Discards Management: reducing plaice discards via beam-trawl effort reallocations

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Summary

Ways to improve the well-being and likewise to reduce the number of fish returned to sea as unwanted waste ('discards') have received major attention by the Dutch commercial beam-trawl fishing sector, and responsible ministries. There are various options to achieve this: make the gear more selective for the right sizes and species; allow more and smaller species to be landed; and protect spawning and nursery areas. While other research is focussed on improving gear selectivity, this report sheds light on the effect of area closures (i.e. reallocating fishing effort to adjacent areas) on the predicted total number of plaice (*Pleuronectes platessa*) discarded from the beam-trawl fishery (80 mm. mesh size, >300 horse power/hp. in engine size).

First, predictions on where and when plaice of a certain size and age can be encountered were coupled with stratified fishing effort information. This generated estimates of the total number of plaice discards for a given week and area (i.e. ICES statistical rectangle, approx. 30 x 30 nautical miles). Discards were high in areas off the Danish west coast and within the first five months of the year. The first 500 of these week and area combinations were ranked in decreasing order of their associated discard numbers. Then, it was simulated that the fishing effort for each of these 500 rectangle/week combinations was set to nil, and one-by-one reallocated to an adjacent rectangle within the same week where less discards could be expected. Overall, these simulation scenarios revealed that 30% of annual fishing effort could be reallocated resulting in an approx. 20% reduction in the predicted total numbers of plaice discards in 2009. The majority of reductions were achieved in year classes 1 and 2 which outweighed a relatively little increase in discards at age 3 and 4. A possible explanation for this increase in discarded older plaice was that fishing effort was reallocated towards deeper habitats where older and larger plaice typically aggregate.

This scenario-based study provided for the first time spatially and temporally resolved estimates of total plaice discards at age. It demonstrated that via fishing effort reallocations, discard numbers can be reduced. Thereby, it also corroborated previous findings of a gradual shift in the distributional patterns of plaice, where maturing juveniles tend to migrate west and northwards into deeper habitats. Nevertheless, the nature of the model and its underlying data from an opportunistic discard sampling programme should be considered within its limitations, when interpreting these results.

1. Introduction

Reducing mortality of discards is one of the aims of the Dutch beam-trawl fishing industry and has gained further momentum through the proposed EU discard ban regulation (EU non paper, May 2011). Options to mitigate mortality, typically focus on reducing the total amount of discards (Broadhurst et al., 2006). This may be achieved through: i) more selective gears via technical and/or operational modifications; ii) minimum landing size and quota allocations; and iii) spatio-temporal fishing closures to protect aggregations of juveniles. In this report, we examine the latter option for reducing discards in a scenario study based on a statistical model of spatial and temporal distributions of discards (Poos et al., submitted manuscript).

Species such as plaice (*Pleuronectes platessa*) may directly or indirectly benefit from a spatio-temporal reduction of fishing effort: directly, through a reduced capture probability in an area of reduced fishing; and indirectly, by improved condition through replenished abundance of benthic prey species (Hiddink et al., 2011). However, positive effects may not be evident in both the shorter and longer term, if these are masked by larger-scale environmental perturbations (Beare et al., 2011).

Historically, a spatio-temporal reduction of fishing effort by beam trawlers targeting flatfish inside the so called “plaice box”, did not result in the anticipated increase of yield nor a decrease of discarding of plaice (Beare et al., 2011). It was suggested that the fixed boundaries of the “plaice box” did not account for dynamic distributional shifts in the age- and density dependent abundance of plaice. Therefore, it may be argued that real-time rather than permanent closures may be more effective in reducing discards, if they are allocated to areas and times where and when the largest numbers of juveniles aggregate (Beare et al., 2011).

