

Catch weight at age

When using catch numbers rather than landings numbers at age, the catch weights at age should also be based on both landings and discards weights. Fish weights were not available from direct observation and were obtained by applying a generic length-weight relationship (Coull et al., 1989):

$$W_L = \gamma * (L)^{\delta} \tag{27}$$

where *W* is weight of a fish at length (L) , γ is constant (0.0082) and δ is constant (3.026). This relationship was applied irrespective of age.

When using catch numbers at age comprising of discard and landings numbers, the weight at age matrix was corrected for difference in catch weight:

$$CWA_{ay} = \frac{CW_{ay}}{LW_{ay}} * LWA_{ay} \quad (28)$$

where CWA_{ay} is the calculated catch weight at age a in year y to be used in the new assessment and LWA_{ay} is the landings weight at age a in year y in the traditional ICES assessment. CW_{ay} and LW_{ay} are the catch weight and landings weight at age a in year y calculated from the mean lengths in the modelled population and the length-weight relationship.

Catch weights at age (CW_a, from discards and landings) from the modelled population were calculated as:

$$CW_{ay} = \sum_l (PC_{lay} * W_{la}) / (\sum PC_{lay}) \quad (29)$$

where CW_{ay} is catch weight at age (a) in year (y), W_{la} is the weight at length l and age a and PC_{lay} is the proportion of the catch of a length group (l) at age (a) in year (y).

Landings weights at age from the modelled population were calculated as:

$$LW_{ay} = \sum_l (PL_{lay} * W_{la}) / (\sum PL_{lay}) \quad (30)$$

where LW_{ay} is landings weight at age *a* in year y, W_{la} is weight at length l and age a and PL_{lay} is the proportion of the landings of a length group l at age a in year y.
Plaice discards mainly occur up to age 6. The catch weight at age matrix was therefore only corrected for discards and landings up to age 6. For this analysis is assumed that all discarded fish die.

Stock assessment
The influence of including discards estimates on the assessments were investigated using XSA (Darby and Flatman, 1994) maintaining all the settings (Table I.2.4) as for the latest plaice assessment carried out by WGNSSK in 2002 (ICES, 2002b).
For many years age 1 fish were not reported in the landings. Therefore the approach could not be used for that age since the discard proportion cannot be applied to a non-existing landing. All age 1 fish were excluded from the assessments, which may introduce a slight bias in the results.
For each of the three sources of growth data (otolith back-calculations (1963-2001), BTS (1985-2001) and SNS (1969-2001)), three assessments were carried out:

- landings numbers at age and landings weight at age
- catch numbers at age and catch weight at age , using a selection ogive for an 80 mm mesh
- catch numbers at age and catch weight at age using a selection ogive for a 60 mm mesh (accounting for the potential effects of liners in the net).

Table I.2.4. Assessment settings for North Sea plaice in 2002**.**

First tuning year	1982, (BTS 1985)
Last tuning year	2001
Time series weight	no taper
Catchability dependent on stocksize for age<	2*
Catchability independent of age for ages>=	10
Survivor estimates shrunk towards the mean F	5 years / 5 ages
s.e. of the mean	0.5
Minimum standard error for pop estimates	0.3
Prior weighting	NL Beam trawl=0
	UK Beam trawl=0
	BTS=1
	SNS=1

* Age 1 fish were excluded from the assessment runs.

Appendix II: Result discard sampling programmes

Table II.1. Average number and weight landed (L) and discarded (D) by species per hour and average discard percentage (%D) for all discard trips combined over 1976-1990**.**

	number			weight		
species	**L**	**D**	**% D**	**L**	**D**	**% D**
plaice	296	312	51	110	40	27
sole	124	24	16	26	3	10
dab	23	1005	98	6	69	92
turbot	3	<1	12	5	<1	4
brill	2	<1	21	2	<1	8
lemon sole	1	2	72	<1	<1	41
flounder	4	14	78	2	4	71
long rough dab	0	3	100	0	<1	100
witch	0	<1	100	0	0	100
scaldfish	0	7	100	0	<1	100
solenette	0	8	100	0	<1	100
cod	15	22	59	15	4	22
whiting	15	70	82	4	9	68
haddock	1	<1	27	1	<1	9
bib	<1	8	94	<1	1	81
poor cod	0	3	100	0	<1	100
herring	0	1	100	0	<1	100
sprat	0	1	100	0	<1	100
twaite shad	0	<1	100	0	<1	100
mackerel	0	<1	100	0	<1	100
horse mackerel		2		<1	<1	94
monk		<1		<1	<1	4
grey gurnard	<1	47	100	<1	3	99
tub gurnard	1	2	55	<1	<1	27
sandeel	0	2	100	0	<1	100
gt sandeel	0	<1	100	0	<1	100
dragonet	0	18	100	0	1	100
hooknose	0	5	100	0	<1	100
lesser weever	0	4	100	0	<1	100
four-bearded rockling	0	<1	100	0	<1	100
bull rout	0	<1	100	0	<1	100
red mullet	0	<1	100	0	0	100
dogfish	0	<1	100	0	<1	100
spurdog	<1	<1	27	<1	0	5
starry smooth-hound	0	<1	100	0	<1	100
roker/thornback ray	<1	1	100	<1	<1	99
rays not identified	<1	<1	28	<1	<1	5

Table II.2. Number of fish discards per hour by species for beam trawl vessels >300 HP and Eurocutters for 1999 to 2001**.**

	Beam trawlers > 300 HP			Eurocutters	
Species	**1999**	**2000**	**2001**	**2000**	**2001**
Dab	2192	1066	1712	351	403
Plaice	176	530	1023	207	193
Whiting	78	141.2	47	22	21
Grey gurnard	179	113	126	16	1
Solenette	200	104	87	27	6
Dragonet	35	67	44	45	4
Haddock	<1	44	<1	1	<1
Scaldfish	86	36	40	16	4
Long rough dab	9	26	3		
Sole	15	25	12	26	44
Lemon sole	3	21	6	2	<1
Starry ray		15	17		
Lesser weever	87	12		4	1
Greater sand-eel	23	9	12	3	4
Sprat		5	1	<1	<1
Hooknose	2	5	7	1	2
Cod	1	5	<1	3	<1
bib	2	4	<1		
Five-bearded rockling		4	3		<1
Witch	6	3	6		
Ammodytidae	<1	2	16	7	2
Four-bearded rockling	2	2			
Horse mackerel	2	2	<1	1	
Tub gurnard	<1	2		20	
Herring		2	3	<1	<1
Bull-rout	<1	1	7	<1	2
Striped red mullet	6	1		<1	
Spotted ray	<1	<1			
Three-bearded rockling		<1			
Poor cod	2	<1		<1	
Turbot	1	<1	<1	1	6
Flounder		<1	<1	7	83
Blonde ray		<1			
Sea-snail		<1			
Brill		<1		4	14
Myxine glutinosa		<1			
Pomatoschistus sp.		<1	2	<1	
Smelt	<1	<1			
Roker		<1	<1	<1	
Norwegian topknot		<1			
Garfish		<1			
Snake blenny		<1			
Norway pout	<1	<1			
Red gurnard		<1			
Mackerel	<1	<1			
Lesser spotted dogfish		<1	<1		
Gobius		<1			
Tope		<1			
Viviparous blenny		<1			

Table II.2. Number of discards per hour by species for beam trawl vessels >300 HP and Eurocutters for 1999 to 2001. Continuation from previous page.

	Beam trawlers > 300 HP			Eurocutters	
Species	**1999**	**2000**	**2001**	**1999**	**2000**
John Dorrey		<1			
Spurdog					
Anglerfish	<1		<1		
Eel	<1				
Twaite shad	<1		<1		<1
Reticulated dragonet			<1		
Syngnathidae			<1	<1	
Smoothhound			<1		
Spotted dragonet				<1	
Greater pipefish				<1	<1
Nilsson's pipefish				<1	
Number of trips	**3**	**13**	**4**	**2**	**1**

Table II.3. Numbers per hour discarded per species over 2002 in descending order. Fish species are shown on the left, other discards on the right of the table**.**

Species	Number	Species	Number
Dab	934	*Ophiura ophiura*	*811*
Plaice	825	*Macropipus sp.*	*532*
Whiting	104	*Asterias rubens*	*452*
Grey gurnard	44	*Astropecten irregularis*	*409*
Sole	31	*Pagurus bernhardus*	*309*
Solenette	29	*Corystes cassivelaunus*	*205*
Scaldfish	25	*Echinocardium cordatum*	*129*
Dragonet	18	*Ensis sp.*	*95*
Lesser weever	17	*Buccinum undatum*	*58*
Cod	11	*Aphrodita aculeata*	*37*
Red gurnard	10	*Psammechinus miliaris*	*22*
Hooknose	6	*Echinidae*	*20*
Bib	5	*Echinocardium cordatum*	*10*
Starry ray	5	*Ammodytes sp.*	*10*
Corbin's sandeel	4	*Asteronyx loveni*	*5*
Horse mackerel	4	*Spisula sp.*	*5*
Poor cod	4	*Alcyonidium diaphanum*	*4*
Lemon sole	2	*Ascidiacea*	*2*
Long rough dab	1	*Cancer pagurus*	*2*
Flounder	<1	*Flustra foliacea*	*2*
Norway pout	<1	*Alcyonium digitatum*	*1*
Striped red mullet	<1	*Lunatia*	*1*
Sea bass	<1	*Mactra corallina*	*<1*
Roker	<1	*Natica catena*	*<1*
Smelt	<1	*Anthozoa*	*<1*
Brill	<1	*Lunatia catena*	*<1*
Bull-rout	<1	*Aequipecten opercularis*	*<1*
Reticulated dragonet	<1	*Sepia officinalis*	*<1*
Herring	<1	*Arctica islandica*	*<1*
Mackerel	<1	*Hyas sp.*	*<1*
Sprat	<1	*Loligo sp.*	*<1*
Pelser	<1	*Neptunea antiqua*	*<1*
John dory	<1	*Lunatia alderi*	*<1*
Nilsson's pipefish	<1	*Luidia sp.*	*<1*
Twaite shad	<1	*Donax vittatus*	*<1*
Lesser spotted dogfish	<1	*Acanthocardia echinata*	*<1*
Four-bearded rockling	<1	*Nephrops norvegicus*	*<1*
Lumpsucker	<1	*Mytilus sp.*	*<1*
Starry smoothhound	<1	*Syngnathus sp.*	*<1*
Anglerfish	<1	*Ophiotrhix fragilis*	*<1*
		Demospongia sp.	*<1*

Table II.4. Numbers per hour discarded per species over 2003 in descending order for vessels >300 HP. Fish species are shown on the left, other discards on the right of the table**.**

Species	Number	Species	Number
Dab	1071	*Astropecten irregularis*	2643
Plaice	959	*Ophiura ophiura*	2354
Solenette	99	*Asterias rubens*	1577
Scaldfish	65	*Liocarcinus holsatus*	800
Grey gurnard	55	*Echinocardium cordatum*	495
Dragonet	46	*Corystes cassivelaunus*	386
Sole	32	*Anthozoa*	268
Whiting	32	*Macropipus sp.*	211
Lesser weever	14	*Pagurus bernhardus*	131
Hooknose	9	*Liocarcinus depurator*	129
Four-bearded rockling	6	*Pagurus sp.*	126
Tub gurnard	5	*Aphrodita aculeata*	85
Lemon sole	5	*Echinocardium sp.*	37
Ammodytes sp.	3	*Nephrops norvegicus*	31
Long rough dab	3	*Psammechinus miliaris*	27
Pomatoschistus sp.	2	*Buccinum undatum*	12
Greater sand-eel	2	*Crangon sp.*	12
Horse mackerel	2	*Liocarcinus marmoreus*	9
Striped red mullet	1	*Acanthocardia echinata*	8
Raitt's sand-eel	1	*Spisula sp.*	8
Sprat	1	*Ascidiacea*	7
Bull-rout	<1	*Lunatia alderi*	7
Herring	<1	*Lanice conchilega*	6
Flounder	<1	*Arctica islandica*	6
Five-bearded rockling	<1	*Cancer pagurus*	6
Red gurnard	<1	*Alloteuthis subulata*	2
Bib	<1	*Aequipecten opercularis*	2
Poor cod	<1	*Necora puber*	1
Lesser spotted dogfish	<1	*Mactra corallina*	1
Reticulated dragonet	<1	*Alcyonidium diaphanum*	<1
Norwegian topknot	<1	*Luidia sp.*	<1
Roker	<1	*Echinidae*	<1
Brill	<1	*Pilumnus hirtellus*	<1
Syngnathus sp.	<1	*Sepia officinalis*	<1
John Dory	<1	*Ensis sp.*	<1
Cod	<1	*Gele spons*	<1
Raja sp.	<1	*Portumnus latipes*	<1
Turbot	<1	*Loligo sp.*	<1
Mackerel	<1	*Eledone cirrhosa*	<1
Snake pipefish	<1	*Macropodia rostrata*	<1
Twaite shad	<1	*Donax vittatus*	<1
Garfish	<1	*Crangon crangon*	<1
Spotted ray	<1	*Thia scutellata*	<1
Blonde ray	<1	*Hagfish*	<1
Spotted dragonet	<1	*Nereis sp.*	<1
		Alcyonium digitatum	<1
		Atelecyclus rotundatus	<1

Table II.5. Numbers per hour discarded per species over 2003 in descending order for eurocutters. Fish species are shown on the left, other discards on the right of the table.

