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Effort management for mixed fisheries in EU waters: a viable alternative for failing TAC management?

Niels Daan & Adriaan D. Rijnsdorp

Abstract

We argue that the failure of fisheries management to constrain exploitation rates of species caught in mixed fisheries is directly related to TACs constraining total reported landings rather than total catches of individual species as well as to the absence of a fleet-based management approach. To investigate the potential of a Total Allowable Effort (TAE) system in these fisheries, we evaluate historic catch and simulated effort forecasts in North Sea sole relative to observed catch and effort levels. The discrepancies between these two pairs of data should provide some guidance regarding the uncertainty in the stock forecast. In the course of 12 years for which data exist, the discrepancy between predicted and observed catch rates has ranged between -40 to +22%, and the stock has apparently been underestimated in 4 years and overestimated in 3 years, while in the remaining 3 years the match was pretty close. The discrepancy proved to be highly significantly correlated with the retrospective bias in the assessments carried out annually, explaining 53% of the variance. Using effort data in the assessment should therefore allow for a real-time evaluation of the assessment uncertainty, which could be taken into account in the forecast. We argue that developing a two-tier TAC/TAE management system would help to prevent TACs being taken at greatly elevated effort levels and therefore might effectively contribute to pushing back the overexploitation in mixed fisheries.

Keywords: CFP, management failure, mixed fisheries, North Sea sole, retrospective analysis, TAC, Total Allowable Effort, assessment uncertainty.

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Introduction

The Common Fisheries Policy (CFP) of the European Union agreed in 1983 allowed for a variety of technical measurements to restrict the use of different gears under various conditions, but is primarily based on setting annual Total Allowable Catches (TAC) for individual stocks. The reason for choosing this type of regulatory framework was not based on evidence that output control (catch management) would be superior to input control (effort management) in the endeavors to reach the stated objective of rational exploitation, but rather on the overriding objective to maintain 'relative stability' among the national fishing industries (Holden, 1992). The negotiations preceding the agreement concentrated on an acceptable division of TAC in fixed quota shares that each country would receive, once and for all. After almost 25 years of experience with the TAC system, the overall status of demersal stocks typically caught in mixed fisheries has only deteriorated (EC, 2001; Sparholt *et al.*, subm.). In contrast, TAC management in single-species directed fisheries, such as for herring, has largely been effective (Simmonds, 2005).

Although there are many factors that may undermine TAC management (inadequate advice, inappropriate management decisions, lack of enforcement; Daan, 1997), there are two fundamental reasons why output control cannot be expected to control exploitation rates of individual species that are caught in mixed fisheries: 1. restrictions on the amount of fish that can be officially landed create an incentive to land fish illegally or, if that is not possible, to discard over-quota catches; 2) the overall TAC for different species and the quota shares of these among countries will never match the catch composition of individual fleets and therefore cannot be balanced, unless the differences between fleets are taken into account. In practice, this would require some kind of effort control at the fleet level (Daan, 1997; Shepherd, 2003).

Illegal landings as well as changes in discard rates undermine the value of landings statistics as the primary indication of the level of extraction of fish from the sea and therefore as input for any stock assessment. Deterioration of the catch statistics, and its consequences for the reliability of stock assessment, is a warning expressed annually and explicitly by ICES (e.g. 2005). Uncertainty about the true extractions and the potential bias caused in the forecasts is is the core of the credibility crisis affecting the entire management system (Rijnsdorp *et al.*, in press).

For many years, the advice on catch options for demersal species cautions that the TAC decided upon for one species should take into account the TAC of others taken in the same fisheries (ICES, 2005), although no real clues were presented as to how this should be done. Therefore, this type of advice may not have been very helpful from a management point of view. In recent years, models have been used to try to figure out how TAC of individual species might be matched (Vinther *et al.*, 2004), but so far these models have not been quite satisfactory (ICES, 2006). The last and most promising development here is a fleet-based model that takes partial F at the fleet level and effort explicitly into account (Rätz *et al.*, subm).