In this report we summarise the results of a scenario study, evaluating the potential for real-time reallocations of spatio-temporal fishing effort. This was done in a two-step approach. In the first step, we predict spatio-temporal distributions of juvenile plaice discards, with a generalized additive mixed model (GAMM, Hastie and Tibshirani, 1990; Poos et al., submitted manuscript). This model takes into account observed discard numbers and stratified fishing effort information (e.g. days at sea by ICES statistical rectangle and week). The model was built using observations of beam-trawled-and-discarded plaice throughout the North Sea between 2000 and 2009 in a long-term monitoring programme (Helmond et al., 2010, 2011); where discard samples were collected regularly throughout the year on board commercial vessels.

This report describes how spatio-temporal predictions on the abundances of discarded and juvenile plaice (ages 1 to 4) were used to evaluate real-time closure scenarios to reduce the amount of plaice discards in the North Sea.

2. Assignment

The objective was to model the spatial and temporal distribution of juvenile plaice discards in response to real-time area closures. This was done using a scenario study of fishing effort reallocation. The work was done on the request of Agentschap NL, Team Mondiale Samenwerking Energie en Klimaat.

3. Materials and Methods

The scenario study used a two-step approach. First, we created a statistical model describing the plaice discarding as a function of several covariates, based on observations in the period 2001-2009 (see Poos et al., submitted manuscript). This statistical model belongs to the class of generalized additive mixed models (GAMM, Hastie and Tibshirani, 1990). It is used to identify ICES statistical rectangles and weeks of high discards per unit effort of fishing (DPUE) in combination with fishing effort statistics. In the second step, the total number of discarded plaice at age (age classes 1-4) were predicted in iterative scenarios where fishing effort was reallocated cumulatively for the first 500 rectangle-weeks with high discards. In the scenarios, fishing effort was allocated away from rectangles with high DPUE by week, and placed in an adjacent rectangle within the same week.

In the GAMM model, count data of discarded numbers of plaice were described as a function of cohort strength (capturing annual variation in recruitment), fish age, fish sex, water depth, date, and location (Poos et al., submitted manuscript). To account for differences in vessel trips, these were incorporated as random effect terms on the model intercept. The model was parameterized with bottom-trawl survey (BTS) and data collected between 2000 and 2009 from an onboard observer discard monitoring programme of demersal beam trawlers (80 mm. mesh size and >300 hp.), where annually approx. 10 trips and an average of 26 hauls per trip (>60% of all hauls) were sampled. The expected difference in count data between the latter discard programme and the former BTS survey is accounted for in the model by using a covariate that generates a different effect of age for the two data sources. In the discard monitoring programme, the volumes of the catch and landings were recorded for each haul. The total volume of discards was estimated by subtracting the landings of commercially valuable species, from the total catch volume. Together with the sampled discard volume (50 l.), it was used to calculate a subsampling factor by which all measured species counts at length were raised.

To account for the effect of swept area on the count data, and the subsampling factors, these were added to the model as an offset. When linked to spatiotemporally resolved fishing effort statistics, for the most recent year of data in this dataset (i.e. 2009), this offset was set to zero to calculate the total (pooled across ages 1-4 and both sexes) number of discarded plaice per hour of total fishing effort (in hours) and km^2 trawled per week and ICES statistical rectangle. The next step simulated in iterative scenarios what would happen to the estimated number of plaice discards at age (i.e. model offset was not zero), if rectangle/week combinations were closed and relocated. First, all rectangle/week combinations that had fishing effort observed in the study period were ranked according to their predicted discard rate in total numbers for ages 1-4 (highest rate ranks first). Next, the scenarios increasingly closed more rectangle/week combinations, following their rank, up to 500 combinations. For each closure, the fishing effort in the closed rectangle was randomly reallocated to an adjacent, neighbouring rectangle in the same week.

