Effort management in a mixed North Sea flatfish fishery

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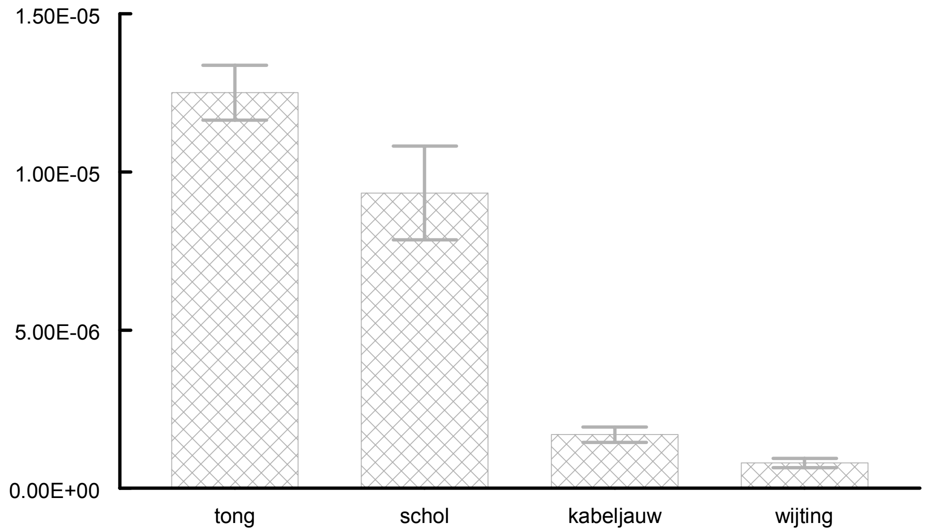
Inhoudsopgave

Nederlandse samenvatting

Het Nederlandse visserijbeleid wordt grotendeels bepaald door regels van de Europese Gemeenschap in het kader van het Gemeenschappelijk Visserijbeleid (GVB, Verordening [EG] 2371,2002) met doelstellingen ten behoeve van de duurzame uitoefening van visserijactiviteiten. Het resulterende visserijbeheer bestaat uit TAC's (Total Allowable Catches) met quota verdelingen, technische maatregelen met restricties aan vangsttuigen ter beperking van ongewenste effecten van de visserij en structuurmaatregelen om de vangstcapaciteit op de lange termijn te beperken.
De jaarlijkse TAC's en Quota's worden vastgesteld door de EG-Raad op grond van voorstellen van de EG-Commissie met inachtneming van de beschikbare wetenschappelijke adviezen. Voor 2007 is dit besluit te vinden in Verordening (EG) nr. 41,2007 van de raad van 21 december 2006, tot vaststelling, voor 2007, van de vangstmogelijkheden voor sommige visbestanden en groepen visbestanden welke in de wateren van de gemeenschap en, voor vaartuigen van de gemeenschap, in andere wateren met vangstbeperkingen van toepassing zijn. De verdeling van de TAC's in (nationale) quota's, de toegestane aanlandingen per land, vlootonderdeel of vaartuig, gebeurt volgens een vaste verdeelsleutel (relatieve stabiliteit) op basis van historische aanlandingen. Dit beheer via TAC's en quota's heeft niet tot de gewenste (lage) visserijsterfte (F, per jaar) geleid en visserij-inspanningbeheer wordt als mogelijk alternatief gezien.
Een TAC beheersysteem, waarbij het quotum de beperkende factor is, reguleert de aanlandingen en niet de visserijsterfte. De visserij wordt pas stop gezet als voor alle doelsoorten het quotum is bereikt. Zolang een van de quota nog niet is uitgeput, kan de visserij worden voortgezet maar mogen soorten waarvan het quotum al wel bereikt is niet meer worden aangeland. De overtollige vangsten worden dan overboord gezet of illegaal aangevoerd en op die manier ontstaat een groot verschil tussen het toegestane quotum, of legaal aangelande en geregistreerde hoeveelheid vis, en de totale vangst die wel met de visserijsterfte samenhangt.
Visserijinspanningbeheer via TAE (Total Allowable Effort) wordt als alternatief voor een TAC beheer beschouwd maar daarvoor dient de relatie tussen visserijsterfte en visserijinspanning bekend te zijn om zo de visserijsterfte direct te kunnen reguleren. Deze studie richt zich op de conversie van de quota voor tong, schol, kabeljauw en wijting in ton per jaar in een visserijinspanning (zeedagen per jaar) voor de belangrijkste vlootonderdelen binnen de Nederlandse kottervisserij.
In deze studie is de vangbaarheidscoëfficiënt (q, per zeedag) van een visbestand en een bepaalde vlootonderdeel gedefinieerd als de fractie van het totale visbestand die gevangen wordt per eenheid van visserijinspanning. De vangbaarheidscoëfficiënt wordt constant verondersteld en kwantificeert daarmee de relatie tussen visserijinspanning van een vlootonderdeel en de visserijsterfte die daarbij gegenereerd wordt.
De schatting van de vangbaarheidscoëfficiënt is uitgevoerd voor vier vlootonderdelen die een substantiële bijdrage leveren aan de aanlandingen en voor soorten waarvan de TAC in de Noordzee jaarlijks door de ICES werkgroep analytisch word vastgesteld (tong, schol, kabeljauw, wijting). De Nederlandse kottervloot werd hiervoor onderverdeeld naar motorvermogen: grote kotters (PK>300) en Eurokotters (225<PK<300) en het gebruikte vistuig: boomkor en bordentrawl. Voor de berekeningen is gebruikt gemaakt van visserijinspanning- en aanlandingsgegevens van de Nederlandse schepen (VIRIS) en de visserijsterfte schattingen van ICES.
Figuur 1 geeft de gemiddelde vangbaarheidscoëfficiënten voor de boomkorvloot van grote schepen (>300pk) in de periode 1996-2005. Met deze vangbaarheidscoëfficiënten kunnen de TAC's voor de vier soorten worden omgerekend in bijbehorende aantallen zeedagen. Hiertoe wordt voor iedere soort eerst het nationale deel van de TAC verdeeld over de verschillende vlootonderdelen. Met dezelfde verdeelsleutel wordt vervolgens de bij de TAC behorende visserijsterfte over landen en vloten verdeeld in partiële visserijsterfte. Het bij de TAC's behorende aantal zeedagen per soort voor dit vlootonderdeel kan dan direct worden berekend uit de partiële visserijsterfte en de vangbaarheidscoëfficiënt.



Figuur I. Vangbaarheidscoëfficiënten van tong, schol, kabeljauw en wijting voor grote boomkotters. De errorbars geven de 95% betrouwbaarheidsintervallen van de schattingen weer.

In volgende voorbeeld is het aantal zeedagen berekend voor de boomkorvisserij op tong in 2008 bij een visserijmortaliteit (F, per jaar) die samenhangt met het TAC advies voor 2008 (F_{2008} = 0.4). Omdat de grote boomkotters 65% van de totale TAC aanlanden is de partiële F voor dit vlootsegment 0.26 per jaar. Bij een vangbaarheidscoëfficiënt van $1.25 \cdot 10^{-5}$ zou de totale visserijinspanning voor deze vloot beperkt moeten blijven tot 20 800 (2000PK) zeedagen voor de tongvisserij. De partiële F voor schol is 0.16 en dit levert in combinatie met een vangbaarheidscoëfficiënt van $9.4 \cdot 10^{-6}$ 17 150 (2000PK) zeedagen voor de scholvisserij op. Op dezelfde manier kan het toegestane aantal zeedagen geschat worden voor de kabeljauw- en wijtingvisserij voor het betreffende vlootonderdeel. Onder een regime van visserij-inspanningbeheer moet de visserijactiviteit van een vlootonderdeel worden gestopt als de zeedagen voor een van de soorten benut is ook al zijn er nog zeedagen voor andere soorten beschikbaar. Het voordeel van dit inspanningbeheer is dat de visserijsterfte dan direct gereguleerd kan worden. Dit sluit aan bij het recent meerjaren beheersplan voor Noordzee tong en schol bestanden in Verordening (EG) nr. 767/2007 van de Raad, waarin beleid geformuleerd wordt om de huidige visserijmortaliteit van Noordzee schol en tong te halveren tot 0.3 en 0.2 per jaar. Naast een jaarlijkse TAC aanpassing op basis van schattingen van de visserijmortaliteit wil men een beperking van de visserijinspanning bereiken via een jaarlijkse bijstelling van het maximum inspanningsniveau voor de verschillende vloten.