Species	Number	Species	Number
Plaice	334	*Ophiura ophiura*	4195
Dab	238	*Asterias rubens*	2743
Solenette	167	*Liocarcinus holsatus*	907
Greater sand-eel	41	*Astropecten irregularis*	316
Scaldfish	37	*Pagurus sp.*	262
Sole	29	*Corystes cassivelaunus*	125
Dragonet	28	*Echinocardium cordatum*	106
Grey gurnard	24	*Ensis siliqua*	60
Lesser weever	5	*Carcinus maenas*	15
Bull-rout	4	*Crangon crangon*	11
Flounder	3	*Lunatia catena*	11
Hooknose	3	*Hyas sp.*	4
Whiting	3	*Anthozoa*	3
Viviparous blenny	<1	*Cancer pagurus*	3
Lemon sole	<1	*Psammechinus miliaris*	2
Bib	<1	*Alloteuthis subulata*	1

Appendix III. Changes in spatial distribution of plaice

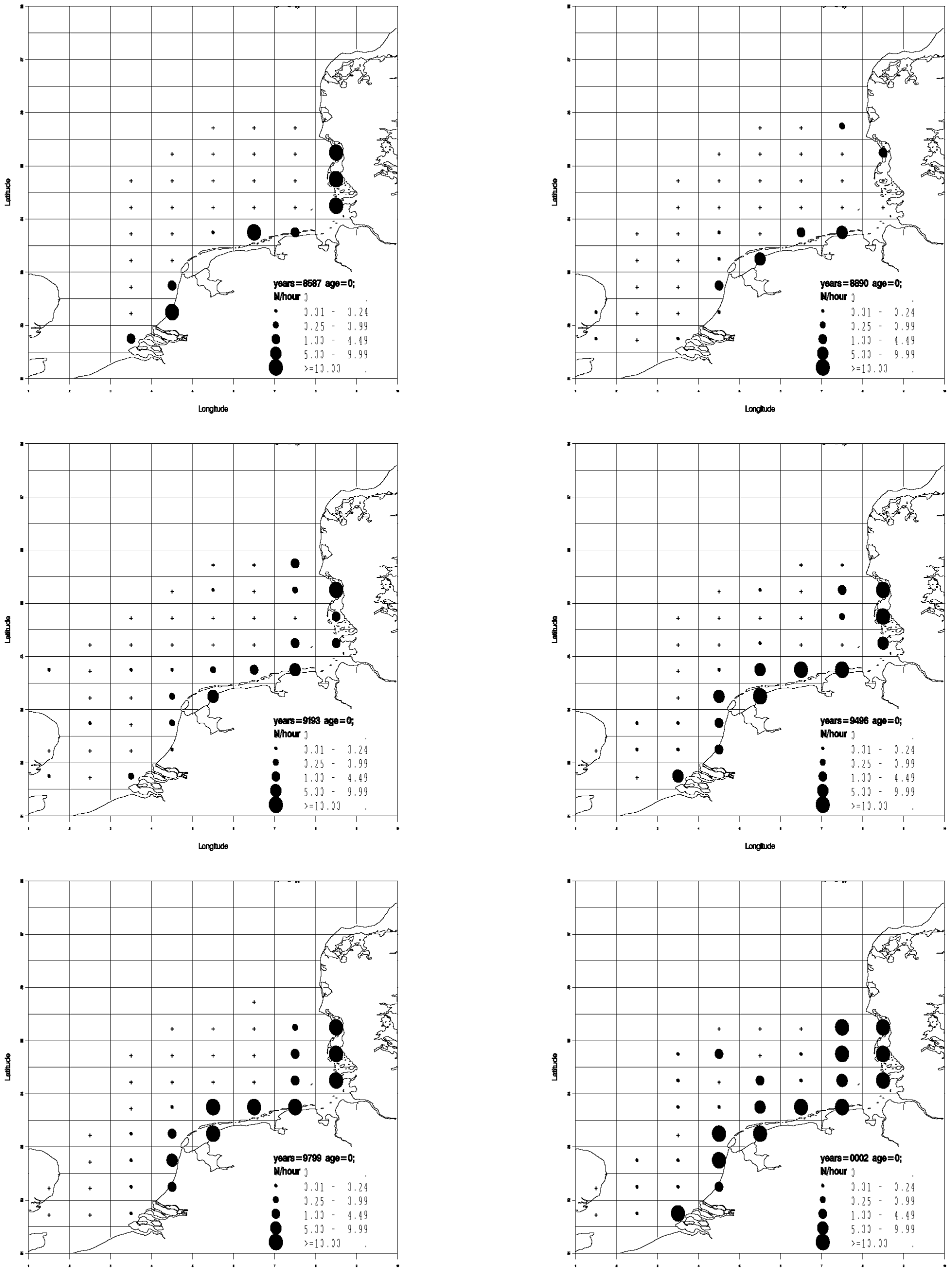

Figure III.1. Distribution of age 0 plaice per ICES rectangle in the North Sea averaged over 3 years during 1985-2002, expressed as number caught per hour**.**

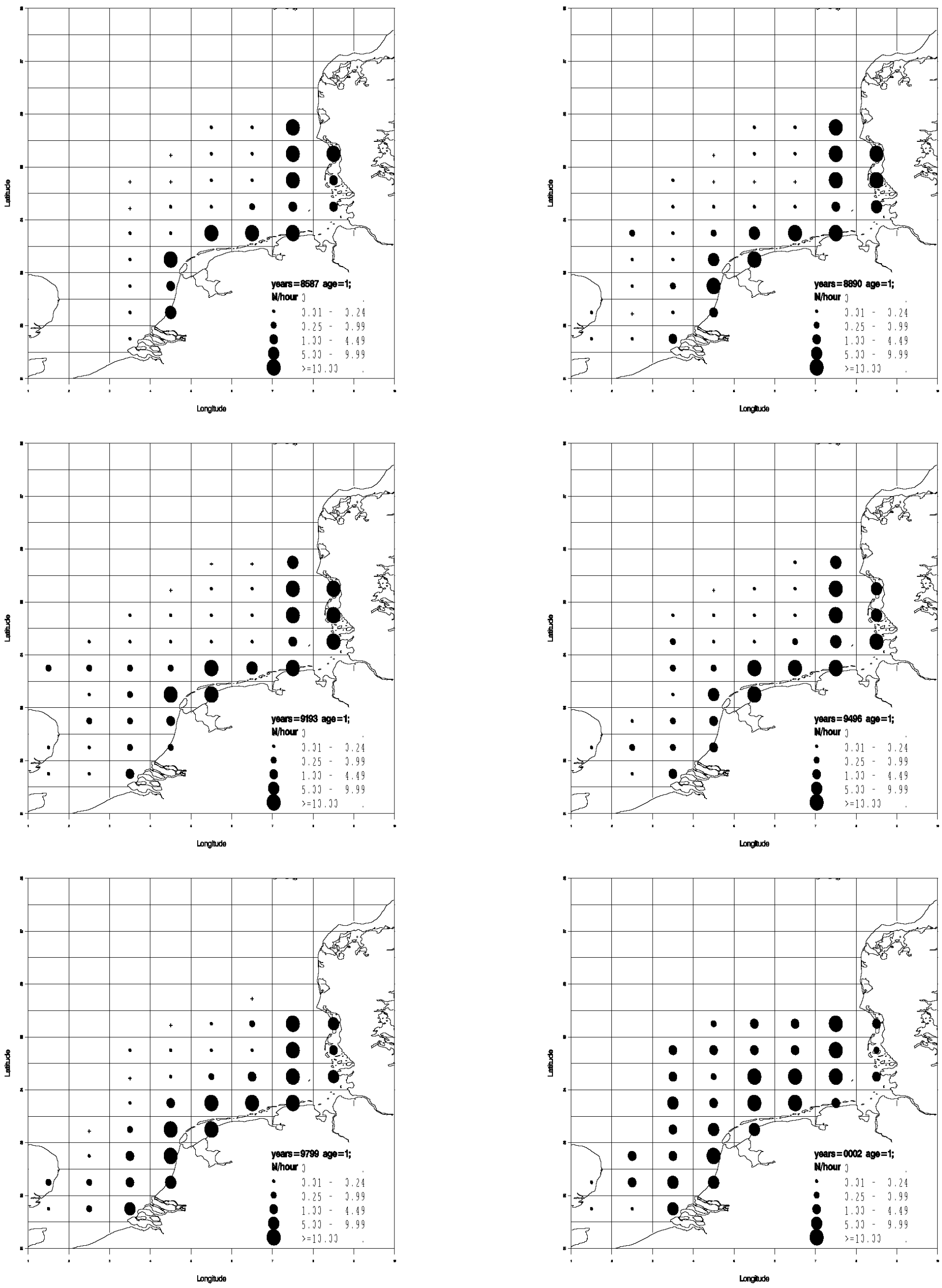

Figure III.2. Distribution of age 1 plaice per ICES rectangle in the North Sea averaged over 3 years during 1985-2002, expressed as number caught per hour**.**

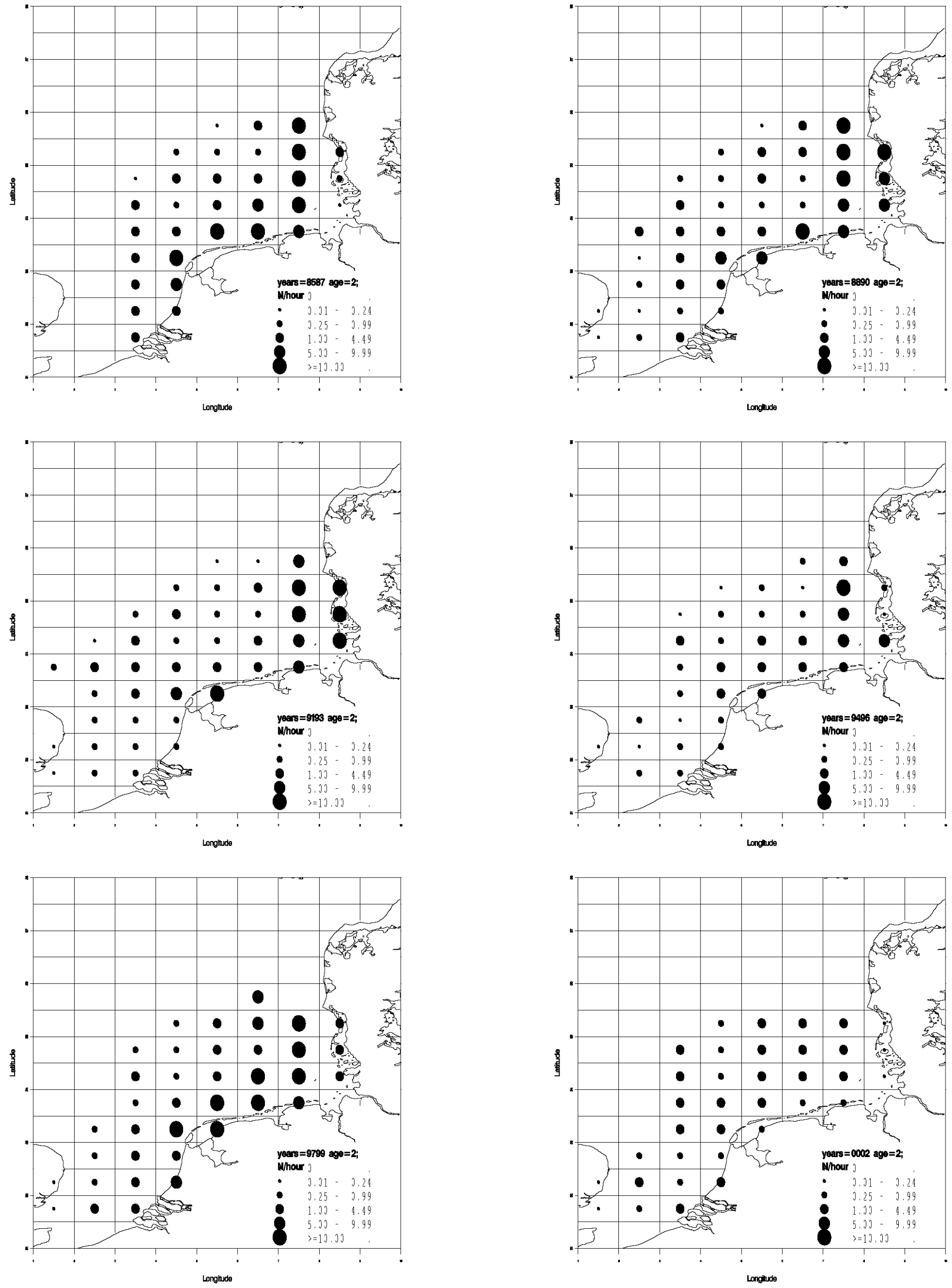

Figure III.3. Distribution of age 2 plaice per ICES rectangle in the North Sea averaged over 3 years during 1985-2002, expressed as number caught per hour**.**