To prevent fishing effort being relocated in a rectangle/week combination with a higher rank (and thus previously closed), we kept a record of such combinations. A similar procedure was used to prevent reallocation of fishing effort into the plaice box. In all of the calculations, discard and fishing effort information of smaller beam-trawl vessels (<300 hp.) were not considered. The freely available software package R (downloadable from http://www.R-project.org; R Core Development Team, 2011;) together with the RODBC, adehabitat, lattice, boot, mgcv, nlme, and rgdal packages were used for all analyses and most graphics. Microsoft™ Excel 2010 was also used to graph some of the results.

4. Results

The GAMM results clearly indicated spatial and temporal effects on plaice discards rates in the 80 mm. beam trawl fleet >300 hp. The highest discards rates were found for very young plaice (ages 1 and 2), in the coastal areas and the area west of the plaice box, when fish grow older and reaching lengths of marketable size classes, less discarding occurs (Fig. 1). Differences in discard rates are also found between sexes and for fish of different cohorts. These effects are discussed in detail in the Poos et. al., submitted manuscript.

Linking model predictions (Fig. 1) and spatio-temporally stratified fishing effort statistics (Fig. 2), resulted in the predicted number of juvenile plaice discards in ICES statistical rectangles trawled per week, rectangle/week combinations (Fig. 3), for the most recent year of data in this dataset (i.e. 2009). Ranking these in decreasing number of discards revealed that the discards rate in the first 500 rectangle/week combinations ranged between 1100 and 4100 fish per hour in 2009. These predictions are considerably higher than the estimated average of 917 discarded plaice per hour for the same year (Helmond et.al., 2011). Within the first 20 combinations, the rate has dropped from the maximum of 4100 fish per hour to 2400 fish per hour. Most of those 20 rectangle/week combinations are in the first 20 weeks of the year (in the reference year 2009), and located in the rectangles west of the plaice box off the Danish coast.

Reallocating 30% of annual fishing effort away from week/rectangle combinations where plaice discard rates in beam-trawl fisheries peaked (in total 500 combinations), resulted in approx. 20% reduction in the predicted total numbers of plaice discards (age classes 1-4; Fig.4). The total reduction in discard numbers is only caused by the reduction in discarding of ages 1 and 2. In contrast, the discarding in age 3 and 4 increased as a result of the effort reallocation (Fig. 4). The relative decrease in discarding as a result of the reallocation is highest in age 1; more than 40% discard reduction of age 1 discards can be achieved (Fig. 4, top). The increase in ages 3 and 4 were less than the decreases in ages 1 and 2, both in absolute and relative terms, explaining the total reduction in discard numbers (Fig. 4).

5. Discussion

In this study, we demonstrated that a reduction of approx. 20% of discarded numbers of plaice was possible by reallocation of 30% of fishing effort. Predominantly, discard numbers of younger ages 1 and 2 were reduced. Our model predictions confirmed the generic pattern of juvenile fish migrating from shallow, coastal habitats into deeper, offshore waters. High concentrations of discards were predicted in areas west of Denmark.

Notwithstanding the above, it should be kept in mind that we explicitly dealt with scenarios to reduce discards of a single species: plaice. Effects from fishing effort reallocations on other species of either discards or landings (e.g. Beare and Machiels, 2011) were not investigated. Further, the results presented in this report should be viewed within the uncertainties and limitations of the applied model and its underlying data. For example, data from the opportunistic discard sampling regime was not strictly stratified in time and space. This is not necessarily a shortcoming of the sampling design, but simply an artefact of the nature of sampling. Even where little sampling took place, the model captures large spatial and temporal patterns in discards. As a consequence, the predicted distributional patterns are approximations of discard patterns, and not real time observations and therefore, cannot account for small-scale and short term changes in discard rates. However, an advantage of the predictions are that they can fill spatial and temporal gaps. So even at times and regions with no discard sampling, an estimate of a discard rate is possible.