Bovenstaande vangbaarheidscoëfficiënten zijn gemiddelde waardes. De coëfficiënten zijn ondermeer afhankelijk van de plaats waar en het moment waarop gevist wordt. Dit betekent dat de vangbaarheid zal toenemen als een visser zich sterker richt op één van de doelsoorten. Om te vermijden dat een visserij met de beschikbare zeedagen toch het toegestane quotum overschrijdt zal rekening gehouden moeten worden met de ruimtelijke en temporele variatie in vangstsucces en vangbaarheid.

Het vangstsucces hangt samen met de ruimtelijke en seizoensmatige verspreiding van een visbestand. Als zeedagen hoofdzakelijk besteed worden in gebieden waar het vangstsucces groter dan gemiddeld is, zullen er minder zeedagen nodig zijn om de quota op te vissen dan hierboven geschat is. Om de benodigde correctie voor vissen in een deelgebied/kwartaal combinatie te schatten zijn de VIRIS aanlandinggegevens geanalyseerd en het resultaat van de boomkorvisserij is samengevat in tabel I. Voor tong is de factor 0 in het noordelijk gebied en varieert tussen 0.7 en 1.5 in het midden en het zuidelijk gebied. Er kan dus in het

noorden gevist worden zonder dat dit zeedagen kost voor tong (en wijting). Voor schol varieert de factor van 0.5 tot 2.1 en dat wil zeggen dat afhankelijk van het gebied waar en het kwartaal waarin gevist wordt de gebruikte zeedagen voor schol verdubbeld of gehalveerd kunnen worden afhankelijk van de gebiedsseizoen-combinatie. De factoren zoals ze geschat zijn voor kabeljauw en wijting lieten een grotere range zien. Wanneer een vaartuig 10 dagen actief is in het 2e kwartaal midden, dan verminderd het tegoed aan zeedagen met respectievelijk 7, 8, 5 en 8 voor tong, schol, kabeljauw en wijting. Een zelfde visserijinspanning in het zuiden gedurende het 3e kwartaal resulteert in een vermindering van 12, 8, 16 en 21 zeedagen voor de verschillende vissoorten.
Het risico dat de toegekende quota worden overschreden, gegeven het voorgestelde visserij-inspanningbeheer werd geschat in deze studie. Hiervoor werden twee soorten onzekerheden onderscheiden. Allereerst de onzekerheid door variabiliteit die de objectieve of stochastische onzekerheid wordt genoemd en werd geschat op basis van de variatie van het vangstsucces rekening houdend met verschillen tussen gebied en seizoen. Daarnaast is er onzekerheid door beperkte kennis die ook wel subjectieve of secondaire onzekerheid genoemd wordt en geschat werd op basis van de variatie van de geschatte vangbaarheidscoëfficiënten. De objectieve onzekerheid was het kleinst voor de boomkor vloot. Om te voorkomen dat de quota overschreden worden (P>0.9) rekening houdend met deze onzekerheid zou de toegestane visserijinspanning met 1, 1, 3 en 4% verminderd moeten worden voor tong, schol, kabeljauw en wijting respectievelijk. De subjectieve onzekerheid is aanzienlijk groter: de benodigde reductie varieert van 15 to 25% afhankelijk van de vissoort.

		1e kwartaal	2e kwartaal	3e kwartaal	4e kwartaal
Noord	sol	0.0	0.0	0.0	0.0
	ple	1.9	1.7	1.9	2.1
	cod	3.5	0.5	0.6	1.7
	whg	0.0	0.0	0.0	0.0
Midden	sol	0.9	0.7	1.0	1.1
	ple	1.4	0.8	0.9	1.3
	cod	3.2	0.5	0.2	0.8
	whg	0.6	0.8	0.2	0.3
Zuid	sol	1.3	1.0	1.2	1.5
	ple	1.2	0.5	0.8	1.2
	cod	4.8	1.5	1.6	3.2
	whg	8.2	4.6	2.1	5.6

Tabel I. Factoren voor de correctie van toegestane zeedagen per gebied en seizoen voor de 4 vissoorten per seizoensgebied combinatie, gevangen door de grote boomkor vloot.

Opgemerkt moet worden dat de coëfficiënten, factoren en onzekerheden berekend zijn op basis van de aanlandingen van de vloot. Als een deel van de vangst aan maatse vis niet wordt aangeland, zal de werkelijke coëfficiënt hoger zijn. Dit speelt mogelijk een rol bij zowel kabeljauw als wijting.

Conclusie

TAC en quota's voor een visbestand zijn om te rekenen naar een toegestane visserijinspanning zoals zeedagen via de partiële visserijsterfte en de vangbaarheidscoëfficiënt van verschillende vloten die het bestand exploiteren.
Door rekening te houden met de temporele en ruimtelijke variatie van het relatieve vangstsucces kan het risico van een TAC of quota overschrijding beperkt worden. Dit met de kanttekening dat er geen rekening gehouden is met mogelijke veranderingen in het vispatroon als het TAC beheersysteem vervangen wordt door een visserijinspanning beheersysteem.
De subjectieve onzekerheid van bovenstaande conversie van quota naar zeedagen door beperkte kennis van processen is groter dan de objectieve of stochastische onzekerheid.

1. Introduction

The North Sea is an important fishing region in EU waters and is intensively fished. Fisheries management in European Community waters is governed by the Common Fishery Policy (CFP)[1], which aims a sustainable management of the fish stocks in Community waters. Its output control system using TAC, single species total allowable catch, and quota as management measures shows some serious drawback (Daan, 1997). Under the system of TACs fishers are allowed to fish as long as they do not oversupply their quota. Thereby, this type of management has built-in an obligation to discard in case too much of a species is caught. This may lead to up- or high grading. The main issue is, how should a mixed stock fishery be managed to ensure that none of the TACs are exceeded and that incentives for discarding at sea are minimized? The harvest strategy used for the North Sea flatfish is constant escapement aiming to maintain the spawning stocks near some (constant) level like Bpa (the precautionary approach threshold for spawning stock biomass) (Caddy and Mahon, 1995). The TACs or quota directly determine the landings and the fishing mortality (F, per year) is then the result of the removals of these landings and the accompanying discards. The rate of fishing mortality is closely related to the level of fishing effort and therefore setting a TAC alone does not effectively limit the exploitation level. It has been acknowledged that TACs are not the correct tool to achieve the conservation objectives (Holden, 1994) and is unsuitable for mixed fisheries (Rossiter and Stead, 2003).

Rijnsdorp et al. (2007) proposed a system of input control via effort management based on the idea that effort restriction will affect the fishing mortality directly. A management decision on effort, by limiting the number of fishing days at sea, will generate a certain fishery mortality and applying this fishery mortality on the stock results in the landings. In case of an effort based management system for a mixed fishery the fishing fleet is managed and not an individual species. A fisher is allowed to land the whole catch resulting in lower discards and better quality of fishery dependent data. As a potential alternative for TAC management, a method was proposed that allows TACs to be converted into a system of effort management.