Rijnsdorp *et al.* (2006, in press) draw attention to the fundamental incongruity between the single-species TAC approach and the fleet-based effort approach, which may make it virtually impossible to resolve the mixed fisheries problem, unless some form of effort management is introduced. After its latest reform in 2002, effort management is now explicitly included in the legal EC instruments, although its use is specifically linked to recovery plans. However, this new option does open the possibility to combine the two approaches in a management system that may repair some of the deficiencies of a singular TAC system.

The discussion pro and con TAC versus effort management is largely based on beliefs, but it has been argued that a 'broad-bush' effort management is preferable over 'ineffective precision TAC management' (Shepherd, 2003). We do not want to indulge in an emotional discussion here, but rather investigate, on the basis of empirical data, whether we can make useful effort predictions. We have shown elsewhere that a partial F approach to decompose overall fishing mortality in FPUE at a highly disaggregated temporal and spatial level allows to estimate realistic patterns in variations in catchability as well as trends in efficiency of a fleet (Rijnsdorp *et al.*, 2006).

Here we use a simple predictive model of the effort by which the annual catch should have been taken according to the ICES forecasts and compare the outcome with the realized effort for a historic time series, using North Sea sole and the Dutch beam trawl fleet as an example. The idea behind this approach is that the discrepancy between predicted and observed catch rates might serve as some measure of the uncertainty in the annual assessment, which can be compared with estimates of the annual bias based on retrospective analyses.

We discuss the results in the light of the potential to integrate input and output control in a two-tier TAC/TAE management system.

Methods

The ICES advice relates essentially to an evaluation of the range of fishing mortalities (F) that meet the short-term requirements of the precautionary approach for sustainable exploitation of single stocks. The catch option interpreted as being the TAC advice (tac) can be seen as corresponding to a Total Allowable F advice (taf; see table 1 for the definition of the symbols used). Similarly, the agreed TAC can be interpreted as an implied Total Allowable F (TAF) that can be obtained by linear extrapolation. This is obviously a rough approximation, but it would be tedious to derive the appropriate relationships from the Working Group reports, because they change continuously. We are here primarily concerned with a 'broad-brush' analysis.

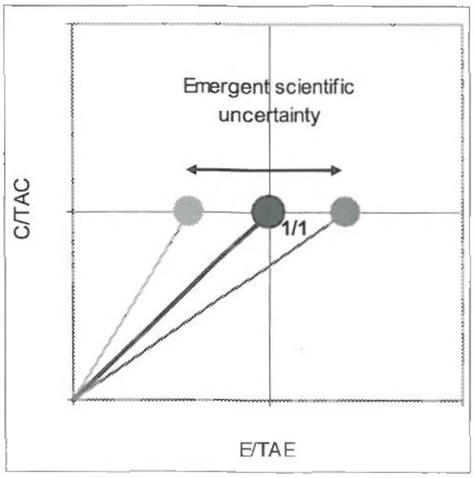

Figure 1. Schematic represention of the observed E with which the TAC has been taken and the implied TAE. The difference is a measure of the scientific uncertainty of the forecast.

Given an estimate of the observed fishing effort (E) associated with the catch (C) in year t-1, we can also make a prediction of the implied Total Allowable Effort (TAE), with which the TAC in year t+1 should be taken. Assuming that catchability does not change over the prediction period (two years), the relationship between E and F would be expected to be linear (Beverton and Holt, 1957). Thus, given a set of E and the corresponding C for past years, we can investigate how well the observed data pair corresponds to the predicted data pair (Figure 1). We assume in this theoretical example that the TAC is enforced so that C=TAC. Standardization of C and E by dividing by TAC and TAE, respectively, facilitates the interpretation, when data for different years are plotted in the same figure.

If the TAC is taken with less E than predicted (TAE), this might indicate that we have underestimated stock size (and overestimated F) and *vice versa*. In practice, the actual C may differ from the TAC. Assuming a linear relationship between C and E close to the TAC/TAE point, the implied predicted E associated with C (Ec) would be represented by the point on the bisectrix that is connected with C by a horizontal line.