The spatio-temporal distribution of discarded numbers does not remain constant, but depends on the incoming recruitment and the changes in depth preference of different age classes (Keeken et al. 2007). When interpreting the outcomes of the study for management purposes this dynamic nature of discard number in space and time should be considered. Therefore, the outcomes of this modeling exercise should be interpreted as such; an indication of the possible effects of effort allocation on the reduction of plaice discards, but not as a ready-made tool to reduce discard of plaice in the beam-trawl fishery. This is also the case for the prediction of future scenarios; this can only be done under the assumption that spatial and temporal distribution of discarded plaice are predictable using historic observations.

Most discarding occurs in rectangle/week combinations with high fishing effort (Fig. 2 and Fig. 3). Rectangle/week combinations with very high discard rate predictions but low effort, ultimately results in a moderate discard total (Fig. 3). Over the last years, fishing effort of large beam trawlers (>300 hp.) concentrates in south western part of the North Sea (Fig. 2), in areas with high discard rates, especially during the first quarter of the year (Fig. 1), resulting in high discard numbers for these week/rectangle combinations (Fig. 2 and 3).

The increase in discards at ages 3 and 4, and decrease in discarded age 1 and 2 plaice as a result of the effort reallocation is in line with known distributional and growth patterns. Larger (and older) plaice move from shallow nurseries into deeper habitats (e.g. Wimpenny, 1953; Bailey, 1997). As our results suggest, with an increasing amount of reallocations of predominantly shallow-water coastal fishing towards deeper waters, the probability to catch older, but still discard-sized plaice will increase; whereas captures of younger plaice will decrease. It is likely that the majority of these older discards are made up of males, due to the known sexual dimorphism (males are smaller) and evolutionary fisheries-induced selection pressure to become mature at a younger age and smaller size (Walraven et al., 2010). In the prediction model, males even of older ages remained in the discard fraction, because due to their slow growth they hardly reached minimum landing size (Walraven et al., 2010; Poos et al., submitted manuscript). However, total numbers of predicted plaice discards were presented here as pooled estimates across both sexes, and thus do not allow for any interpretation.

Reallocations were done on the level of an ICES statistical rectangle and adjacent rectangles were randomly chosen. However, such a procedure may be too simplistic, considering the plethora of factors (management regulations, weather, habitat features, catch diaries, etc.) that can influence a fisher's choice of where to fish. Such fine-scale behaviours were not reflected in our fishing effort reallocation scenarios, and thus, may not reflect real choices.

Finally, our predictions could not consider two phenomena which may have had antagonistic effects on the rate of reductions of discarded number of fish as a function of fishing effort reallocation. Firstly, our predictions do not include a model of what happens to the fish that survive in closed rectangle/week combinations. In a real life situation, these fish will likely migrate and increase the fish densities in other rectangle week combinations. Hence, the discarding in those rectangles will likely increase, and decrease the discarding reduction that we predict with our statistical model. Secondly, small-scale dynamics in plaice distribution (e.g. Poos et al., 2007; Rijnsdorp et al., 2011) may actually be responsible for much higher, localized discard rates which were not captured if no discard sample was taken there. Thus, trip-level data on a coarse stratification level (i.e. ICES statistical rectangle) are possibly yielding underestimates of the true discard rates, and hence will underestimate the achievable gain from real-time closures.

6. Conclusion

From this scenario study we conclude that discarded numbers of plaice can be successfully reduced by reallocation of beam-trawl fishing effort, e.g. real-time area closures. Our results indicated that a 30% reallocation of fishing effort could lead to a reduction of approx. 20% of discarded numbers of plaice. However, the variable spatio-temporal distribution of discards should be considered when interpreting the outcomes of the study for management purposes.

7. Quality Assurance

IMARES utilises an ISO 9001:2008 certified quality management system (certificate number: 57846-2009-AQ-NLD-RvA). This certificate is valid until 15 December 2012. The organisation has been certified since 27 February 2001. The certification was issued by DNV Certification B.V. Furthermore, the chemical laboratory of the Environmental Division has NEN-AND-ISO/IEC 17025:2005 accreditation for test laboratories with number L097. This accreditation is valid until 27 March 2013 and was first issued on 27 March 1997. Accreditation was granted by the Council for Accreditation.