In this paper a frame is provided for this alternative fishery management procedure through fishing effort control rules instead of landing control rules. The purpose of the study is to turn the TAC/quota system into a TAEs, total allowable efforts, system, without compromising on the principle of relative stability and without changing the aim of the CFP and the strategic reference points. In order to develop a model to convert fishery mortality rates based on quota into nominal fishing efforts like numbers of fishing days, information on the effectiveness, efficiency and exploitation pattern of fishing fleets is necessary. Here such information was gathered from the analysis of historic data of the Dutch demersal fishery, based on official landing statistics.

2. Material and Methods

2.1. Data

Data on landings and fishing effort by fishing trip of the relevant fleets are extracted from the national VIRIS database. VIRIS is a landing registration system that has been set up by the Dutch ministry of Agriculture, Nature and Food Quality in order to process the European log-book forms from fishers that are collected for inspection purposes.

[1] Council Regulation (EC) No 2371/2002 of 20 December 2002 on the conservation and sustainable exploitation of fisheries resources under the Common Fisheries Policy

Fishers fill out days at sea and landings per species (kg) for each ICES rectangle (~30x30 nautical miles) during each trip. At first, the main commercial species (plaice, *Pleuronectes platessa*; sole, *Solea solea*; cod, *Gadus morhua*; whiting, *Merlangius merlangus*; dab, *Limanda limanda*; turbot, *Psetta maxima* and brill, *Scopthalmus rhombus*) were registered. Since 2000 almost all landed species are recorded. The data are made available for research once a year and use of the data needs approval by managers and can only be presented in aggregated form. The dataset contains ship ID, country, gear code, harbor (start and return), ICES rectangle and species using character string as format. Trip ID, mesh size, date (start and return), effort, landing per species, length and engine power of the vessel is stored in numeric format. The landings were aggregated by trip and assigned to the ICES rectangle with the largest landing during that trip. For spatial analysis these ICES rectangles were grouped into three area's that could be relevant to the management regulations: north, mid and south (Figure 1). The north area covers the North Sea area north of 55°N and the south area is the area south of 53°N. The mid area is the intermediate area. For temporal analysis fishing trip dates were grouped into quarter of the year.

The Dutch -2007- quota of sole, plaice, cod and whiting are 75, 38, 9.5 and 7 percent of the total North Sea TACs for the respective species[2]. The combined quota of dab and flounder are 60% and those of turbot and brill are 55% of the North Sea TACs. The Dutch cutter fleet is dominated by large trawlers landing approximately 90% of the national plaice and sole total. These trawlers (>300 HP) operate in the offshore waters (>51°N) outside the 12-mile zone and the plaice box (Rijnsdorp et al., 2006). The number of vessels has declined since 1990 partly in response to the fleet-reduction policy of the European Community. The rest of the cutter fleet consists of smaller Eurocutters (250-300 HP) which are active mainly in the coastal zone. Apart from beam trawls as major gear occasionally otter board trawls are used as fishing gear. Thus 4 fleets, namely large trawlers (1) or Eurocutters (2) using beam trawl (a) or otter board trawl (b) were selected and analyzed separately. The landings of species with an analytical TAC were included (sole, plaice, cod, whiting).

2.2. Partial fishery mortality and catchability

Yearly catch of a fleet is a function of its fishing effort (E, e.g. [standardized Hp] days fished per year), stock size (biomass) and catchability coefficient (q, per day at sea fished). The partial fishery mortality (per year) imposed by that fleet is $E \cdot q$. Total fishery mortality estimates (F_{tot}, per year) in ICES area IV of plaice, sole, cod and whiting are available from the single species stock assessments done by the ICES Working Group (ICES, 2007). The TACs are distributed in quota among countries following the relative stability principle. The Working Group report also contains total landings of the 4 species.

Total annual fishery mortality per species averaged over the age classes 2-6, from 1990 onwards and updated to 2005 was taken and split into a partial fishery mortality ($F_{partial}$, per year) according to its proportionality with the ratio between the sum of the landings of the fleet analyzed (L_{fleet}) derived from the VIRIS database and the total landings (L_{tot}) in ICES area IV.

$$F_{partial} = F_{tot} \cdot \left(\frac{L_{fleet}}{L_{tot}} \right)$$

Annual landings and efforts (E_{tot}) of the various fleets were calculated from the VIRIS database. For the effort estimations engine power (HP) and days of active fishing during a trip were taken into account. Effort (days at sea) applied during each trip was standardized to 2000 HP for large trawlers and 300 HP for Eurocutters.

[2] Council Regulation (EC) No 41/2006 of 21 December 2006 fixing for 2007 the fishing opportunities and associated conditions for certain fish stocks and groups of fish stocks, applicable in Community waters and, for Community vessels, in waters where catch limitations are required

The catchability of a fleet, q, gives the fishing mortality imposed per unit of effort (standardized Hp fishing days at sea) and was estimated by the ratio $F_{partial}/E_{tot}$ of the fleet per year, because $F_{partial} = q \cdot E_{tot}$ and q is assumed to be independent of the variation in the abundance of the fish. Catchability represents here the effectiveness of the fleet.

Following this retrospective analysis of the catchability the restricted fishing effort of a fishing fleet is then calculated from the TAC with the accompanying forecasted or predicted F, F_{pred}. F_{pred} is then partitioned into partial predicted F, $F_{part.pred}$ for the various fleets based on the landing shares of that fleet. Total number of permitted fishing days at sea for a species, giving partial predicted fishing mortality and the catchability of the fleet is calculated as $E_{fleet} = F_{part.pred}/q_{fleet}$. In case that the permitted fishing days are equally distributed among fleet vessels, the individual (vessel) effort quotas are then the total permitted number of fishing days divided by the number of fleet vessels.

2.3. Landing per Unit of Effort and temporal-spatial conversion rates

When yield and fishing effort are considered as the output and input respectively of a fishery fleet, the ratio of output and input or landing per unit of effort (LpUE, kg per day at sea) can be regarded representative for the temporal and spatial efficiency of the fishery due to variation in fish abundance. Higher predicted LpUE values mean that an input of a fishing day in the area and season most probably will generate higher landings. To take this variation into account the predicted LpUE values are transformed into effort multipliers for all combinations of area and season.

LpUE was estimated using the ratio of the landing (kg) of a species during a vessel trip and the effort applied during the trip in (2000 or 300 HP) days at sea. The variability in LpUE of the species and fleets was analyzed using least squares to fit general linear models (SAS, 2002 proc GLM). The LpUE estimations were log-transformed because the original data distributions were positively skewed. Moreover, temporal and spatial effects in abundance data are usually multiplicative and log-normal distributions provide non-zero confidence intervals for spatial and temporal combinations with low estimates. The landing data of the different fleets show a number of zero values and a log-normal distribution does not allow for zero's in the dataset. To deal with this problem, observations with structural zero landings were removed from the data-set in those cases when the species is not present in the area (sole and whiting in area North). The remaining zero landings were transformed by adding a constant of 1, 1, 10 and 20 kg for cod, whiting, sole and plaice respectively. The value of the constant was selected such that the parametric analysis of variance assumptions that errors are normally distributed and have a constant variance are still satisfied (Fletcher et al. 2005).