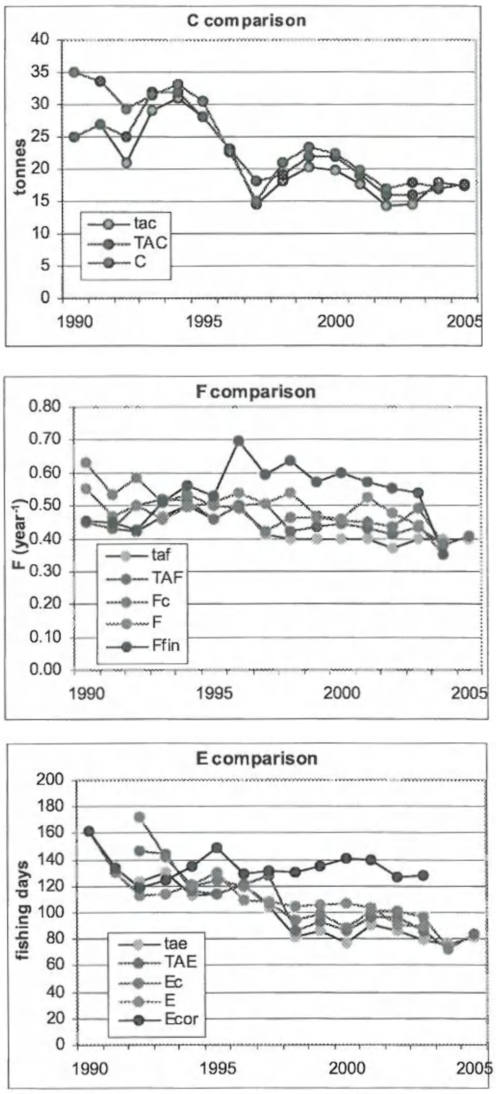

Figure 2. Comparison of observed and estimated values of catches (top), fishing mortalities (middle) and effort (bottom) as implied by the prediction in year t-1. For codes see table 1.

For no stock that we know of, do detailed effort data exist for all fleets. Therefore, we limit our analysis to North Sea sole and the Dutch beamtrawl fleet (>300Hp). This fleet is responsible for ca 80% of the landings and detailed effort data (days fishing) are available for 14 years. We assume that the cpue is representative for the total fleet, so that we can raise the effort by the catch ratio.

The calculations are straightforward (Table 2). Figure 2 summarizes the development in the various C, F and E parameters. For F, we have included both the estimate in year t+1 (F) and the final estimate from the most recent assessment (Ffin). For E, we have also included a corrected value (Ecor) based on an annual increase in catching efficiency of 2.8% (Rijnsdorp et al., 2006).

As indicated above, the discrepancy between the standardized C/E pair from the values implied by the prediction (essentially a linear extrapolation of the TAC/TAE pair) is supposed to provide information on the over- or underestimation of stock sizes and fishing mortality in the annual forecasts. This should also be a component of the retrospective bias apparent from the annual assessments (Figure 3). Therefore, we correlated the relative discrepancy between (standardized) observed and implied effort by the prediction ([E-Ec]/TAE) with the relative changes in F from the assessment in year t+1 to the assessment in the final year (Ffin/F) and similarly for SSB.

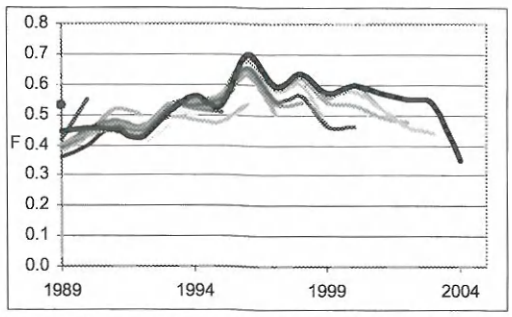

Figure 3. Retrospective analyses for North Sea sole (from ICES, 2005).

Results

The correlation between F and E was not significant ($R=0.46$; Figure 4), and the one between F and Ecor even less so ($R=0.40$). Surprisingly, the correlations between Ffin and E and Ecor were negative ($R=-0.49$ and -0.13, respectively).