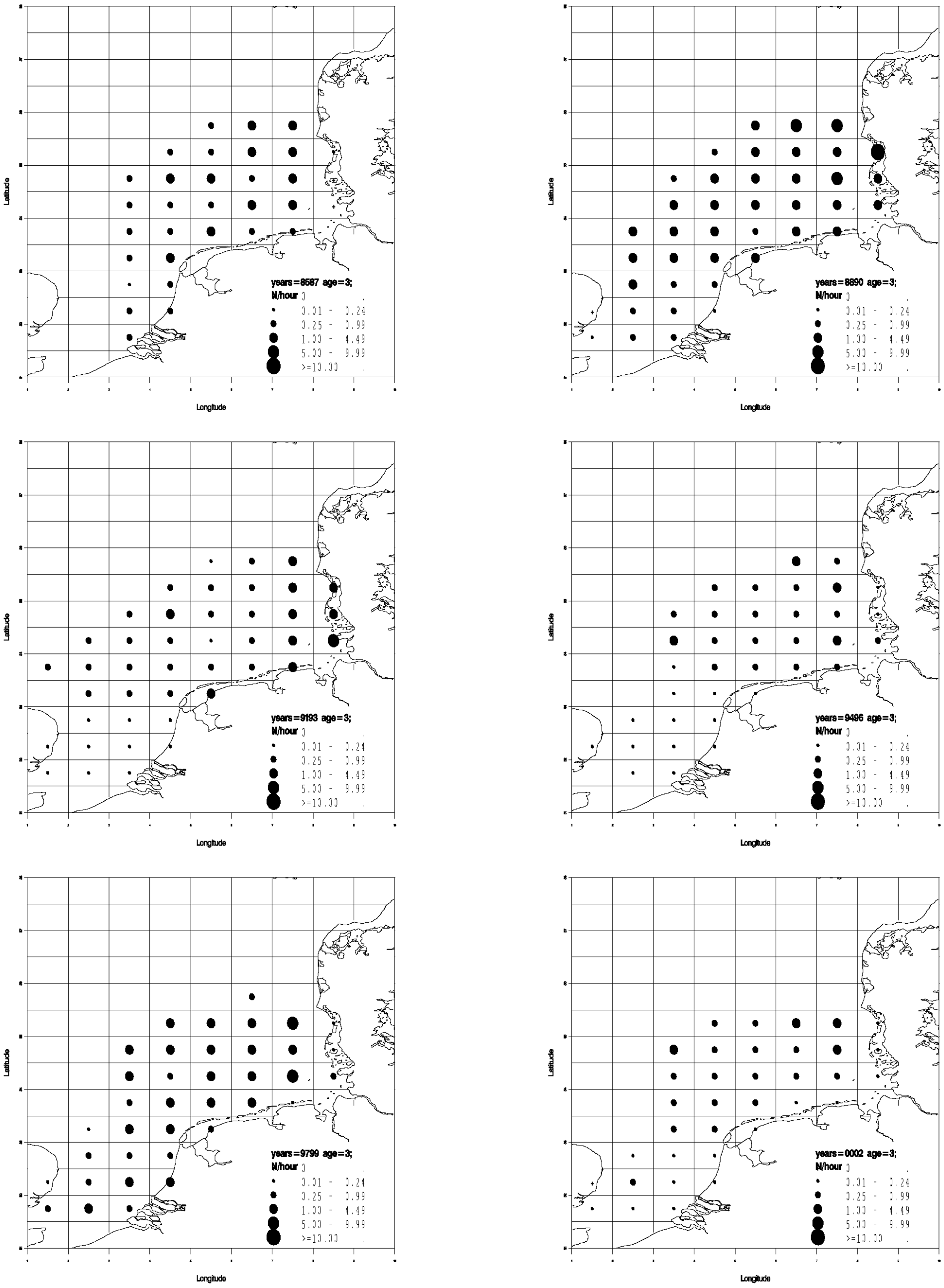

Figure III.4. Distribution of age 3 plaice per ICES rectangle in the North Sea averaged over 3 years during 1985-2002, expressed as number caught per hour**.**

Appendix IV: Simulation of discards

Table IV.1. Quarter 1. Modelled proportion discards per year and age for otolith back-calculations, BTS and SNS surveys using an ogive based on 80 mm mesh size.

	age 2			age 3			age 4			age 5			age 6		
year	otolith	BTS	SNS	otolith	BTS	SNS	otolith	BTS	SNS	otolith	BTS	SNS	otolith	BTS	SNS
1963	1.00			0.72			0.25			0.03			0.00		
1964	1.00			0.77			0.18			0.03			0.00		
1965	1.00			0.70			0.23			0.02			0.00		
1966	1.00			0.91			0.17			0.03			0.00		
1967	1.00			0.74			0.45			0.01			0.00		
1968	1.00			0.81			0.20			0.10			0.00		
1969	1.00		0.91	0.78		0.77	0.28		0.70	0.02		0.70	0.01		0.55
1970	1.00		0.93	0.66		0.72	0.24		0.62	0.04		0.52	0.00		0.55
1971	0.99		0.92	0.62		0.75	0.14		0.54	0.03		0.41	0.00		0.32
1972	0.99		0.90	0.61		0.73	0.12		0.59	0.01		0.32	0.00		0.22
1973	0.99		0.93	0.56		0.69	0.11		0.56	0.01		0.38	0.00		0.14
1974	1.00		0.93	0.56		0.76	0.09		0.51	0.01		0.35	0.00		0.19
1975	0.99		0.92	0.63		0.77	0.09		0.60	0.00		0.29	0.00		0.16
1976	0.98		0.90	0.53		0.74	0.12		0.61	0.00		0.39	0.00		0.12
1977	0.98		0.90	0.43		0.69	0.08		0.57	0.01		0.40	0.00		0.20
1978	0.98		0.89	0.44		0.70	0.04		0.50	0.00		0.36	0.00		0.21
1979	0.98		0.90	0.49		0.69	0.05		0.51	0.00		0.28	0.00		0.18
1980	0.98		0.92	0.41		0.70	0.06		0.50	0.00		0.29	0.00		0.12
1981	0.99		0.90	0.47		0.73	0.04		0.52	0.00		0.28	0.00		0.12
1982	0.99		0.90	0.56		0.70	0.06		0.56	0.00		0.30	0.00		0.11
1983	0.99		0.91	0.51		0.69	0.09		0.51	0.00		0.35	0.00		0.13
1984	0.99		0.93	0.59		0.73	0.07		0.51	0.00		0.29	0.00		0.16
1985	0.99	0.96	0.93	0.56	0.73	0.76	0.10	0.48	0.55	0.00	0.29	0.29	0.00	0.10	0.12
1986	0.99	0.99	0.94	0.53	0.71	0.76	0.09	0.49	0.60	0.01	0.29	0.33	0.00	0.12	0.12
1987	1.00	1.00	0.95	0.57	0.84	0.79	0.08	0.44	0.60	0.00	0.29	0.39	0.00	0.11	0.15
1988	1.00	0.99	0.95	0.65	0.86	0.80	0.09	0.58	0.65	0.00	0.20	0.39	0.00	0.09	0.20
1989	1.00	0.99	0.94	0.67	0.81	0.81	0.13	0.62	0.66	0.01	0.32	0.45	0.00	0.04	0.20
1990	0.99	0.99	0.91	0.66	0.85	0.78	0.15	0.62	0.67	0.01	0.45	0.47	0.00	0.14	0.26
1991	0.99	0.99	0.89	0.59	0.83	0.72	0.14	0.67	0.62	0.01	0.43	0.48	0.00	0.23	0.27
1992	0.99	0.99	0.87	0.59	0.79	0.67	0.10	0.57	0.54	0.01	0.42	0.42	0.00	0.17	0.29
1993	0.99	0.99	0.89	0.49	0.83	0.64	0.10	0.57	0.48	0.01	0.38	0.32	0.00	0.20	0.23
1994	0.97	0.98	0.87	0.52	0.84	0.68	0.06	0.65	0.45	0.01	0.38	0.26	0.00	0.19	0.14
1995	0.97	0.98	0.86	0.39	0.73	0.65	0.07	0.59	0.49	0.00	0.40	0.23	0.00	0.13	0.10
1996	0.98	0.99	0.86	0.37	0.77	0.62	0.03	0.51	0.45	0.00	0.42	0.27	0.00	0.21	0.08
1997	0.97	0.99	0.88	0.44	0.77	0.63	0.03	0.47	0.42	0.00	0.26	0.23	0.00	0.16	0.11
1998	1.00	1.00	0.96	0.38	0.85	0.67	0.05	0.57	0.43	0.00	0.30	0.20	0.00	0.11	0.08
1999	1.00	1.00	0.94	0.65	0.89	0.83	0.03	0.63	0.48	0.00	0.34	0.22	0.00	0.10	0.07
2000	0.99	0.99	0.91	0.63	0.83	0.78	0.13	0.65	0.70	0.00	0.34	0.26	0.00	0.09	0.07
2001	0.98	0.98	0.88	0.52	0.81	0.72	0.12	0.66	0.63	0.01	0.48	0.52	0.00	0.16	0.10

Table IV.2. Quarter 2. Modelled proportion discards per year and age for otolith back-calculations, BTS and SNS surveys using an ogive based on 80 mm mesh size.

	age 2			age 3			age 4			age 5			age 6		
year	otolith	BTS	SNS	otolith	BTS	SNS	otolith	BTS	SNS	otolith	BTS	SNS	otolith	BTS	SNS
1963	0.96			0.44			0.10			0.01			0.00		
1964	0.94			0.51			0.07			0.01			0.00		
1965	0.99			0.41			0.09			0.00			0.00		
1966	0.96			0.73			0.06			0.01			0.00		
1967	0.97			0.47			0.24			0.00			0.00		
1968	0.97			0.56			0.08			0.04			0.00		
1969	0.93		0.83	0.52		0.70	0.12		0.62	0.01		0.64	0.00		0.43
1970	0.91		0.85	0.38		0.63	0.10		0.53	0.01		0.43	0.00		0.43
1971	0.91		0.84	0.34		0.68	0.05		0.44	0.01		0.32	0.00		0.22
1972	0.89		0.81	0.33		0.65	0.04		0.49	0.00		0.23	0.00		0.14
1973	0.89		0.86	0.28		0.61	0.04		0.46	0.00		0.28	0.00		0.08
1974	0.92		0.86	0.28		0.68	0.03		0.40	0.00		0.25	0.00		0.11
1975	0.87		0.85	0.34		0.69	0.03		0.50	0.00		0.20	0.00		0.09
1976	0.81		0.81	0.25		0.67	0.04		0.51	0.00		0.29	0.00		0.06
1977	0.82		0.81	0.18		0.60	0.02		0.48	0.00		0.31	0.00		0.12
1978	0.85		0.80	0.18		0.61	0.01		0.40	0.00		0.27	0.00		0.13
1979	0.80		0.81	0.22		0.60	0.01		0.41	0.00		0.20	0.00		0.10
1980	0.84		0.84	0.16		0.62	0.02		0.39	0.00		0.20	0.00		0.06
1981	0.89		0.81	0.20		0.66	0.01		0.41	0.00		0.19	0.00		0.07
1982	0.86		0.81	0.28		0.61	0.01		0.46	0.00		0.21	0.00		0.06
1983	0.90		0.83	0.24		0.61	0.03		0.41	0.00		0.25	0.00		0.07
1984	0.89		0.86	0.31		0.65	0.02		0.40	0.00		0.21	0.00		0.09
1985	0.87	0.79	0.86	0.28	0.53	0.68	0.03	0.29	0.45	0.00	0.14	0.20	0.00	0.02	0.07
1986	0.89	0.91	0.88	0.25	0.49	0.69	0.03	0.30	0.50	0.00	0.13	0.24	0.00	0.03	0.06
1987	0.93	0.96	0.89	0.28	0.71	0.73	0.02	0.29	0.51	0.00	0.16	0.29	0.00	0.04	0.09
1988	0.93	0.91	0.89	0.36	0.69	0.74	0.03	0.37	0.56	0.00	0.06	0.30	0.00	0.01	0.12
1989	0.93	0.96	0.87	0.39	0.77	0.75	0.04	0.59	0.57	0.00	0.27	0.36	0.00	0.02	0.12
1990	0.90	0.94	0.83	0.37	0.77	0.71	0.05	0.54	0.59	0.00	0.34	0.37	0.00	0.07	0.16
1991	0.90	0.92	0.79	0.31	0.71	0.64	0.05	0.53	0.53	0.00	0.28	0.39	0.00	0.11	0.17
1992	0.85	0.91	0.77	0.30	0.63	0.59	0.03	0.41	0.44	0.00	0.25	0.33	0.00	0.06	0.19
1993	0.86	0.93	0.80	0.22	0.72	0.55	0.03	0.43	0.38	0.00	0.24	0.23	0.00	0.09	0.14
1994	0.78	0.86	0.77	0.24	0.68	0.60	0.02	0.47	0.34	0.00	0.20	0.18	0.00	0.06	0.08
1995	0.76	0.87	0.75	0.15	0.59	0.55	0.02	0.46	0.39	0.00	0.26	0.15	0.00	0.05	0.05
1996	0.82	0.87	0.76	0.14	0.54	0.52	0.01	0.29	0.34	0.00	0.19	0.19	0.00	0.05	0.04
1997	0.77	0.90	0.79	0.18	0.59	0.54	0.01	0.29	0.31	0.00	0.11	0.15	0.00	0.05	0.06
1998	0.93	0.96	0.91	0.15	0.73	0.58	0.01	0.42	0.33	0.00	0.16	0.13	0.00	0.03	0.04
1999	0.92	0.93	0.87	0.36	0.73	0.77	0.01	0.41	0.37	0.00	0.14	0.14	0.00	0.02	0.03
2000	0.87	0.90	0.83	0.34	0.72	0.71	0.04	0.52	0.62	0.00	0.20	0.17	0.00	0.03	0.04
2001	0.82	0.89	0.78	0.25	0.66	0.64	0.04	0.50	0.54	0.00	0.30	0.44	0.00	0.05	0.05