To allow for the comparison of spatial and seasonal effects between years, the main year effect was removed by subtracting the yearly means from the individual $\log(LpUE)_i$:

$$\varepsilon_{j,i} = \log(LpUE)_{j,i} - \overline{\log(LpUE)_j}$$

The remaining distribution of residuals ($\varepsilon_{i,y}$) , used for further analysis, has a mean of 0. These residuals were used in the analysis of variance (ANOVA) with area (north mid and south) and season (quarter 1 to 4) as main factors. To allow for differences in the effects from year to year the tree way interaction area·season·year was included in the model:

$$\varepsilon_{j,k,l,i} = A_l + S_k + A_l \cdot S_k \cdot Y_j + \varepsilon''_{j,k,l,i}$$

The antilog transformed model prediction for a particular area season year combination represent then the effort multiplication factor to compensate for the variation in LpUE between area's and seasons for the different species. For example, incase the effort multiplication factor for a certain species equals 1.5 for a specific area-season combination and a fisher decides to fish then and there for 4 days, his effort quota for that species is reduced by 6 days. The effort quota for the other species are reduced similarly according to the values of the multiplication factors for the respective species. If the remaining effort quota for one of the species becomes zero, the fisher stops fishing.

2.4 Errors and risk

The transformation of landing quota into fishing effort quota could incorporates the undesirable event that given a certain amount of allowed number of days at sea in the year to come the agreed quota's and target TAC point estimate are exceeded. The probability or likelihood that this will happen is, given that catchability was estimated unbiased, theoretically 0.5. To avoid quota exceeding the actual allowed effort should be lowered with a percentage similar to the upper confidence range as % of the estimated quota. To quantify the error distribution around the expected quota, the residuals of LpUE or multipliers estimation was taken as a starting point, because these distributions are already corrected for temporal and spatial variation in catchability and fish abundance. The standard error of the residuals, given the number of fishing trips per year for a given fleet is then used to estimate how much the quota point estimates may possibly exceeded (expressed as a percentage) given a probability or likelihood of 0.9

Since the coefficient of variation (CV) is easily estimated from the standard deviation of the log-transformed distribution as

$$C.V = \sqrt{e^{sd^2} - 1} \cdot 100$$

The risk formula, estimating the exceeding percentage, $\% = \sqrt{e^{se \cdot 1.28^2} - 1} \cdot 100$, where 1.28 is the z-statistic of the area 0.9 under the standard normal probability curve, below this z-statistic. The probability of any other level of exceeding can then be estimated by using the appropriate z statistic. The allowed effort should be reduced with the calculated percentage to avoid quota exceeding with a probability of 0.9

Apart from objective uncertainty which rises from the variability of the underlying stochastic system there is also a subjective uncertainty that results from not having the complete information on the state of fish stocks and fishery. To quantify this we use the variation of the catchability coefficient estimates from year to year. The standard deviation of the log transformed catchability coefficients was calculated and used in the risk formula described above.

3. Results

3.1. Partial fishery mortality and catchability

The average annual fishing effort applied from 1995 to 2005 by the fleets: large trawlers using beam trawl or otter board trawls as fishing gear and Eurocutters using beam trawl or otter board trawls are summarized in Table 1. On average the effort of the large trawlers equaled 29500 (2000 HP) days at sea and 8400 (300 HP) days at sea for Eurocutters. Approximate 30% of the Eurocutter-effort was used for fishing with otter-board trawls as gear, while less then 1.5% of the large trawler effort was applied using this gear. The time-series of the large trawler effort showed a significant negative trend of -1270 (2000 HP) days at sea per year. The nominal total effort of this fleet has reduced by 30% during the period of the analysis to approximately 23000 (2000HP) days at sea per year. The Eurocutters using beam trawl as gear showed a negative trend in effort of -250 (300 HP) days at sea per year, which is a reduction of 35% over the 10 year period.

The effort relative distributed over the quarters of the year and the area's is shown in Figure 2. The fishing effort of the large beam trawlers is equally distributed over the quarters. On average 38% of the effort was applied in the south, 55% in the mid area and 7% in the north. Higher efforts were observed in quarter 1 of area south, quarter 3 area mid and quarter 2 of area north. The pattern of Eurocutters using beam trawl showed high fishing effort in quarter 2 and 3 being respectively 1.56 and 1.26 times higher then the overall average per quarter. The overall seasonal pattern of Eurocutters using otter trawl as gear ranged from 0.8 to 1.2 the average per quarter per year. The effort switched from area north in quarter 4 and 1 to area mid in quarter 2 and 3.

Estimated partial Fs ($F_{partial}$, per year) of the large beam trawler catches in the period 1996 to 2005 of plaice, sole, cod and whiting are shown in figure 3a. Partial F of sole and whiting showed a high correlation of 0.85 ($p<0.01$) with the fishing effort applied. The correlation coefficients between partial F and fishing effort of cod and plaice were 0.45 and not significant. The resulting catchability coefficients are shown in figure 3b and ranged from $1.25 \cdot 10^{-05}$ per day at sea for sole to $8.12 \cdot 10^{-07}$ per day at sea for whiting. The catchability coefficient for plaice and cod were $8.78 \cdot 10^{-06}$ and $1.57.10^{-06}$ per day at sea. Only the catchability coefficient of whiting showed a significant (negative) linear time-trend.

Estimated partial Fs (per year) for the Eurocutter (using beam trawls) catches in the period 1996 to 2005 of plaice, sole, cod and whiting are shown in figure 4a. Partial F of cod and plaice showed a high correlation of 0.85 ($p<0.01$) and 0.95 ($p<0.01$) respectively with the fishing effort. The correlation coefficients between partial F and fishing effort of whiting and sole were 0.42 and not significant. The resulting catchability coefficients are shown in figure 4b and ranged from $6.6 \cdot 10^{-06}$ for sole to $4.0 \cdot 10^{-07}$ for Whiting. The catchability coefficient for plaice was $2.3 \cdot 10^{-06}$ and cod $6.3 \cdot 10^{-07}$. The catchability coefficients of plaice, cod and whiting showed significant negative linear time-trends.

The estimates for partial F's and accompanying catchability coefficients of large trawlers and Eurocutters using otter board trawls as gear is summarized in table 2. Results for these fleets are generally characterized by their higher variability.

3.2. Landing per Unit of Effort and multipliers

Table 3 summarizes the result for multipliers of the various species and fleets in different area / quarter combinations.

Large trawlers using beam trawl showed the highest LpUE of plaice in the northern area: on average the plaice LpUE was 1.8 times higher then the overall mean LpUE. The multiplier decreased to 1.1 and 0.8 for the mid and south area respectively. Multipliers lower then one were observed in quarter 2 and 3 area mid and south. Other area-quarter combinations showed higher multipliers. The multiplier of sole in the south area was found 1.2. Multipliers lower then 1 were found for quarter 1 and 2 in the mid area. The results found for cod using the same vessel gear combination showed that the multiplier found during quarter 4 was 3.7. In area south multiplier values above 1 were found and during quarter 2, 3 and 4 for area mid and north multiplier values lower then 1 were found. The results found for whiting shown in table 5 revealed that the LpUE found in area south were found 4.7 times higher then average. Lower values with a multiplier 0.4 were observed in area mid.

The results for other vessel-type/gear/species combination show larger variation of the multipliers for fishing effort. Values of plaice landed by large trawlers using otter trawls were highest for the northern area and lowest in the south, where particularly low values (0.2) were observed during quarter 1 and 4. A significant positive linear trends was found for the time series of quarter 1 in the mid area, while quarter 3 in the same area showed a negative trend. The plaice multipliers of Eurocutters using beam trawl were also highest in the north area and lowest in the south. Quarter 1 and 4 showed higest values, especially in the south area. Eurocutters using otter trawls as gear showed highest values in the mid area and quarter 3

Multipliers of sole landings were higher for the south area. Quarter 2 and 3 show higher multipliers for all vessel gear combination except large trawlers using beam trawls. Large beam trawlers in quarter 1 and 4 showed the highest multipliers. Whiting and cod results showed large variation and were on average higher for the south area. Over all vessel-gear combinations cod multipliers were highest for quarter 1. Eurocutters using beam trawl showed an extreme high multiplier (39.6) for the first quarter in area north.