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Figures

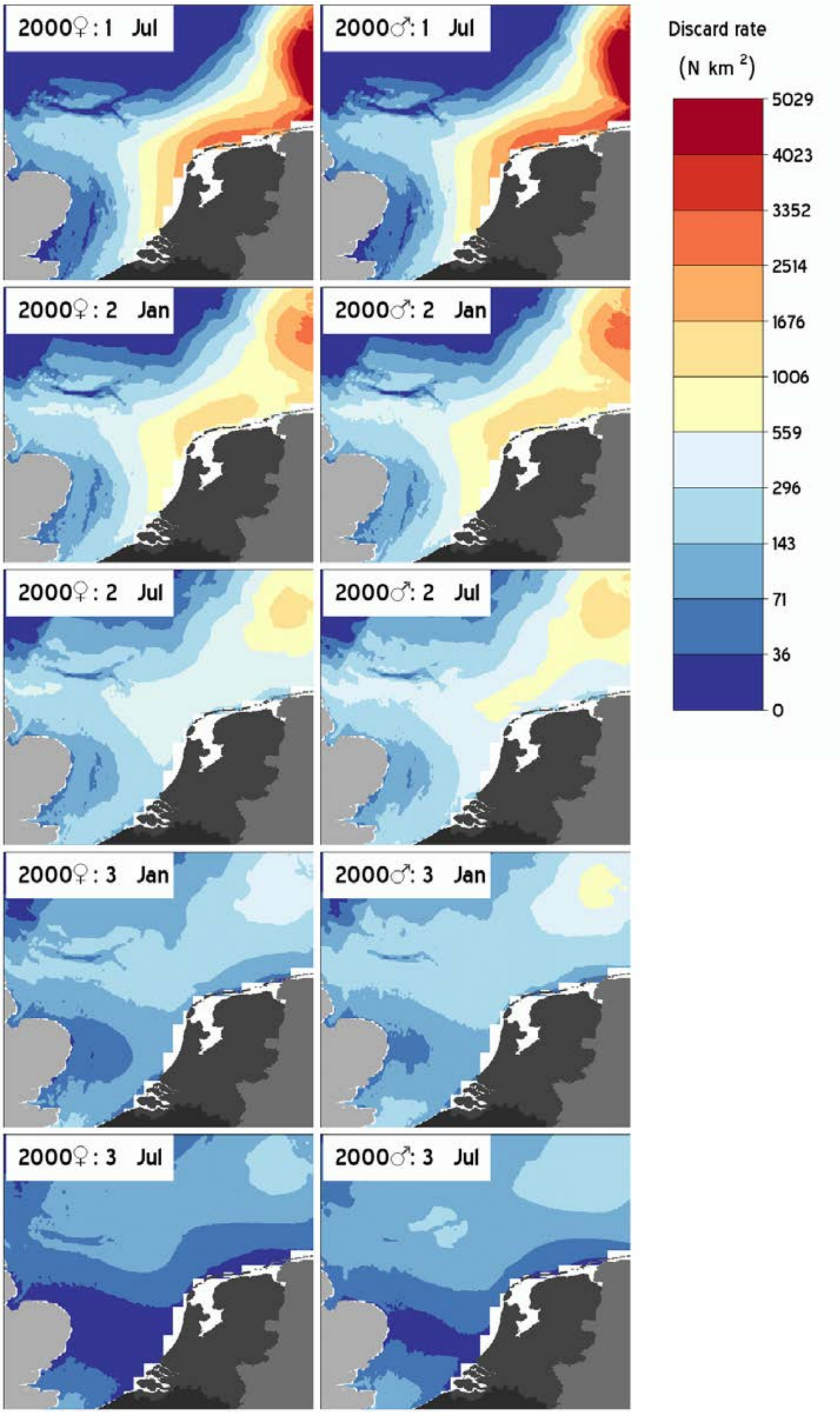

Figure 1. Model predicted spatio-temporal distribution of density of females (left panels) and males (right panels) of cohort 2000 for 1.5 to 3.5 year old plaice in the North Sea (as reported by Poos et al., submitted manuscript). Note that each column of panels represents a single cohort throughout its life.