Table IV.3. Quarter 3. Modelled proportion discards per year and age for otolith back-calculations, BTS and SNS surveys using an ogive based on 80 mm mesh size**.**

	age 2			age 3			age 4			age 5			age 6		
year	otolith	BTS	SNS	otolith	BTS	SNS	otolith	BTS	SNS	otolith	BTS	SNS	otolith	BTS	SNS
1963	0.77			0.18			0.03			0.00			0.00		
1964	0.70			0.23			0.02			0.00			0.00		
1965	0.91			0.17			0.03			0.00			0.00		
1966	0.74			0.45			0.01			0.00			0.00		
1967	0.81			0.20			0.10			0.00			0.00		
1968	0.78			0.28			0.02			0.01			0.00		
1969	0.66		0.72	0.24		0.62	0.04		0.52	0.00		0.55	0.00		0.31
1970	0.62		0.75	0.14		0.54	0.03		0.41	0.00		0.32	0.00		0.32
1971	0.61		0.73	0.12		0.59	0.01		0.32	0.00		0.22	0.00		0.13
1972	0.56		0.69	0.11		0.56	0.01		0.38	0.00		0.14	0.00		0.07
1973	0.56		0.76	0.09		0.51	0.01		0.35	0.00		0.19	0.00		0.04
1974	0.63		0.77	0.09		0.60	0.00		0.29	0.00		0.16	0.00		0.06
1975	0.53		0.74	0.12		0.61	0.00		0.39	0.00		0.12	0.00		0.05
1976	0.43		0.69	0.08		0.57	0.01		0.40	0.00		0.20	0.00		0.03
1977	0.44		0.70	0.04		0.50	0.00		0.36	0.00		0.21	0.00		0.06
1978	0.49		0.69	0.05		0.51	0.00		0.28	0.00		0.18	0.00		0.07
1979	0.41		0.70	0.06		0.50	0.00		0.29	0.00		0.12	0.00		0.05
1980	0.47		0.73	0.04		0.52	0.00		0.28	0.00		0.12	0.00		0.03
1981	0.56		0.70	0.06		0.56	0.00		0.30	0.00		0.11	0.00		0.03
1982	0.51		0.69	0.09		0.51	0.00		0.35	0.00		0.13	0.00		0.03
1983	0.59		0.73	0.07		0.51	0.00		0.29	0.00		0.16	0.00		0.03
1984	0.56		0.76	0.10		0.55	0.00		0.29	0.00		0.12	0.00		0.05
1985	0.53	0.59	0.76	0.09	0.37	0.60	0.01	0.19	0.33	0.00	0.07	0.12	0.00	0.00	0.03
1986	0.57	0.76	0.79	0.08	0.33	0.60	0.00	0.19	0.39	0.00	0.06	0.15	0.00	0.00	0.03
1987	0.65	0.82	0.80	0.09	0.51	0.65	0.00	0.15	0.39	0.00	0.06	0.20	0.00	0.00	0.04
1988	0.67	0.83	0.81	0.13	0.65	0.66	0.01	0.34	0.45	0.00	0.05	0.20	0.00	0.01	0.06
1989	0.66	0.83	0.78	0.15	0.59	0.67	0.01	0.41	0.47	0.00	0.12	0.26	0.00	0.00	0.06
1990	0.59	0.83	0.72	0.14	0.67	0.62	0.01	0.44	0.48	0.00	0.24	0.27	0.00	0.03	0.09
1991	0.59	0.78	0.67	0.10	0.57	0.54	0.01	0.41	0.42	0.00	0.17	0.29	0.00	0.04	0.10
1992	0.49	0.76	0.64	0.10	0.46	0.48	0.01	0.28	0.32	0.00	0.13	0.23	0.00	0.01	0.11
1993	0.52	0.81	0.68	0.06	0.61	0.45	0.01	0.34	0.26	0.00	0.15	0.14	0.00	0.04	0.08
1994	0.39	0.65	0.65	0.07	0.49	0.49	0.00	0.30	0.23	0.00	0.08	0.10	0.00	0.01	0.04
1995	0.37	0.69	0.62	0.03	0.42	0.45	0.00	0.32	0.27	0.00	0.14	0.08	0.00	0.01	0.02
1996	0.44	0.74	0.63	0.03	0.42	0.42	0.00	0.22	0.23	0.00	0.13	0.11	0.00	0.02	0.02
1997	0.38	0.72	0.67	0.05	0.39	0.43	0.00	0.16	0.20	0.00	0.04	0.08	0.00	0.01	0.03
1998	0.65	0.88	0.83	0.03	0.61	0.48	0.00	0.32	0.22	0.00	0.09	0.07	0.00	0.01	0.02
1999	0.63	0.79	0.78	0.13	0.59	0.70	0.00	0.28	0.26	0.00	0.07	0.07	0.00	0.00	0.01
2000	0.52	0.76	0.72	0.12	0.60	0.63	0.01	0.41	0.52	0.00	0.12	0.10	0.00	0.01	0.01
2001	0.44	0.76	0.66	0.07	0.54	0.54	0.01	0.42	0.43	0.00	0.21	0.33	0.00	0.02	0.02

Table IV.4. Quarter 4. Modelled proportion discards per year and age for otolith back-calculations, BTS and SNS surveys using an ogive based on 80 mm mesh size**.**

	age 2			age 3			age 4			age 5			age 6		
year	otolith	BTS	SNS	otolith	BTS	SNS	otolith	BTS	SNS	otolith	BTS	SNS	otolith	BTS	SNS
1963	0.77			0.18			0.03			0.00			0.00		
1964	0.70			0.23			0.02			0.00			0.00		
1965	0.91			0.17			0.03			0.00			0.00		
1966	0.74			0.45			0.01			0.00			0.00		
1967	0.81			0.20			0.10			0.00			0.00		
1968	0.78			0.28			0.02			0.01			0.00		
1969	0.66		0.72	0.24		0.62	0.04		0.52	0.00		0.55	0.00		0.31
1970	0.62		0.75	0.14		0.54	0.03		0.41	0.00		0.32	0.00		0.32
1971	0.61		0.73	0.12		0.59	0.01		0.32	0.00		0.22	0.00		0.13
1972	0.56		0.69	0.11		0.56	0.01		0.38	0.00		0.14	0.00		0.07
1973	0.56		0.76	0.09		0.51	0.01		0.35	0.00		0.19	0.00		0.04
1974	0.63		0.77	0.09		0.60	0.00		0.29	0.00		0.16	0.00		0.06
1975	0.53		0.74	0.12		0.61	0.00		0.39	0.00		0.12	0.00		0.05
1976	0.43		0.69	0.08		0.57	0.01		0.40	0.00		0.20	0.00		0.03
1977	0.44		0.70	0.04		0.50	0.00		0.36	0.00		0.21	0.00		0.06
1978	0.49		0.69	0.05		0.51	0.00		0.28	0.00		0.18	0.00		0.07
1979	0.41		0.70	0.06		0.50	0.00		0.29	0.00		0.12	0.00		0.05
1980	0.47		0.73	0.04		0.52	0.00		0.28	0.00		0.12	0.00		0.03
1981	0.56		0.70	0.06		0.56	0.00		0.30	0.00		0.11	0.00		0.03
1982	0.51		0.69	0.09		0.51	0.00		0.35	0.00		0.13	0.00		0.03
1983	0.59		0.73	0.07		0.51	0.00		0.29	0.00		0.16	0.00		0.03
1984	0.56		0.76	0.10		0.55	0.00		0.29	0.00		0.12	0.00		0.05
1985	0.53	0.61	0.76	0.09	0.39	0.60	0.01	0.20	0.33	0.00	0.07	0.12	0.00	0.00	0.03
1986	0.57	0.81	0.79	0.08	0.39	0.60	0.00	0.25	0.39	0.00	0.09	0.15	0.00	0.01	0.03
1987	0.65	0.80	0.80	0.09	0.49	0.65	0.00	0.14	0.39	0.00	0.05	0.20	0.00	0.00	0.04
1988	0.67	0.81	0.81	0.13	0.63	0.66	0.01	0.32	0.45	0.00	0.04	0.20	0.00	0.00	0.06
1989	0.66	0.86	0.78	0.15	0.64	0.67	0.01	0.47	0.47	0.00	0.15	0.26	0.00	0.00	0.06
1990	0.59	0.81	0.72	0.14	0.64	0.62	0.01	0.40	0.48	0.00	0.21	0.27	0.00	0.02	0.09
1991	0.59	0.80	0.67	0.10	0.59	0.54	0.01	0.43	0.42	0.00	0.18	0.29	0.00	0.04	0.10
1992	0.49	0.78	0.64	0.10	0.49	0.48	0.01	0.30	0.32	0.00	0.15	0.23	0.00	0.02	0.11
1993	0.52	0.74	0.68	0.06	0.51	0.45	0.01	0.25	0.26	0.00	0.10	0.14	0.00	0.02	0.08
1994	0.39	0.65	0.65	0.07	0.49	0.49	0.00	0.30	0.23	0.00	0.08	0.10	0.00	0.01	0.04
1995	0.37	0.69	0.62	0.03	0.42	0.45	0.00	0.33	0.27	0.00	0.14	0.08	0.00	0.01	0.02
1996	0.44	0.70	0.63	0.03	0.38	0.42	0.00	0.19	0.23	0.00	0.10	0.11	0.00	0.01	0.02
1997	0.38	0.79	0.67	0.05	0.48	0.43	0.00	0.22	0.20	0.00	0.07	0.08	0.00	0.02	0.03
1998	0.65	0.83	0.83	0.03	0.53	0.48	0.00	0.25	0.22	0.00	0.06	0.07	0.00	0.00	0.02
1999	0.63	0.78	0.78	0.13	0.57	0.70	0.00	0.27	0.26	0.00	0.06	0.07	0.00	0.00	0.01
2000	0.52	0.80	0.72	0.12	0.66	0.63	0.01	0.47	0.52	0.00	0.15	0.10	0.00	0.01	0.01
2001	0.44	0.76	0.66	0.07	0.56	0.54	0.01	0.43	0.43	0.00	0.23	0.33	0.00	0.02	0.02

Table IV.5. Quarter 1. Modelled proportion discards per year and age for otolith back-calculations, BTS and SNS surveys using an ogive based on 60 mm mesh size.