To illustrate the variation among years the time-series of the multiplier values of plaice were plotted for all 12 season-area combinations of large beam trawlers in Figure 5. Significant ($P<0.01$) positive time-trends were found for the series of multiplier values in the north for all quarters. The results of sole, cod and whiting are shown in Figure 6, 7 and 8 respectively. None of the sole time-series showed a significant trend. Significant ($P<0.01$) positive time-trends were found for the series of cod multiplier values in the south and mid area for quarter 1. During quarter 2 and 3 significant ($P<0.05$) trends were observed for area mid and north. Whiting values showed a significant trend for the mid area quarters (positive) and a negative trend for the mid area quarter 3. The variability, expressed as CV around the average was high for whiting (35%) and cod (43%) compared to plaice (14%) and sole (19%).

3.3. Quantify the uncertainty and risks

The maximum exceeding percentage of the nominal quota, under the conditions that the catchability coefficient estimates are unbiased and at a given probability of 0.9 is shown in Figure 9 for species, vessel and gear combinations. At this probability there is still a chance of exceeding the upper limit at 1 out of 10 cases. In case the given probabilities are changed to 0.99, 0.95 or 0.8 the presented percentages should be multiplied with 2.4, 1.3 or 0.65 respectively. The upper limits differ to a great extend depending on the species, vessel-type and gear combination. For plaice and sole caught by large beam trawlers the percentages are below 1%. To prevent possible quota exceeding allowed fishing effort should be reduced with these percentages. Other species, vessel and gear combinations exceeding percentages range from 3 % for plaice caught by Eurocutters using beam trawls to percentages of more then 10% that were found for cod and whiting caught by large beam trawlers.

Potential quota exceeding percentages are larger in case the subjective uncertainty of the catchability coefficient estimates were taken in to account, based on the variation from year to year. These results are presented in figure 10. The percentages found for the major species-vessel-gear combination, plaice & sole caught by large beam trawlers were 26.2 and 14% respectively. Results for cod and whiting were 26.4 and 34.9%. Eurocutters using beam-trawl as gear showed exceeding percentages of 26, 32, 66 and 94 for sole, plaice, cod and whiting respectively. The percentages for fleets using otter board as gear where above 60% and 100% for Eurocutters and large trawlers respectively.

4. Discussion & conclusion

The scope of this study is to address the conversion of a TAC (output) management system into a fishing effort (input) management system for a mixed demersal trawl fishery. It should be realized that the overruling management system remains a TAC and quota system. The effect of the effort measures on catches and landings must be monitored continuously on a real time basis in order to be able to make real time adjustments in the effort allocation to prevent overshooting of quota.

The catchability coefficient, q (per day at sea) is used as the overall conversion factor of quotas, expressed as partial Fs, into nominal fishing efforts and its prediction is simple and straightforward. For example, the ICES TAC advice of North sea sole corresponds with F_{2008} being equals to 0.4 per year and contribution of the large beam trawler fleet to its exploitation is approximately 65%, resulting in a partial F for this fleet of 0.26. The estimated q was $1.25 \cdot 10^{-05}$, which then results in a total fishing effort limitation of 20 800 (2000 Hp) days at sea for sole caught by large beam trawlers. Catchability is probably never constant but subject to complex random and nonrandom variation. The main problem when implementing a fishing effort management regime is the subjective uncertainty caused by our imperfect knowledge on the relationship between fishing mortality and fishing effort that leads to a considerable risk of exceeding the quota. Catchability will also change after the introduction of a fishing effort management system because this results in reallocation of fishing effort between fishing area's and/or seasons. This means that the key question remains how the fleets are behaving. It is assumed that catchability of the most valuable species will increase because limits on effort lead to competition among fishers for the available fishing opportunities. Similarly the existence of technological creep may lead to higher Fs and lower fish biomass. So, transition of TAC to TAE will most probably lead to a more efficient fishery by either a direct increase of the catchability or a spatial and/or temporal shift of fishing effort with the accompanying change in efficiency.

The seasonal and temporal variation of LpUE was used to estimate effort multipliers when the allocated fishing effort is applied in a certain area-season combination. The total fishing effort of large trawlers has reduced considerably over the last 10 years. The spatial and temporal allocation of the effort in relative terms has remained constant across the time period under examination. After implementing an effort management system the spatial and temporal fishing pattern will most probably change. Such a change may also have an effect on the LpUE values and therefore the catches and effort should be monitored and these data should be used to update and eventually change the multiplication factors for the efforts in specific season area combinations. The initial allocation of effort could be a fixed number of allowed days at sea for each vessel for a short period for instance a month. In this respect the information derived from vessel monitoring systems (VMS) and catch reports could be used to keep track of fishing pattern changes and allow feedback into real-time fisheries management decisions in the succeeding periods.

A vessel belonging to a fleet managed under an effort limitation system is free to plan its fishery activity within the nominal number of allowed days at sea and taking into account the multipliers for the various species. Under these constraints all fish caught above the minimum landing size can be landed. Ultimately the effort limitation within a multi-species fishery is set to that of the species, whose limits are exceeded first and the fishery stops as soon as the allowed effort this species is reached. Most probably the stock dynamics of the most valuable major species (e.g. North Sea sole) determines the effort level to a large extend. Here the management may intervene by using different temporal and spatial multipliers. Currently these multipliers are only based on LpUE values as recorded in the registration system and weighted for the duration of a trip. Depending on relevant objectives or criteria, the inputs and/or weights used to estimate the multipliers can be modified and will then result in a different temporal and spatial management regime. Similarly, the current (biological) risk assessment on exceeding TACs and quotas may be extended to evaluate the risk against predefined criteria, because fishery systems are complex and contain ecological, social and economic processes that interact.

LpUE is used instead of CpUE, because temporal and spatial information on amounts of discarded fish is lacking. In case the allowed quota for an important target species are too high and it is not possible to catch the amount, this lead to serious problems under a TAC management regime because the fleet will continue to search for the target species and only catches other species whose quota are already taken or are undersized. The result is a serious discard problem. Usually these high quota are the result of overestimated stock size and underestimated fishing mortality or restrictions in quota change between years. Under an effort management an underestimation of fishing mortality will lead to a low allowed fishing effort level needed to land the TAC. Since the effort levels are defined for all the species, the risk of discarding the fish is lower in comparison with the TAC management system.

The success of a management system with limitation of fishing effort depends on the potential for input substitution. The risk of input substitution, which is the substitution of effort towards species with unregulated input for species that are regulated by restricted input, is prevented by simultaneously setting allowed fishing effort levels for all exploited species. In this study risk analysis was done to assess an issue that can go wrong namely exceeding quotas and/or TACs and how likely this is. The next step is risk management, which deals with the issues what can be done to reduce either the likelihoods or the consequences. Probability of exceeding quota is large for the minor fleets and a effort management system should concentrate first on the large beam trawler fleet, with quota shares of plaice and sole TACs of 0.3 and 0.6 respectively. Otter board trawls, OTB, is a category in the VIRIS database that contains also some other gears such as twin riggers. In the framework of this study it was impossible to distinguish between the gears used in the OTB category. This might be one of the reasons for the large variation found for the OTB effort multipliers.

Under the current TAC management system, the national Dutch quota is distributed to fishers via individual quota, which are tradable goods (ITQ). Tradability of allowed days at sea is more complex because the proposed multi-species approach and differences in engine capacity that results in variable efficiencies. When transfer or trade of fishing days at sea is allowed to vessels with higher engine power, the chance of introducing technological creep is considerable because the fleet becomes more effective.