Figure 5 shows the standardized discrepancies between C and E, relative to the TAC/TAE levels. Data points above the diagonal refer to situations where the catch is taken with less effort than predicted (stock underestimated), whereas the points below the diagonal indicate situations where more effort has been required than predicted. The horizontal (or vertical) distance between each data point and the diagonal might be interpreted as indicative of the uncertainty in the forecast in terms of predicted catch rates. Only in 1997, the TAC could not be exhausted but the actual catch was exactly as predicted for the actual effort. Also in 1994 and 2001, the matches were excellent. For the other years, catches often exceeded the TAC up to 18%, whereas the observed E was between 40% less to 20% higher than the Ec implied by the prediction.

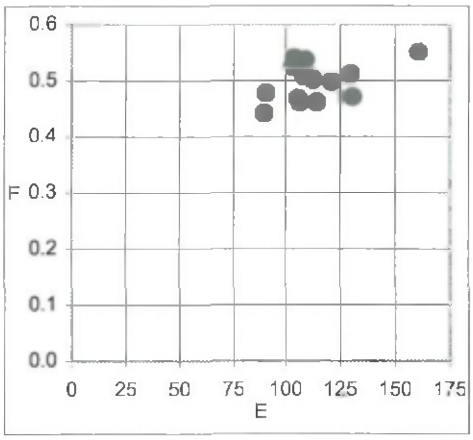

Figure 4. Plotted relationship between F and E (correlation not significant).

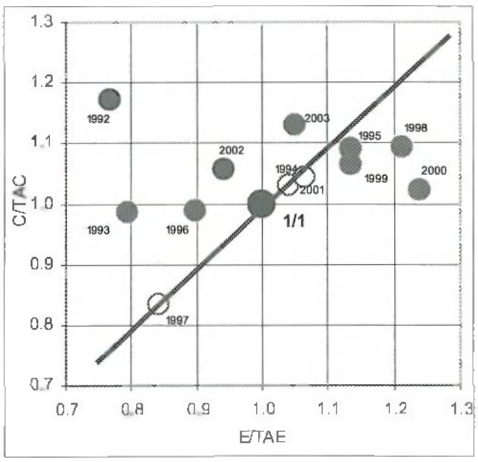

Figure 5. Standardized discrepancies between observed catch and effort pairs relative to the TAC/TAE reference.

This difference in relative variation in C/TAC versus E/TAE is of course related to the fact that management puts a cap on catch (landings) and not on effort. It may just reflect our uncertainty about the true catches because of unreported landings or high-grading.

As we had hoped for, these discrepancies were highly significantly correlated with the retrospective change in F from the first year of being assessed to the final assessment year. Of course, these retrospective changes in F and SSB are themselves strongly correlated (R^2=0.84) and the patterns are therefore mirrorlike. The figure should be read in this way that if the catch in year x is taken with a higher effort than predicted (stock is overestimated), this will ultimately result in an upward adjustment in the estimated F after several annual updates of the assessment. Conversely, the SSB will be adjusted downward. The variance explained by the correlations is considerable (52% for F; 65% for SSB).

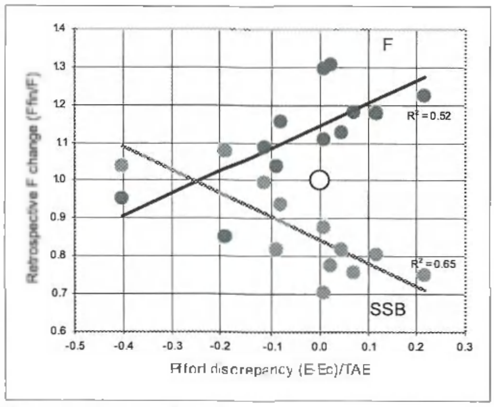

Figure 6. Retrospective change in F and SSB versus the observed discrepancy in effort between E and Ec in the same year.

Discussion

Although the method has been used here for the total sole catch, by raising Dutch beam-trawl effort to the total catch, in practice it should be applied to individual fleets using the partial F concept. We had hoped to finish a similar exercise for the plaice catch by the Dutch beam trawl fleet, but the recent disruption in the plaice assessment time series by including discards cause a problem. Nevertheless, the approach seems promising for investigating the causes of bias as suggested by retrospective analysis.