	age 2			age 3			age 4			age 5			age 6		
year	otolith	BTS	SNS	otolith	BTS	SNS	otolith	BTS	SNS	otolith	BTS	SNS	otolith	BTS	SNS
1963			0.73			0.25			0.03			0.00			
1964			0.78			0.18			0.03			0.00			
1965			0.71			0.23			0.02			0.00			
1966			0.92			0.17			0.03			0.00			
1967			0.75			0.45			0.01			0.00			
1968			0.82			0.20			0.10			0.00			
1969		0.94	0.79		0.83	0.28		0.74	0.02		0.74	0.01		0.57	
1970		0.96	0.67		0.77	0.25		0.66	0.04		0.54	0.00		0.57	
1971		0.95	0.63		0.80	0.14		0.58	0.03		0.43	0.00		0.33	
1972		0.93	0.62		0.78	0.12		0.63	0.01		0.33	0.00		0.22	
1973		0.96	0.57		0.74	0.11		0.60	0.01		0.39	0.00		0.14	
1974		0.96	0.57		0.81	0.09		0.54	0.01		0.36	0.00		0.19	
1975		0.95	0.63		0.82	0.09		0.64	0.00		0.30	0.00		0.16	
1976		0.93	0.54		0.79	0.12		0.65	0.00		0.40	0.00		0.12	
1977		0.94	0.43		0.74	0.08		0.61	0.01		0.42	0.00		0.20	
1978		0.93	0.44		0.75	0.04		0.54	0.00		0.38	0.00		0.21	
1979		0.94	0.49		0.74	0.05		0.55	0.00		0.29	0.00		0.18	
1980		0.95	0.41		0.75	0.06		0.53	0.00		0.30	0.00		0.12	
1981		0.94	0.47		0.79	0.04		0.55	0.00		0.29	0.00		0.12	
1982		0.93	0.57		0.75	0.06		0.60	0.00		0.31	0.00		0.11	
1983		0.95	0.51		0.74	0.09		0.55	0.00		0.36	0.00		0.13	
1984		0.96	0.60		0.78	0.07		0.54	0.00		0.30	0.00		0.17	
1985	0.95	0.96	0.56	0.70	0.81	0.10	0.42	0.59	0.00	0.24	0.30	0.00	0.07	0.12	1.00
1986	0.99	0.97	0.53	0.65	0.81	0.09	0.41	0.64	0.01	0.21	0.35	0.00	0.08	0.12	1.00
1987	0.99	0.97	0.57	0.79	0.84	0.08	0.34	0.64	0.00	0.20	0.40	0.00	0.06	0.16	1.00
1988	0.99	0.98	0.66	0.85	0.85	0.09	0.53	0.69	0.00	0.15	0.41	0.00	0.06	0.20	1.00
1989	0.99	0.97	0.68	0.83	0.86	0.13	0.63	0.70	0.01	0.30	0.47	0.00	0.04	0.20	1.00
1990	0.99	0.94	0.67	0.84	0.83	0.15	0.59	0.72	0.01	0.40	0.49	0.00	0.11	0.26	1.00
1991	0.99	0.92	0.60	0.81	0.77	0.14	0.61	0.67	0.01	0.36	0.51	0.00	0.17	0.28	1.00
1992	0.99	0.91	0.59	0.79	0.72	0.10	0.55	0.58	0.01	0.38	0.44	0.00	0.14	0.29	1.00
1993	0.99	0.93	0.50	0.82	0.69	0.10	0.52	0.52	0.01	0.32	0.33	0.00	0.16	0.23	1.00
1994	0.97	0.91	0.52	0.81	0.73	0.06	0.58	0.48	0.01	0.30	0.27	0.00	0.12	0.14	1.00
1995	0.97	0.90	0.39	0.72	0.69	0.07	0.55	0.53	0.00	0.35	0.23	0.00	0.10	0.10	1.00
1996	0.98	0.90	0.37	0.72	0.67	0.03	0.43	0.48	0.00	0.33	0.28	0.00	0.14	0.08	1.00
1997	0.99	0.92	0.44	0.76	0.68	0.03	0.43	0.44	0.00	0.21	0.24	0.00	0.12	0.11	1.00
1998	1.00	0.98	0.38	0.81	0.72	0.05	0.48	0.46	0.00	0.21	0.21	0.00	0.06	0.08	1.00
1999	0.99	0.97	0.66	0.87	0.88	0.03	0.56	0.51	0.00	0.26	0.22	0.00	0.06	0.07	1.00
2000	0.99	0.94	0.63	0.85	0.83	0.13	0.66	0.75	0.00	0.33	0.26	0.00	0.09	0.07	1.00
2001	0.98	0.92	0.53	0.80	0.77	0.12	0.63	0.67	0.01	0.43	0.55	0.00	0.12	0.10	1.00

Table IV.6. Quarter 2. Modelled proportion discards per year and age for otolith back-calculations, BTS and SNS surveys using an ogive based on 60 mm mesh size**.**

	age 2			age 3			age 4			age 5			age 6		
year	otolith	BTS	SNS	otolith	BTS	SNS	otolith	BTS	SNS	otolith	BTS	SNS	otolith	BTS	SNS
1963	0.97			0.44			0.10			0.01			0.00		
1964	0.95			0.51			0.07			0.01			0.00		
1965	1.00			0.42			0.09			0.00			0.00		
1966	0.97			0.74			0.06			0.01			0.00		
1967	0.98			0.47			0.24			0.00			0.00		
1968	0.97			0.57			0.08			0.04			0.00		
1969	0.94		0.87	0.53		0.75	0.12		0.66	0.01		0.67	0.00		0.44
1970	0.93		0.90	0.38		0.68	0.10		0.56	0.01		0.44	0.00		0.45
1971	0.92		0.88	0.34		0.73	0.05		0.46	0.01		0.33	0.00		0.22
1972	0.90		0.86	0.33		0.70	0.04		0.52	0.00		0.23	0.00		0.14
1973	0.90		0.90	0.28		0.65	0.04		0.49	0.00		0.29	0.00		0.08
1974	0.93		0.91	0.28		0.73	0.03		0.43	0.00		0.26	0.00		0.11
1975	0.88		0.89	0.34		0.74	0.03		0.53	0.00		0.20	0.00		0.09
1976	0.82		0.85	0.25		0.71	0.04		0.54	0.00		0.30	0.00		0.06
1977	0.83		0.86	0.18		0.65	0.02		0.50	0.00		0.31	0.00		0.12
1978	0.86		0.85	0.18		0.66	0.01		0.42	0.00		0.27	0.00		0.13
1979	0.81		0.86	0.22		0.64	0.01		0.43	0.00		0.20	0.00		0.10
1980	0.85		0.89	0.17		0.66	0.02		0.41	0.00		0.21	0.00		0.06
1981	0.90		0.86	0.20		0.70	0.01		0.44	0.00		0.19	0.00		0.07
1982	0.87		0.85	0.28		0.66	0.01		0.49	0.00		0.21	0.00		0.06
1983	0.91		0.88	0.24		0.65	0.03		0.43	0.00		0.26	0.00		0.07
1984	0.90		0.90	0.31		0.69	0.02		0.42	0.00		0.21	0.00		0.09
1985	0.88	0.83	0.90	0.28	0.56	0.73	0.03	0.31	0.48	0.00	0.14	0.20	0.00	0.03	0.07
1986	0.90	0.93	0.92	0.25	0.50	0.74	0.03	0.30	0.53	0.00	0.12	0.25	0.00	0.03	0.06
1987	0.94	0.95	0.93	0.29	0.68	0.78	0.02	0.24	0.54	0.00	0.11	0.30	0.00	0.02	0.09
1988	0.94	0.94	0.93	0.36	0.76	0.79	0.03	0.42	0.59	0.00	0.08	0.31	0.00	0.02	0.12
1989	0.94	0.95	0.91	0.39	0.73	0.80	0.04	0.52	0.61	0.00	0.20	0.37	0.00	0.01	0.12
1990	0.91	0.93	0.87	0.37	0.75	0.76	0.05	0.48	0.63	0.00	0.28	0.39	0.00	0.05	0.16
1991	0.91	0.92	0.84	0.31	0.70	0.68	0.05	0.50	0.56	0.00	0.24	0.41	0.00	0.08	0.18
1992	0.86	0.94	0.82	0.30	0.67	0.63	0.03	0.44	0.46	0.00	0.26	0.33	0.00	0.07	0.19
1993	0.87	0.93	0.85	0.22	0.72	0.59	0.03	0.41	0.40	0.00	0.21	0.23	0.00	0.08	0.14
1994	0.79	0.88	0.82	0.24	0.70	0.64	0.02	0.47	0.36	0.00	0.19	0.18	0.00	0.05	0.08
1995	0.77	0.88	0.80	0.15	0.59	0.59	0.02	0.44	0.41	0.00	0.24	0.15	0.00	0.04	0.05
1996	0.83	0.91	0.81	0.14	0.58	0.56	0.01	0.32	0.36	0.00	0.21	0.19	0.00	0.06	0.04
1997	0.78	0.93	0.84	0.18	0.64	0.58	0.01	0.31	0.32	0.00	0.13	0.15	0.00	0.05	0.06
1998	0.94	0.96	0.94	0.15	0.70	0.62	0.01	0.37	0.34	0.00	0.13	0.13	0.00	0.02	0.04
1999	0.93	0.95	0.91	0.36	0.78	0.82	0.01	0.44	0.39	0.00	0.16	0.14	0.00	0.02	0.03
2000	0.88	0.93	0.87	0.34	0.76	0.76	0.04	0.55	0.66	0.00	0.21	0.17	0.00	0.03	0.04
2001	0.83	0.91	0.83	0.25	0.69	0.68	0.04	0.52	0.57	0.00	0.31	0.45	0.00	0.05	0.05

Table IV.7. Quarter 3. Modelled proportion discards per year and age for otolith back-calculations, BTS and SNS surveys using an ogive based on 60 mm mesh size**.**

	age 2			age 3			age 4			age 5			age 6		
year	otolith	BTS	SNS	otolith	BTS	SNS	otolith	BTS	SNS	otolith	BTS	SNS	otolith	BTS	SNS
1963	0.78			0.18			0.03			0.00			0.00		
1964	0.71			0.23			0.02			0.00			0.00		
1965	0.92			0.17			0.03			0.00			0.00		
1966	0.75			0.45			0.01			0.00			0.00		
1967	0.82			0.20			0.10			0.00			0.00		
1968	0.79			0.28			0.02			0.01			0.00		
1969	0.67		0.77	0.25		0.66	0.04		0.54	0.00		0.57	0.00		0.32
1970	0.63		0.80	0.14		0.58	0.03		0.43	0.00		0.33	0.00		0.32
1971	0.62		0.78	0.12		0.63	0.01		0.33	0.00		0.22	0.00		0.13
1972	0.57		0.74	0.11		0.60	0.01		0.39	0.00		0.14	0.00		0.07
1973	0.57		0.81	0.09		0.54	0.01		0.36	0.00		0.19	0.00		0.04
1974	0.63		0.82	0.09		0.64	0.00		0.30	0.00		0.16	0.00		0.06
1975	0.54		0.79	0.12		0.65	0.00		0.40	0.00		0.12	0.00		0.05
1976	0.43		0.74	0.08		0.61	0.01		0.42	0.00		0.20	0.00		0.03
1977	0.44		0.75	0.04		0.54	0.00		0.38	0.00		0.21	0.00		0.06
1978	0.49		0.74	0.05		0.55	0.00		0.29	0.00		0.18	0.00		0.07
1979	0.41		0.75	0.06		0.53	0.00		0.30	0.00		0.12	0.00		0.05
1980	0.47		0.79	0.04		0.55	0.00		0.29	0.00		0.12	0.00		0.03
1981	0.57		0.75	0.06		0.60	0.00		0.31	0.00		0.11	0.00		0.03
1982	0.51		0.74	0.09		0.55	0.00		0.36	0.00		0.13	0.00		0.03
1983	0.60		0.78	0.07		0.54	0.00		0.30	0.00		0.17	0.00		0.03
1984	0.56		0.81	0.10		0.59	0.00		0.30	0.00		0.12	0.00		0.05
1985	0.53	0.65	0.81	0.09	0.41	0.64	0.01	0.21	0.35	0.00	0.08	0.12	0.00	0.01	0.03
1986	0.57	0.79	0.84	0.08	0.34	0.64	0.00	0.20	0.40	0.00	0.06	0.16	0.00	0.01	0.03
1987	0.66	0.85	0.85	0.09	0.53	0.69	0.00	0.15	0.41	0.00	0.06	0.20	0.00	0.00	0.04
1988	0.68	0.83	0.86	0.13	0.63	0.70	0.01	0.30	0.47	0.00	0.04	0.20	0.00	0.00	0.06
1989	0.67	0.84	0.83	0.15	0.59	0.72	0.01	0.40	0.49	0.00	0.11	0.26	0.00	0.00	0.06
1990	0.60	0.81	0.77	0.14	0.61	0.67	0.01	0.36	0.51	0.00	0.17	0.28	0.00	0.01	0.09
1991	0.59	0.79	0.72	0.10	0.55	0.58	0.01	0.38	0.44	0.00	0.14	0.29	0.00	0.03	0.10
1992	0.50	0.82	0.69	0.10	0.52	0.52	0.01	0.32	0.33	0.00	0.16	0.23	0.00	0.02	0.11
1993	0.52	0.81	0.73	0.06	0.58	0.48	0.01	0.30	0.27	0.00	0.12	0.14	0.00	0.03	0.08
1994	0.39	0.72	0.69	0.07	0.55	0.53	0.00	0.35	0.23	0.00	0.10	0.10	0.00	0.02	0.04
1995	0.37	0.72	0.67	0.03	0.43	0.48	0.00	0.33	0.28	0.00	0.14	0.08	0.00	0.01	0.02
1996	0.44	0.76	0.68	0.03	0.43	0.44	0.00	0.21	0.24	0.00	0.12	0.11	0.00	0.02	0.02
1997	0.38	0.81	0.72	0.05	0.48	0.46	0.00	0.21	0.21	0.00	0.06	0.08	0.00	0.02	0.03
1998	0.66	0.87	0.88	0.03	0.56	0.51	0.00	0.26	0.22	0.00	0.06	0.07	0.00	0.00	0.02
1999	0.63	0.85	0.83	0.13	0.66	0.75	0.00	0.33	0.26	0.00	0.09	0.07	0.00	0.00	0.01
2000	0.53	0.80	0.77	0.12	0.63	0.67	0.01	0.43	0.55	0.00	0.12	0.10	0.00	0.01	0.01
2001	0.44	0.77	0.71	0.07	0.54	0.58	0.01	0.41	0.45	0.00	0.20	0.34	0.00	0.02	0.02