The temporal and spatial analysis of LpUE variation was in this study done at aggregated levels of 4 fleets, 3 area's and 4 quarters over 10 years and the observation on which the analyses were based have a resolution of an individual vessel with trip duration (1 to 5 days) and ICES rectangles (30x30 nm). The analysis can be executed at any aggregated resolution level in-between depending on the management objectives. It should be realized however, that changes of the aggregation level affect the objective uncertainty. Similar the estimation of the catchability coefficients at fleet-gear levels can also be done at lower resolution e.g. by calculating a partial F for an individual vessel trip and ICES rectangle.

For an effective and feasible fishing effort management system enforcement is still necessary but this is easier than in a TAC and quota management system, because it is simpler to monitor a vessel's activities compared to its catches. The current analysis did not include the use of multiple gear during one trip and the change of gears is hardly noticeable by controllers. Fishers should register their intention on the gear category that will be used during a predefined management period.

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Tables

Table 1. Overall average fishing effort and significant time-trends found for the vessel gear combinations analyzed.

vessel type \ gear code	gear code	Average	S.E.	Δ effort/yr	S.E
large trawler	**TBB**	29200	400	-1270	140
large trawler	**OTB**	360	40	N.S.	.
Eurocutter	**TBB**	5600	160	-250	60
Eurocutter	**OTB**	2800	170	240	60

Table 2. Estimates of partial F's and catchability coefficients of fleets using otter board trawls as gear for sole, plaice, cod and whiting.

fish species \ vessel type	vessel type	partial F	S.E.	q	S.E
sole	**BT**	0.00014	0.00027	$5.9 \cdot 10^{-7}$	$9.0 \cdot 10^{-7}$
plaice	**BT**	0.0029	0.0014	$8.1 \cdot 10^{-6}$	$2.3 \cdot 10^{-6}$
cod	**BT**	0.0035	0.0024	$9.0 \cdot 10^{-6}$	$4.0 \cdot 10^{-6}$
whiting	**BT**	0.0019	0.0014	$8.2 \cdot 10^{-6}$	$7.5 \cdot 10^{-6}$
sole	**EC**	0.00052	0.00042	$1.2 \cdot 10^{-6}$	$7.5 \cdot 10^{-7}$
plaice	**EC**	0.0031	0.0021	$6.9 \cdot 10^{-6}$	$3.1 \cdot 10^{-6}$
cod	**EC**	0.018	0.0080	$4.5 \cdot 10^{-5}$	$1.8 \cdot 10^{-5}$
whiting	**EC**	0.097	0.0058	$2.4 \cdot 10^{-5}$	$1.2 \cdot 10^{-5}$

Table 3. Multipliers of the fishing effort per season and area of all possible species/vessel-type/gear combinations.

	quarter							quarter				
species	1	2	3	4	vessel	**area**	gear	1	2	3	4	species
ple	1.9	1.7	1.9	2.1	LT	**N**	TBB	3.5	0.5	0.6	1.7	cod
ple	1.4	0.8	0.9	1.3	LT	**M**	TBB	3.2	0.5	0.2	0.8	cod
ple	1.2	0.5	0.8	1.2	LT	**S**	TBB	4.8	1.5	1.6	3.2	cod
ple	1.6	1.4	1.7	1.8	LT	**N**	OTB	1.5	0.6	3.5	1.1	cod
ple	1.3	0.9	1.9	1.6	LT	**M**	OTB	3.2	1.1	0.7	1.0	cod
ple	0.2	0.4	1.3	0.2	LT	**S**	OTB	3.5	0.8	0.9	3.7	cod
ple	2.5	3.4	4.5	3.0	EC	**N**	TBB	39.6	4.1	0.1	9.7	cod
ple	1.6	0.7	1.3	2.4	EC	**M**	TBB	14.5	0.5	0.3	2.1	cod
ple	1.3	0.9	0.8	1.5	EC	**S**	TBB	6.1	0.9	0.5	7.9	cod
ple	2.2	2.2	4.6	4.6	EC	**N**	OTB	2.5	0.9	1.9	0.2	cod
ple	3.3	1.1	1.7	1.5	EC	**M**	OTB	1.1	0.6	0.2	0.8	cod
ple	0.7	1.0	1.3	0.6	EC	**S**	OTB	2.5	0.3	0.4	3.6	cod
sol	0.9	0.7	1.0	1.1	LT	**M**	TTB	0.6	0.8	0.2	0.3	whg
sol	1.3	1.0	1.2	1.5	LT	**S**	TTB	8.2	4.6	2.1	5.6	whg
sol	0.8	0.9	0.8	2.1	LT	**M**	OTB	0.3	3.1	1.3	0.5	whg
sol	2.4	2.6	7.7	1.8	LT	**S**	OTB	20.3	28.6	18.0	443	whg
sol	0.6	0.7	0.7	0.8	EC	**M**	TTB	1.9	0.8	0.4	1.1	whg
sol	1.0	1.3	1.6	0.8	EC	**S**	TTB	2.9	1.0	0.5	12.0	whg
sol	0.8	0.8	1.0	1.3	EC	**M**	OTB	0.7	1.1	0.9	0.7	whg
sol	1.1	1.8	1.7	1.1	EC	**S**	OTB	0.8	1.7	1.9	6.0	whg

Figures

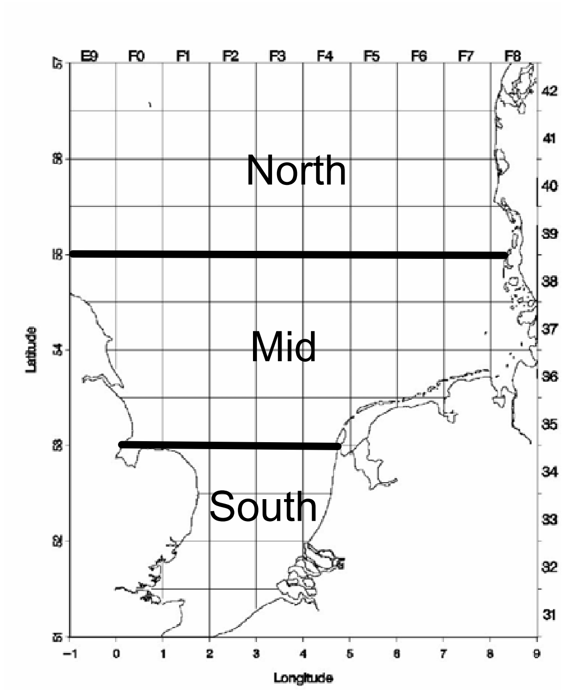
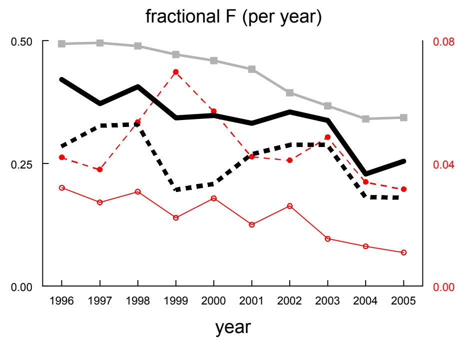


Figure 1. North sea ICES rectangles and the grouping into three areas used in the analysis.