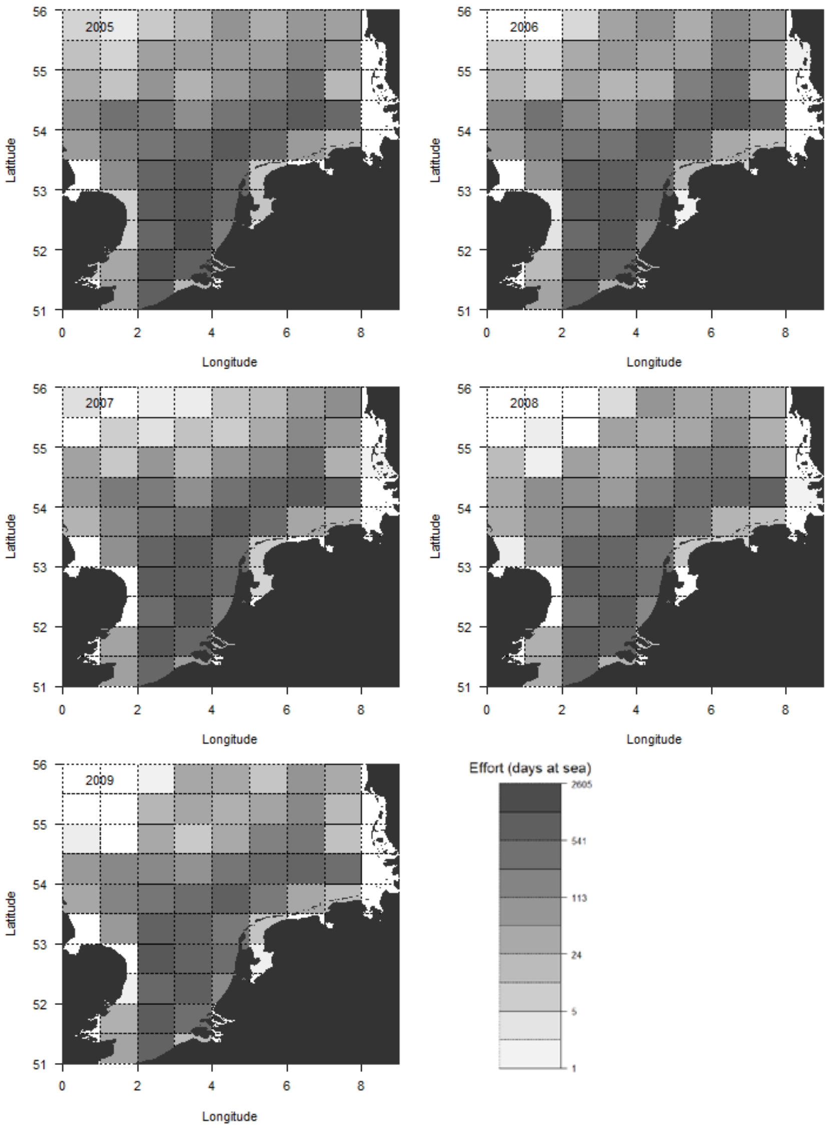

Figure 2. Distribution of total fishing effort of the beam-trawl fleet (80 mm. mesh and >300 hp.) per rectangle and year expressed in days at sea between 2005 and 2009.