Table IV.8. Quarter 4. Modelled proportion discards per year and age for otolith back-calculations, BTS and SNS surveys using an ogive based on 60 mm mesh size.

	age 2			age 3			age 4			age 5			age 6		
year	otolith	BTS	SNS	otolith	BTS	SNS	otolith	BTS	SNS	otolith	BTS	SNS	otolith	BTS	SNS
1963	0.78			0.18			0.03			0.00			0.00		
1964	0.71			0.23			0.02			0.00			0.00		
1965	0.92			0.17			0.03			0.00			0.00		
1966	0.75			0.45			0.01			0.00			0.00		
1967	0.82			0.20			0.10			0.00			0.00		
1968	0.79			0.28			0.02			0.01			0.00		
1969	0.67		0.77	0.25		0.66	0.04		0.54	0.00		0.57	0.00		0.32
1970	0.63		0.80	0.14		0.58	0.03		0.43	0.00		0.33	0.00		0.32
1971	0.62		0.78	0.12		0.63	0.01		0.33	0.00		0.22	0.00		0.13
1972	0.57		0.74	0.11		0.60	0.01		0.39	0.00		0.14	0.00		0.07
1973	0.57		0.81	0.09		0.54	0.01		0.36	0.00		0.19	0.00		0.04
1974	0.63		0.82	0.09		0.64	0.00		0.30	0.00		0.16	0.00		0.06
1975	0.54		0.79	0.12		0.65	0.00		0.40	0.00		0.12	0.00		0.05
1976	0.43		0.74	0.08		0.61	0.01		0.42	0.00		0.20	0.00		0.03
1977	0.44		0.75	0.04		0.54	0.00		0.38	0.00		0.21	0.00		0.06
1978	0.49		0.74	0.05		0.55	0.00		0.29	0.00		0.18	0.00		0.07
1979	0.41		0.75	0.06		0.53	0.00		0.30	0.00		0.12	0.00		0.05
1980	0.47		0.79	0.04		0.55	0.00		0.29	0.00		0.12	0.00		0.03
1981	0.57		0.75	0.06		0.60	0.00		0.31	0.00		0.11	0.00		0.03
1982	0.51		0.74	0.09		0.55	0.00		0.36	0.00		0.13	0.00		0.03
1983	0.60		0.78	0.07		0.54	0.00		0.30	0.00		0.17	0.00		0.03
1984	0.56		0.81	0.10		0.59	0.00		0.30	0.00		0.12	0.00		0.05
1985	0.53	0.65	0.81	0.09	0.41	0.64	0.01	0.21	0.35	0.00	0.08	0.12	0.00	0.01	0.03
1986	0.57	0.79	0.84	0.08	0.34	0.64	0.00	0.20	0.40	0.00	0.06	0.16	0.00	0.01	0.03
1987	0.66	0.85	0.85	0.09	0.53	0.69	0.00	0.15	0.41	0.00	0.06	0.20	0.00	0.00	0.04
1988	0.68	0.83	0.86	0.13	0.63	0.70	0.01	0.30	0.47	0.00	0.04	0.20	0.00	0.00	0.06
1989	0.67	0.84	0.83	0.15	0.59	0.72	0.01	0.40	0.49	0.00	0.11	0.26	0.00	0.00	0.06
1990	0.60	0.81	0.77	0.14	0.61	0.67	0.01	0.36	0.51	0.00	0.17	0.28	0.00	0.01	0.09
1991	0.59	0.79	0.72	0.10	0.55	0.58	0.01	0.38	0.44	0.00	0.14	0.29	0.00	0.03	0.10
1992	0.50	0.82	0.69	0.10	0.52	0.52	0.01	0.32	0.33	0.00	0.16	0.23	0.00	0.02	0.11
1993	0.52	0.81	0.73	0.06	0.58	0.48	0.01	0.30	0.27	0.00	0.12	0.14	0.00	0.03	0.08
1994	0.39	0.72	0.69	0.07	0.55	0.53	0.00	0.35	0.23	0.00	0.10	0.10	0.00	0.02	0.04
1995	0.37	0.72	0.67	0.03	0.43	0.48	0.00	0.33	0.28	0.00	0.14	0.08	0.00	0.01	0.02
1996	0.44	0.76	0.68	0.03	0.43	0.44	0.00	0.21	0.24	0.00	0.12	0.11	0.00	0.02	0.02
1997	0.38	0.81	0.72	0.05	0.48	0.46	0.00	0.21	0.21	0.00	0.06	0.08	0.00	0.02	0.03
1998	0.66	0.87	0.88	0.03	0.56	0.51	0.00	0.26	0.22	0.00	0.06	0.07	0.00	0.00	0.02
1999	0.63	0.85	0.83	0.13	0.66	0.75	0.00	0.33	0.26	0.00	0.09	0.07	0.00	0.00	0.01
2000	0.53	0.80	0.77	0.12	0.63	0.67	0.01	0.43	0.55	0.00	0.12	0.10	0.00	0.01	0.01
2001	0.44	0.77	0.71	0.07	0.54	0.58	0.01	0.41	0.45	0.00	0.20	0.34	0.00	0.02	0.02

Table IV.9. Mean $F_{2\text{-}3}$ from assessments run with landings numbers-at-age (land) and catch numbers-at-age assuming 80 mm and 60 mm mesh size**.**

	otolith back-calculations			BTS			SNS		
year	**land**	**80**	**60**	**land**	**80**	**60**	**land**	**80**	**60**
1963	0.048	0.094	0.363						
1964	0.118	0.243	0.713						
1965	0.106	0.248	0.895						
1966	0.051	0.112	0.404						
1967	0.080	0.173	0.638						
1968	0.117	0.267	0.843						
1969	0.160	0.289	0.743				0.160	0.367	0.435
1970	0.202	0.311	0.680				0.202	0.436	0.511
1971	0.161	0.289	0.715				0.161	0.390	0.468
1972	0.219	0.374	0.826				0.219	0.485	0.566
1973	0.284	0.445	0.901				0.284	0.604	0.706
1974	0.253	0.347	0.673				0.253	0.521	0.606
1975	0.121	0.202	0.471				0.121	0.312	0.382
1976	0.199	0.293	0.544				0.199	0.462	0.544
1977	0.219	0.345	0.647				0.219	0.506	0.594
1978	0.270	0.388	0.723				0.270	0.539	0.615
1979	0.328	0.444	0.722				0.328	0.611	0.691
1980	0.416	0.551	0.895				0.416	0.767	0.868
1981	0.377	0.547	1.016				0.377	0.701	0.793
1982	0.413	0.557	0.926				0.413	0.712	0.793
1983	0.330	0.480	0.934				0.330	0.631	0.718
1984	0.322	0.467	0.880				0.322	0.624	0.722
1985	0.300	0.442	0.833	0.300	0.640	0.720	0.300	0.618	0.723
1986	0.339	0.498	0.953	0.339	0.882	1.062	0.339	0.707	0.836
1987	0.246	0.372	0.802	0.246	0.803	1.033	0.246	0.546	0.656
1988	0.186	0.277	0.615	0.186	0.513	0.654	0.186	0.392	0.469
1989	0.208	0.366	0.895	0.208	0.831	1.087	0.208	0.511	0.631
1990	0.184	0.228	0.307	0.184	0.388	0.447	0.184	0.337	0.379
1991	0.241	0.289	0.374	0.241	0.469	0.528	0.241	0.407	0.445
1992	0.260	0.319	0.451	0.260	0.579	0.695	0.260	0.430	0.469
1993	0.309	0.370	0.518	0.309	0.620	0.725	0.309	0.477	0.516
1994	0.352	0.398	0.464	0.352	0.592	0.645	0.352	0.523	0.559
1995	0.402	0.474	0.647	0.402	0.751	0.848	0.402	0.617	0.665
1996	0.356	0.407	0.514	0.356	0.609	0.675	0.356	0.520	0.553
1997	0.364	0.411	0.474	0.365	0.662	0.744	0.364	0.553	0.592
1998	0.257	0.273	0.287	0.257	0.487	0.552	0.257	0.421	0.459
1999	0.139	0.144	0.151	0.140	0.318	0.374	0.139	0.297	0.341
2000	0.157	0.175	0.201	0.160	0.360	0.421	0.157	0.303	0.343
2001	0.340	0.363	0.382	0.343	0.590	0.644	0.340	0.497	0.527

Table IV.10. Recruitment (*1000) from assessments run with landings numbers-at-age (land) and catch numbers-at-age assuming 80 mm and 60 mm mesh size.

	otolith back-calculations			BTS			SNS		
year	land	80	60	land	80	60	land	80	60
1963	288	406	420						
1964	285	3566	6321						
1965	925	1676	1947						
1966	280	1596	2884						
1967	276	449	480						
1968	251	437	467						
1969	222	1719	2783				222	458	536
1970	296	1620	2437				296	635	758
1971	335	2463	3745				335	764	921
1972	249	1730	2458				249	593	716
1973	210	1500	2133				210	637	835
1974	489	2302	3438				489	1024	1215
1975	407	1380	1800				407	890	1067
1976	303	864	1029				303	613	719
1977	291	1293	1603				291	761	945
1978	423	1852	2374				423	1009	1207
1979	388	1284	1527				388	1012	1235
1980	400	1773	2240				400	1191	1522
1981	596	4731	6754				596	1620	1989
1982	383	1822	2397				383	892	1064
1983	923	8454	12636				923	2482	3072
1984	531	3088	4320				531	1532	1959
1985	548	2999	4048	548	1244	1458	548	1709	2219
1986	473	3311	4736	473	2042	3073	473	1645	2269
1987	1107	8848	14111	1107	5178	8601	1107	3344	4378
1988	476	2181	3410	476	1260	1688	476	1258	1559
1989	498	4916	8073	498	2361	3956	498	1335	1701
1990	360	594	671	360	760	870	360	694	768
1991	354	625	710	354	765	877	354	652	715
1992	360	704	808	360	1058	1380	360	656	717
1993	362	728	849	362	984	1234	362	732	816
1994	255	371	385	255	553	622	255	510	564
1995	220	442	489	220	551	671	220	421	466
1996	290	479	519	289	683	803	290	539	590
1997	256	344	355	256	662	805	256	493	546
1998	879	1189	1299	871	1757	2025	879	1962	2292
1999	262	346	370	256	497	560	262	489	538
2000	161	265	287	160	367	428	161	344	388
2001	181	313	327	182	445	522	181	397	450

Table IV.11. SSB from assessments run with landings numbers-at-age (land) and catch numbers-at-age assuming 80 mm and 60 mm mesh size.