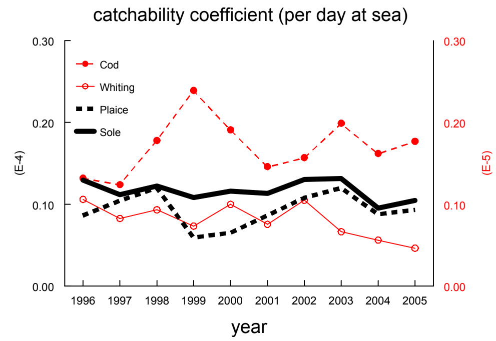
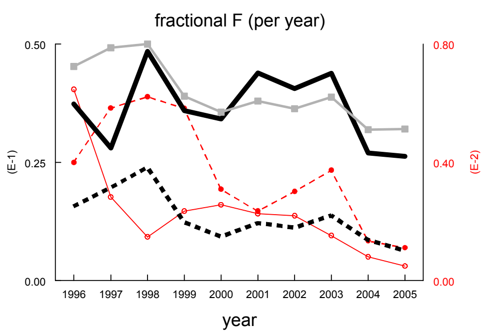


Figure 2a (left): Partial fishery mortality imposed by the large beam trawl fleet from 1996 to 2005 of sole (bold black line, right axis), plaice (bold broken black line, right axis), cod (thin broken red line and closed circles, left axis) and whiting (red line and open circles, left axis). Total effort (relative) is shown as a gray line with closed squares.

Figure 2b (right): Catchability coefficients of large beam trawl vessels from 1996 to 2005 for sole (bold black line, right axis), plaice (bold broken black line, right axis), cod (thin broken red line and closed circles, left axis) and whiting (red line and open circles, left axis).



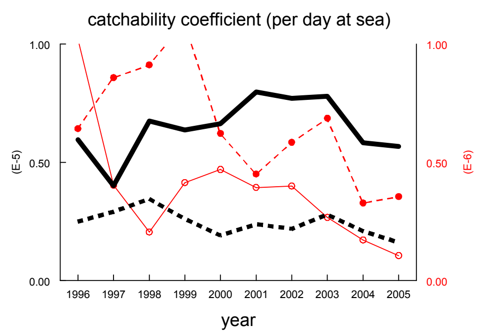


Figure 3a (left): Partial fishery mortality imposed by the Eurocutter beam trawl fleet from 1996 to 2005 of sole, plaice, cod and whiting. Total effort (relative) is also shown. For legend, see figure 1.

Figure 3b (right): Catchability coefficients of Eurocutter beam trawl vessels from 1996 to 2005 for sole, plaice, cod and whiting. For legend, see figure 1.

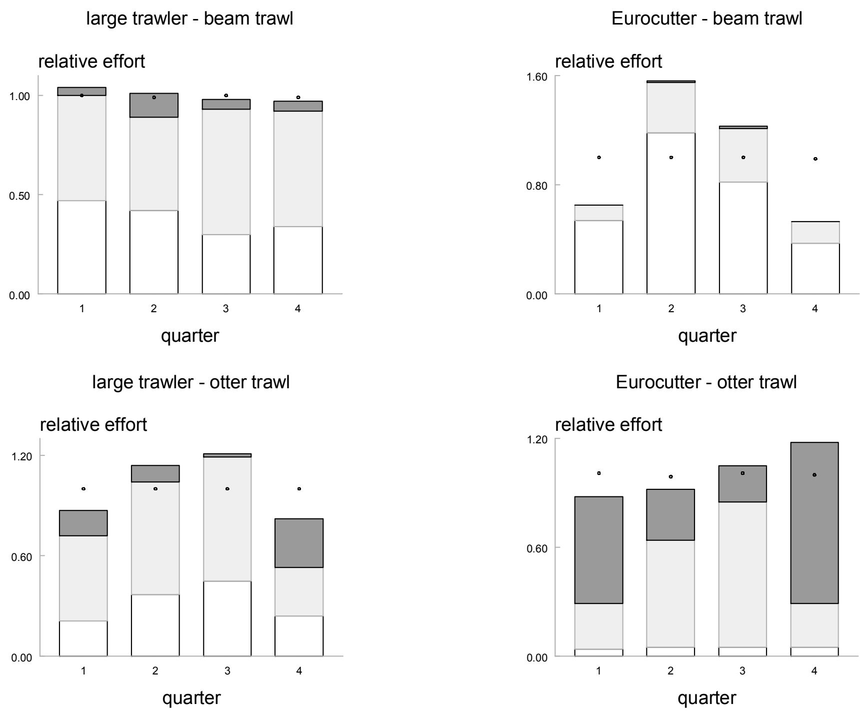


Figure 4. Average relative fishing effort distributed over 4 quarters and 3 area's (south: white; mid: light-grey; north:dark-grey) of the vessel-gear combinations analysed. Scatter of open circles indicates the location of a relative effort of 1, meaning that fishing effort in that quarter is ¼ of the overall mean effort per year. The absolute average efforts and the time-series trends found are summarized in Table 1.

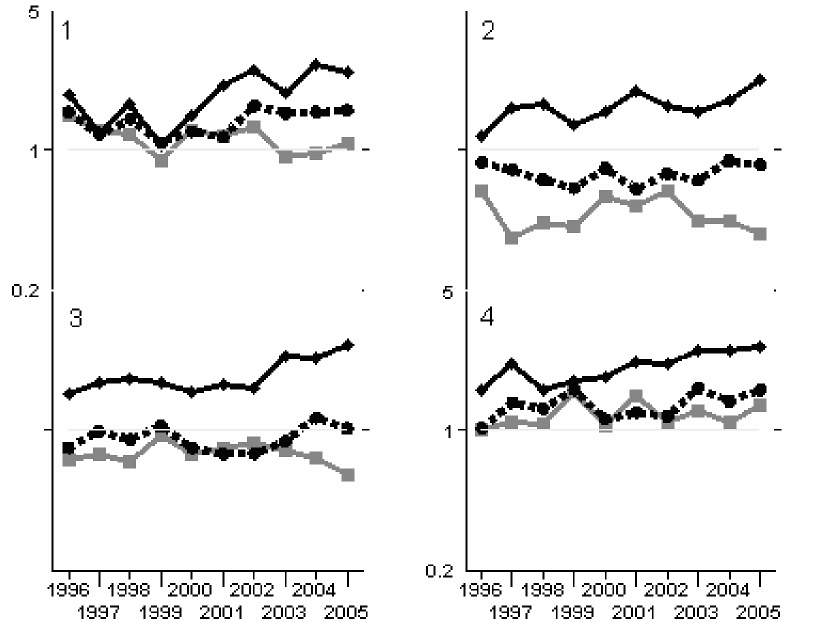


Figure 5. Time-series of relative LpUE values of plaice (expressed as multipliers 0.2-5) for 4 quarters and 3 area's (south: light grey; mid: broken-black; north: blank) of the large trawlers using beam trawl.

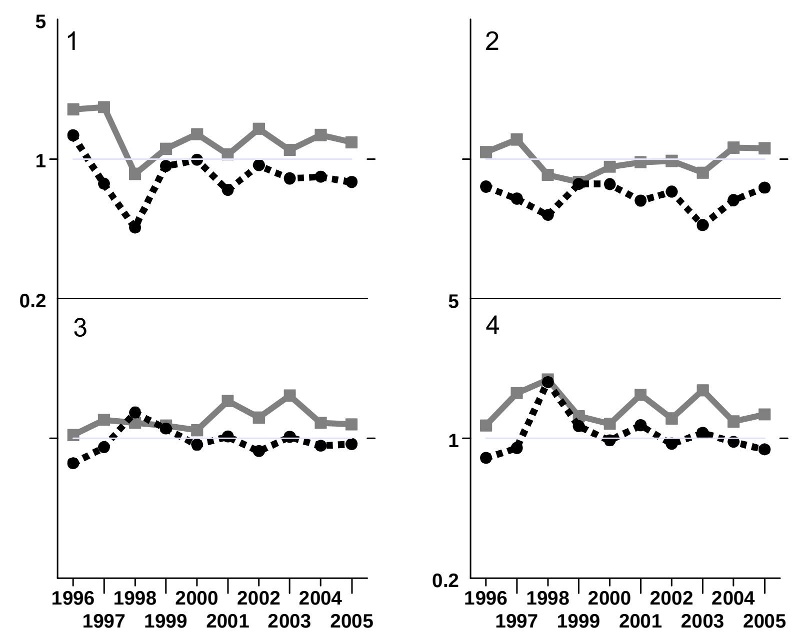


Figure 6. Time-series of relative LpUE values of sole (expressed as multipliers 0.2-5) for 4 quarters and 3 area's (south: light grey; mid: broken-black; north: blank) of the large trawlers using beam trawl.