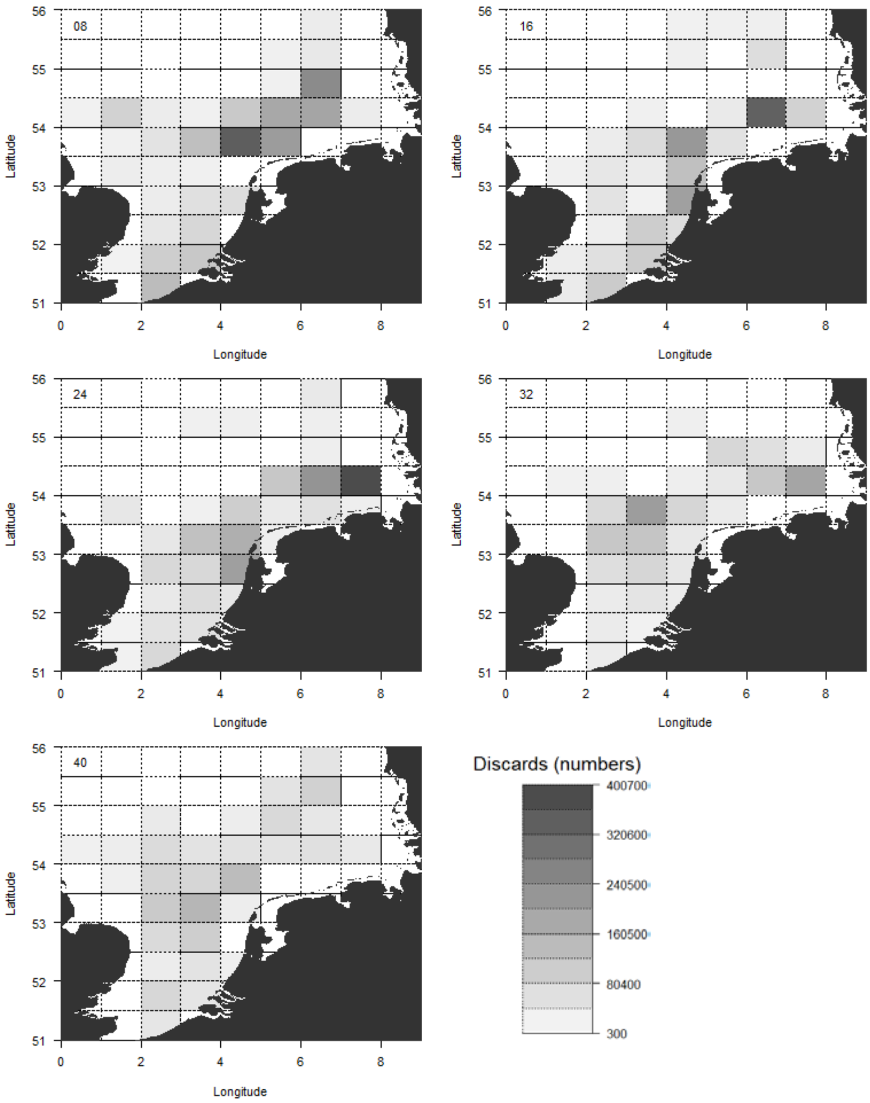

Figure 3. Model predicted total number of discarded plaice (pooled ages 1-4, and sexes) per ICES statistical rectangle in the North Sea for 5 selected weeks (6, 16, 24, 32 and 40) in 2009.