	otolith back-calculations			BTS			SNS		
year	**land**	**80**	**60**	**land**	**80**	**60**	**land**	**80**	**60**
1963	440	460	461						
1964	423	761	1037						
1965	414	498	525						
1966	416	591	725						
1967	493	532	535						
1968	456	490	494						
1969	418	584	692				480	628	652
1970	400	574	677				421	512	531
1971	372	643	802				357	425	441
1972	376	588	688				346	424	443
1973	335	512	596				297	367	385
1974	309	527	660				328	421	445
1975	320	462	520				301	403	429
1976	314	383	401				292	399	421
1977	329	458	496				268	371	395
1978	322	500	563				288	394	420
1979	309	426	456				292	409	439
1980	295	459	513				250	390	432
1981	305	829	1082				253	420	469
1982	297	489	558				262	411	448
1983	320	1123	1564				336	603	686
1984	320	604	729				370	653	739
1985	352	620	730	352	488	516	405	715	809
1986	351	640	779	351	555	659	368	653	753
1987	378	1140	1650	378	831	1171	460	917	1087
1988	357	566	697	357	589	662	393	713	799
1989	392	885	1225	392	736	925	475	847	940
1990	361	400	409	361	514	538	421	652	686
1991	310	345	354	310	433	453	373	538	560
1992	275	327	341	275	427	475	325	440	455
1993	243	295	310	243	385	425	287	390	406
1994	205	222	224	205	300	315	250	336	348
1995	183	213	219	183	271	290	196	260	270
1996	163	188	193	163	239	256	170	223	230
1997	145	158	159	145	222	241	145	197	206
1998	208	242	254	207	338	370	203	338	374
1999	212	229	231	210	325	345	213	356	389
2000	257	273	274	255	361	376	270	416	442
2001	228	246	245	225	294	305	244	323	334

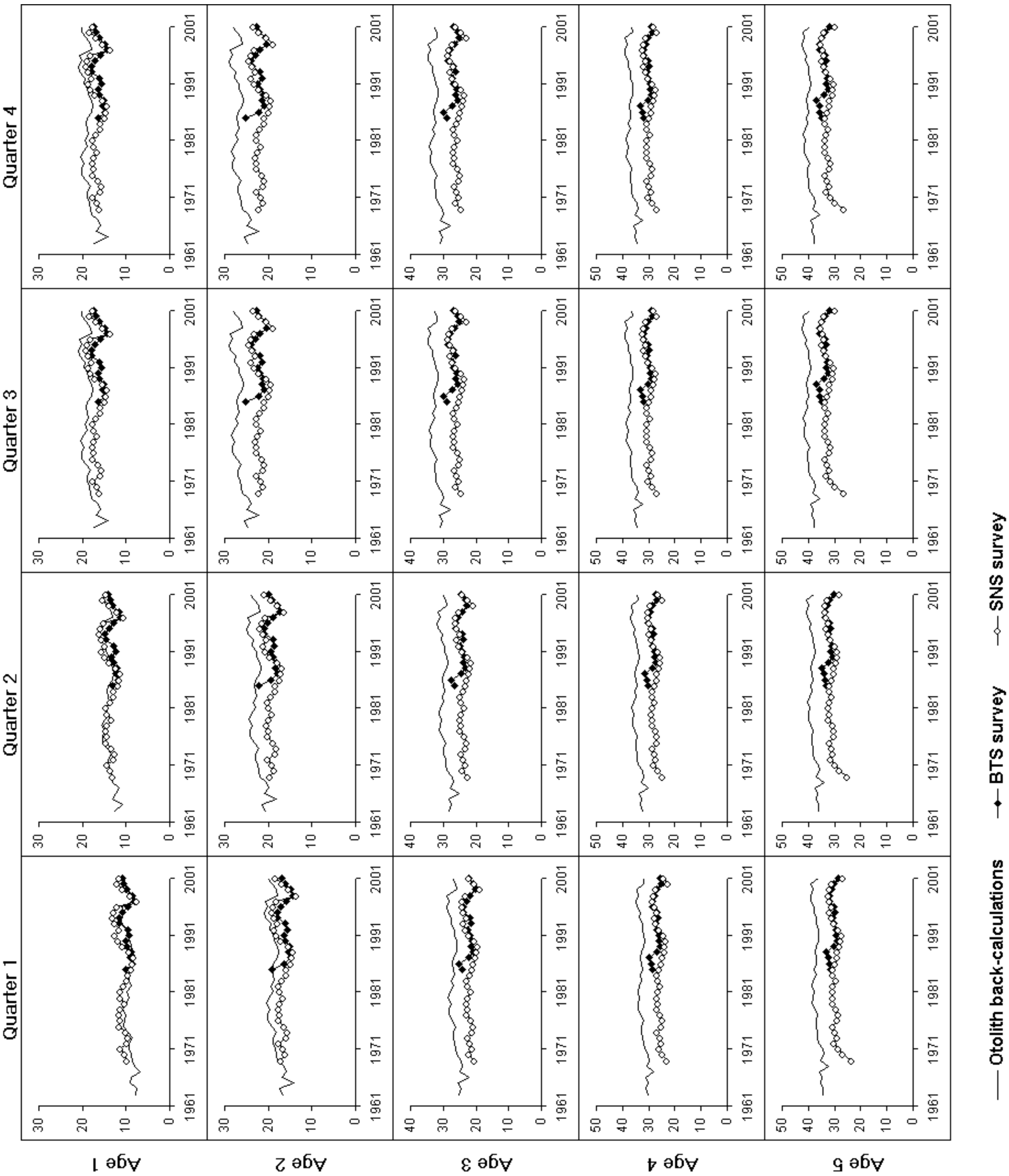

Figure IV.1. Simulated mean length by quarter and age. Growth signals derived from otolith back-calculations and BTS and SNS surveys respectively.

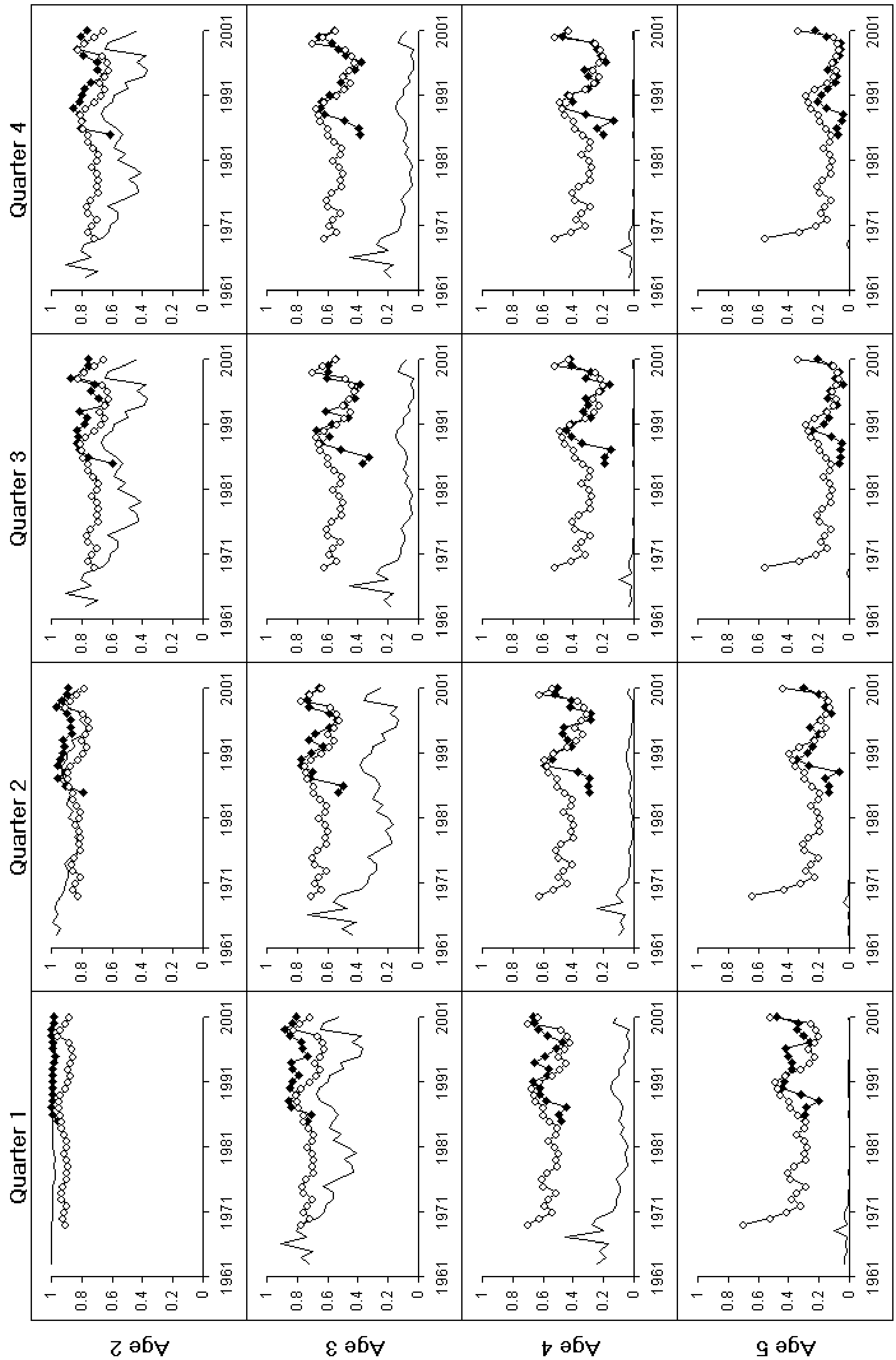

Figure IV.2a. Simulated proportion discarded assuming a 80 mm mesh size fishery**.**

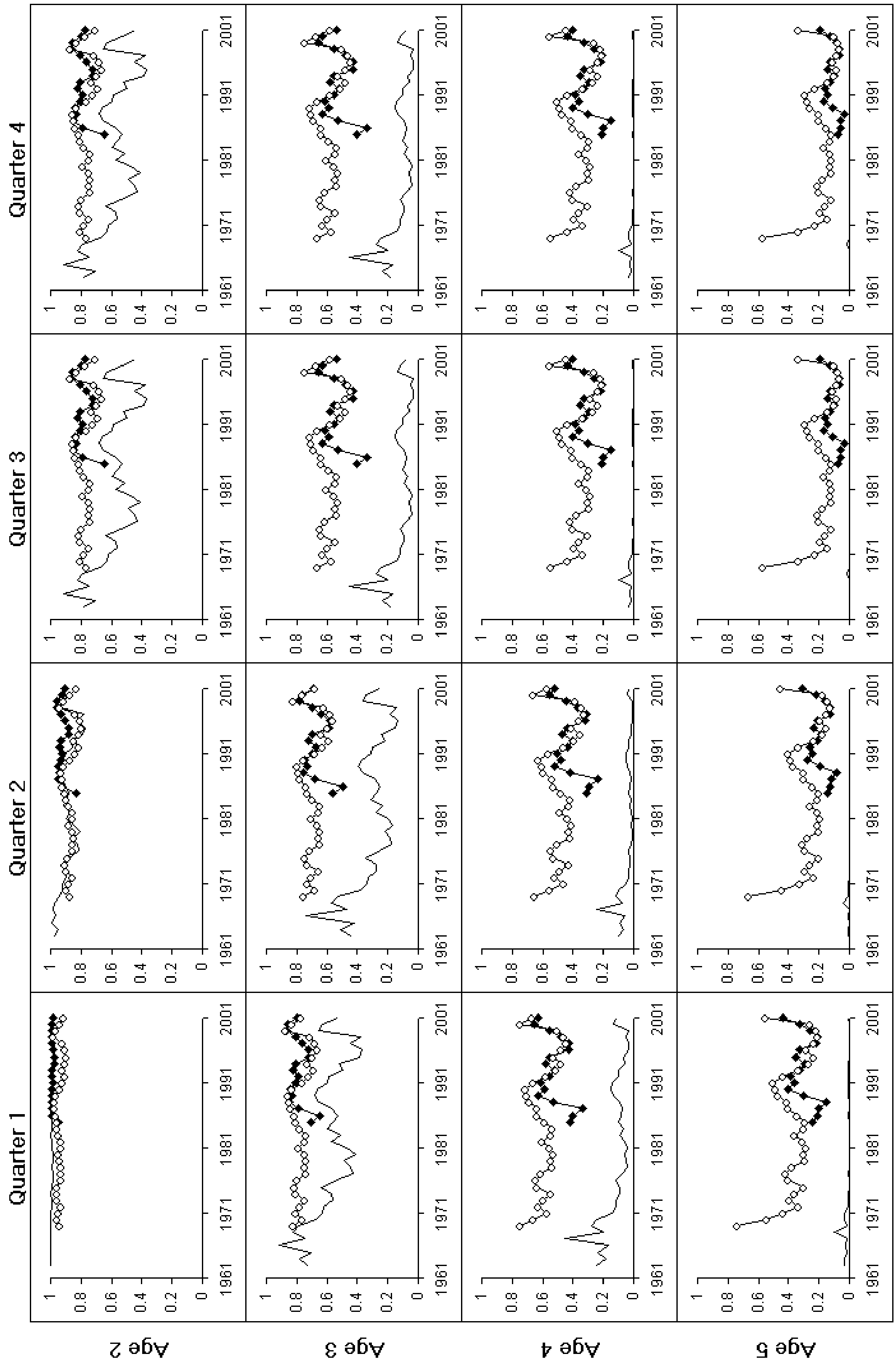

Figure IV.2b. Simulated proportion discarded assuming a 60 mm mesh size fishery.