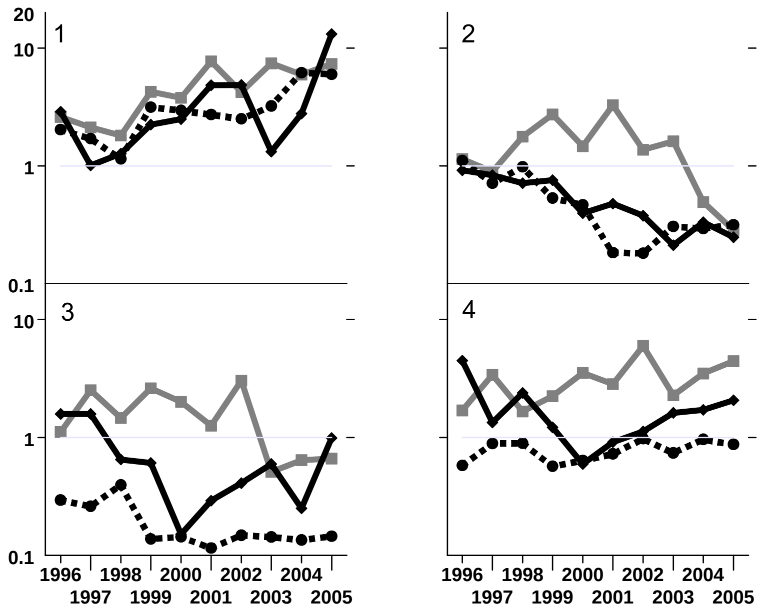


Figure 7. Time-series of relative LpUE values of cod (expressed as multipliers 0.2-5) for 4 quarters and 3 area's (south: light grey; mid: broken-black; north: blank) of the large trawlers using beam trawl.

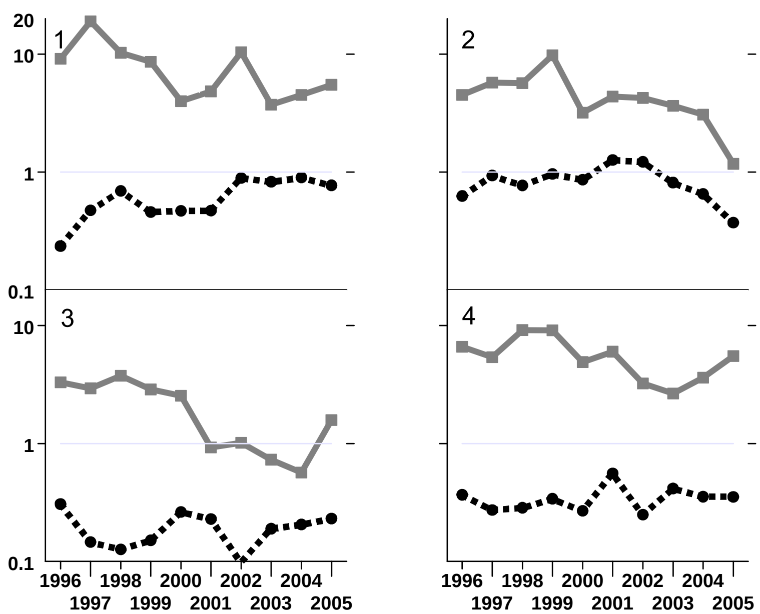


Figure 8. Time-series of relative LpUE values of whiting (expressed as multipliers 0.2-5) for 4 quarters and 3 area's (south: light grey; mid: broken-black; north: blank) of the large trawlers using beam trawl.

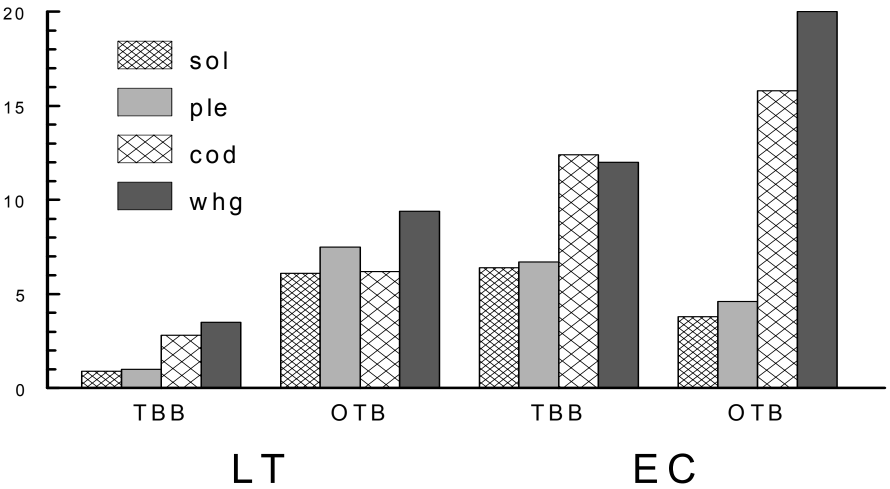


Figure 9. Objective uncertainty of the conversion of partial F based on TAC to allowed fishing days at sea for the various fleet-gear-species combinations, expressed as percentage exceeding of the TAC, given a probability of 0.9.

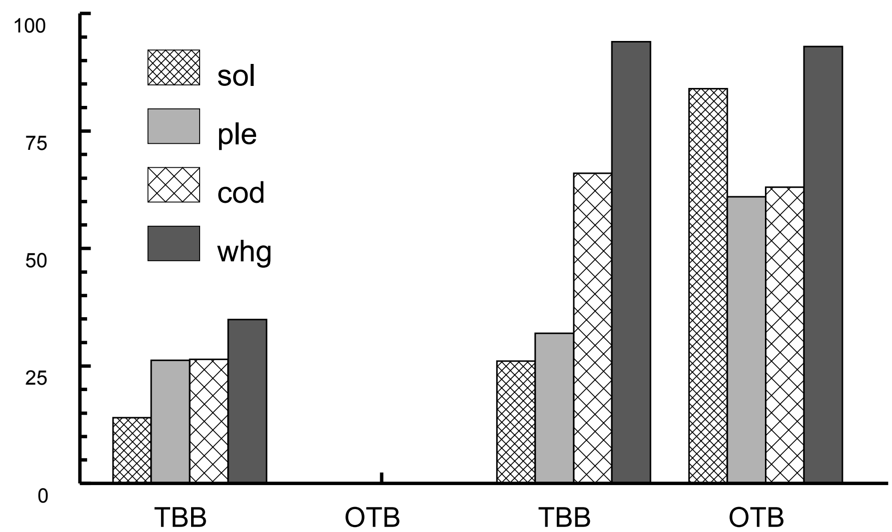


Figure 10. Subjective uncertainty of the conversion of partial F based on TAC to allowed fishing days at sea for the various fleet-gear-species combinations, expressed as percentage exceeding of the TAC, given a probability of 0.9.

Verantwoording

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