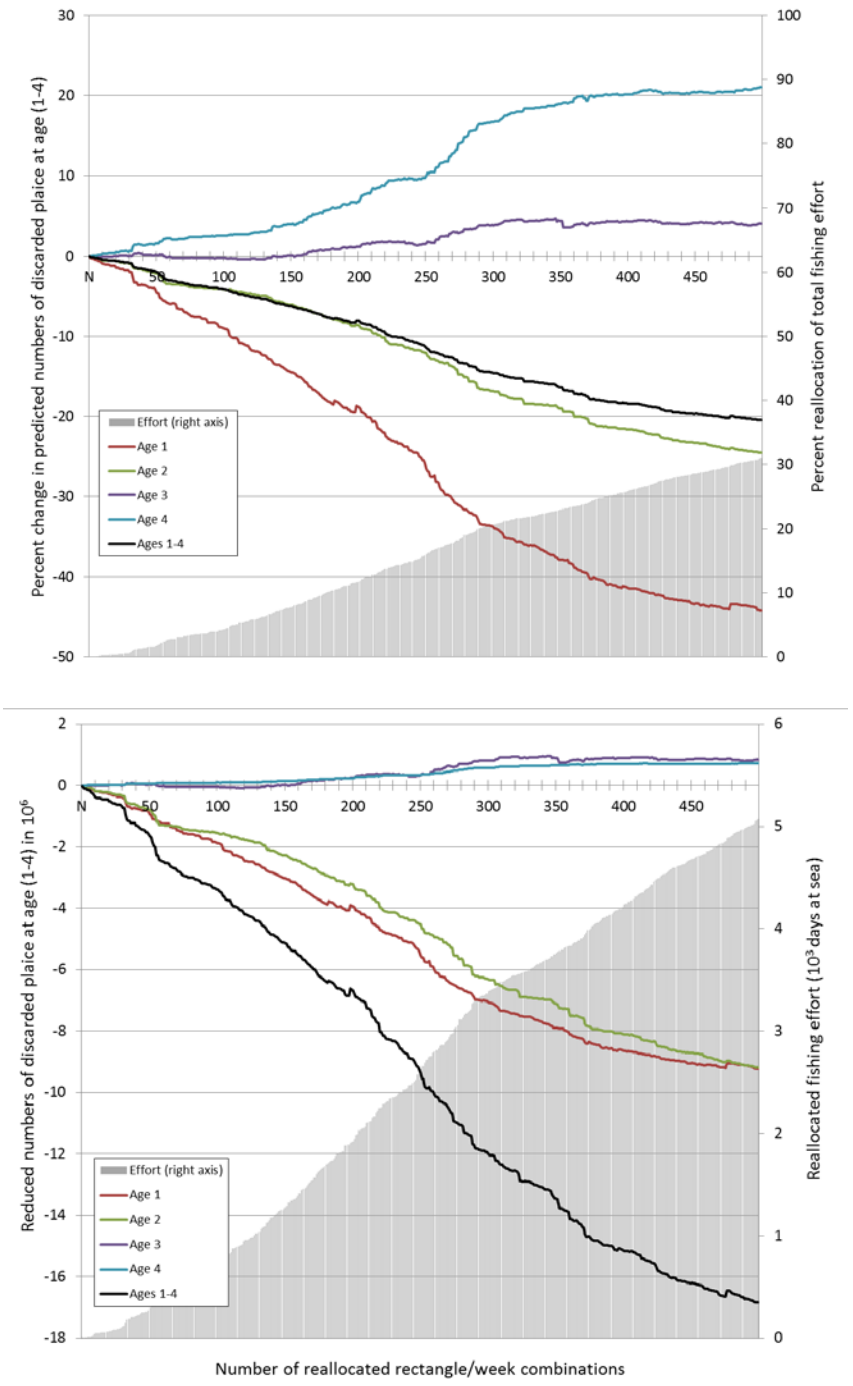

Figure 4. Change in the predicted total number of plaice discards at age (left y-axis, in percent at the top, and in absolute numbers at the bottom) after fishing effort was re-allocated cumulatively (2009, right y-axis, in percent, top, and in absolute numbers, bottom) for the n=500 rectangle/week combinations in which high numbers of plaice discards were predicted.

Justification

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Project Number: 430.11.02.901

The scientific quality of this report has been peer reviewed by the a colleague scientist and the head of the department of IMARES.

Approved: Prof. dr. Adriaan Rijnsdorp
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