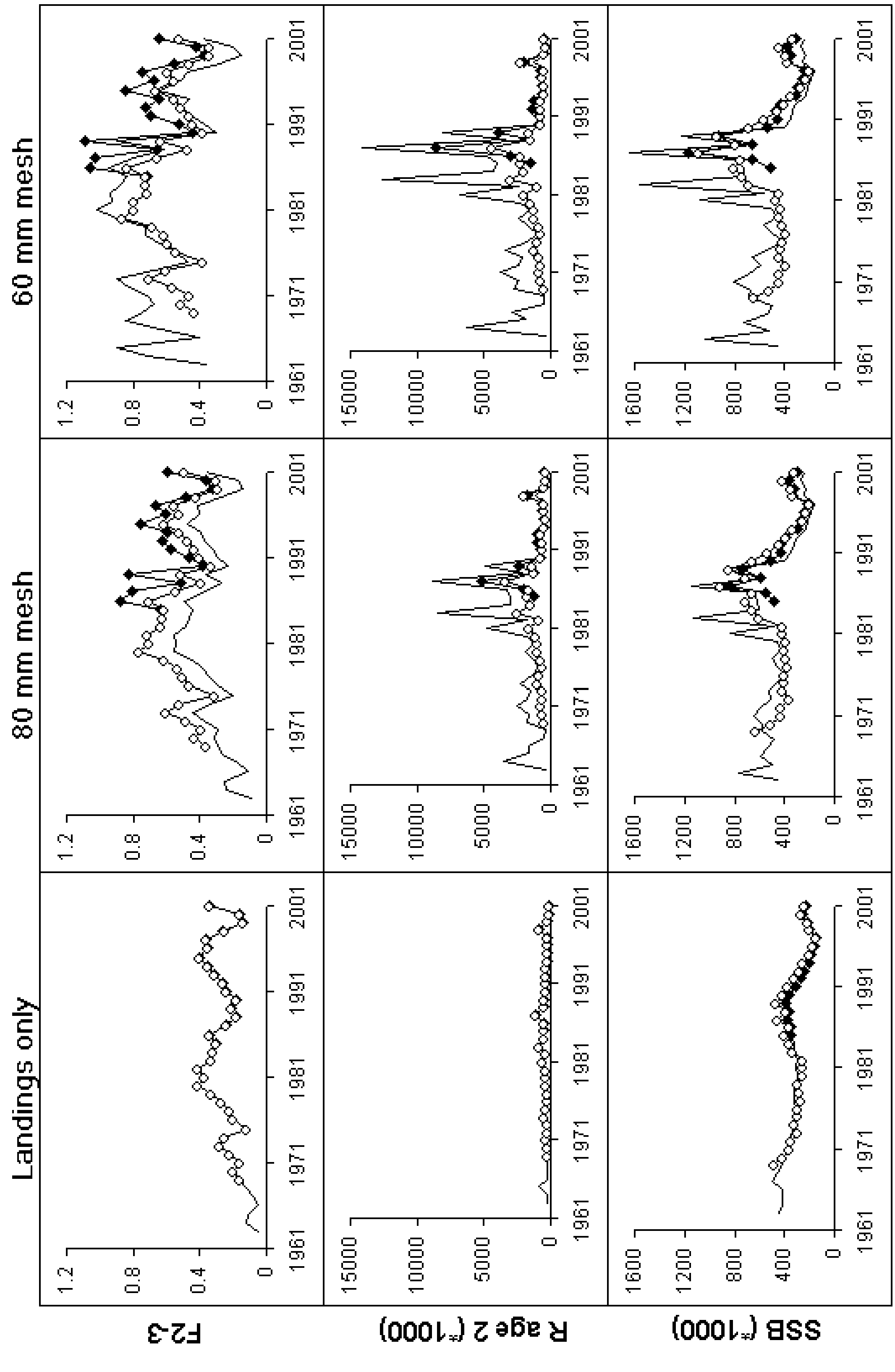

Figure IV.3a. Stock assessment results (SSB (in thousand tonnes), recruitment at age 2 (in thousands) and mean fishing mortality for ages 2 and 3) for three different scenario's (landings only, landings and discards assuming 80 and 60 mm gear) using three data sources to generate discard information (otolith back-calculations and BTS and SNS surveys).

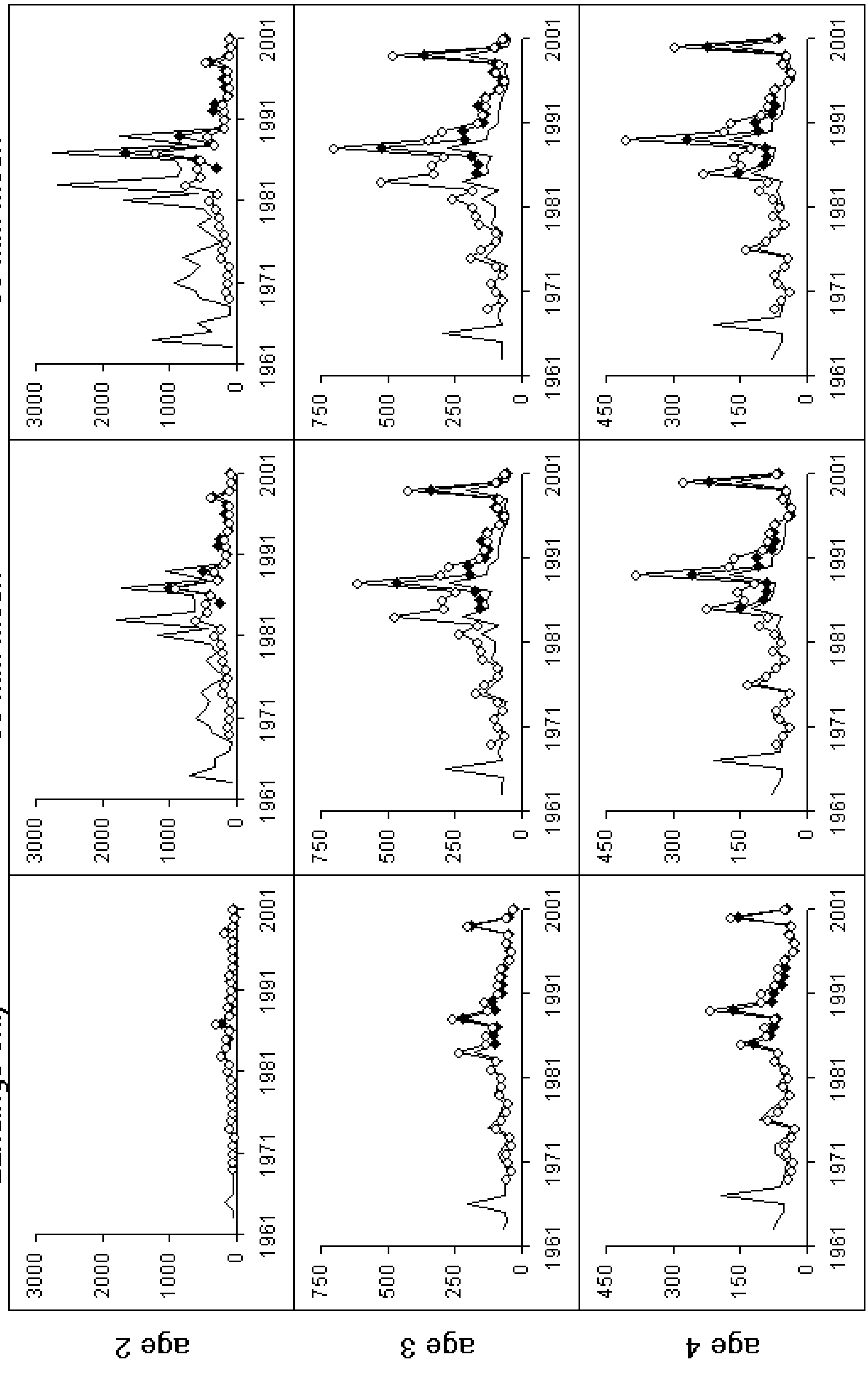

Figure IV.3b. Stock assessment results (biomass at ages 2, 3 and 4 in thousand tonnes) for three different scenario's (landings only, landings and discards assuming 80 and 60 mm gear) using three data sources to generate discard information (otolith back-calculations and BTS and SNS surveys).

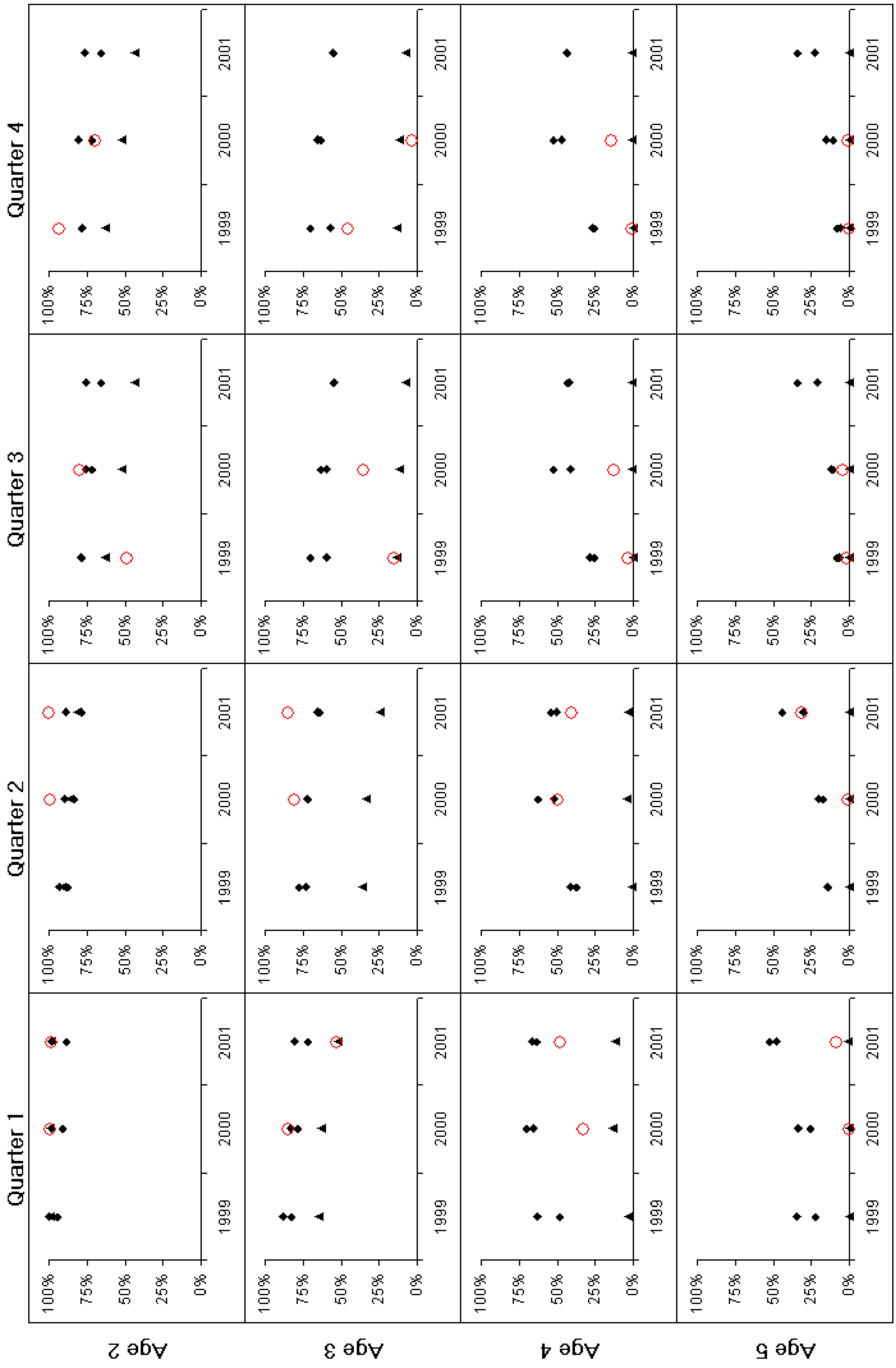

Figure IV.4. Comparison of observed discards proportion from onboard sampling of Dutch beam trawl vessels (1999-2001, red open circle) with simulated discards proportions based on growth data from otolith back-calculations (black triangle) and BTS (black square) and SNS (black circle) surveys by quarter, assuming 80 mm gear.