If the relationship between retrospective bias and assessment uncertainty based on effort data is more generally valid, there is a potential for real time correction, because, if not for the forecast itself, the discrepancy between observed and predicted effort in the last year of the assessment provides a real-time clue for correcting suspected over- or underestimates of stock sizes. How this should be done is not entirely straightforward. For instance, the correlations in Figure 6 don't pass through the point [1,1], which suggests that there is always a tendency for the retrospective F in sole to increase over a wide range of effort discrepancies.

The interpretation of Figure 5 may of course be biased by considerable underreporting of landings, while there is no reason to assume that the effort data are biased. This would move all points upwards. With 10% underreporting, one might conclude consistent underestimation of stock sizes, which may be responsible for an apparent increase in F observed in the retrospective analysis. Whatever, the analysis does point to uncertainty in the forecast, but how that uncertainty propagates in the assessment is a different matter.

Figure 5 raises another interesting thought. In some years, over-quota landings have been reported by fleets that had apparently increased their number of fishing days considerably. This would seem an optimum condition for overexploitation! Precautionary management might be more effective, if a two-tier system were introduced that sets both TAC and TAE for individual fleets. Whenever, one of the two is exceeded, the fishery might be closed (Figure 7). However, one might also allow some additional catches above the TAC, if these are taken with less than predicted effort. Such an additional window might be seen by the fishers as an allowance for situations, where the uncertainty of the assessment has led to markedly underestimated stock sizes (light green zone in upper-left corner of Figure 7).

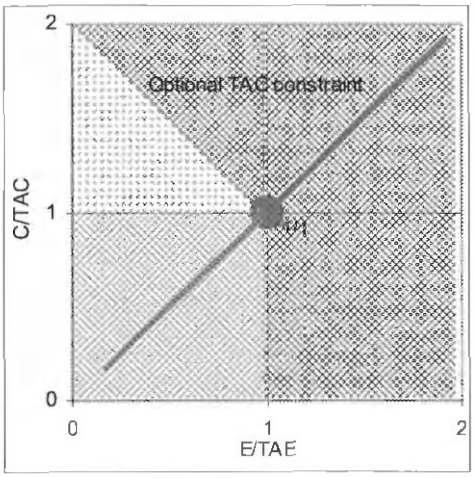

Figure 7. Tentative proposal to combine TAC and TAE management, where the fishery must be stopped if one of the two constraints is reached. See also text.

Of course, this approach to management is no panacea for all stocks and fisheries. There are many fleets where effort regulations in terms of fishing days would not control the catch potential (such as pelagic and longline fisheries) and where input control might make management even less efficient.

Also, such an integrated TAC/TAE system would not directly resolve the quality issue of catch statistics, because there would still be an incentive for underreporting. However, the effort cap would reduce the problem, just as expected from capacity control but probably more effectively. Thus, at least some improvements might be expected, and thereby assessment quality might be enhanced.

The absence of a correlation between E and Ffin is worrying, because a relation between the two should be the basis of effort management. However, one must take into account that in sole, there is actually limited signal in any of the two parameters and the points present just a small cloud within the parameter space, with variations possibly largely the result of assessment uncertainty. Moreover, the relationship between the discrepancy between predicted and observed effort and the retrospective strongly suggest that the effort data make a significant contribution to resolving the quality of the assessment. Thus, even if adjustment of the management system is not feasible because of national constraints within the EU, the scientific advice on stocks exploited in mixed fisheries might be improved by taking effort data more effectively into account, because at least it elucidates uncertainty and may be used to provide more precautionary TAC advice.

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Table 1. Definition of symbols and formula used.

tac	input	total allowable catch (corresponding to taf) advised by ICES for year t
taf	input	maximum F advised by ICES
tae	tae=Et-2*(taf/Ft-2)	total allowable effort implied by the ICES advice
TAC	input	agreed Total Allowable Catch for year t
TAF	TAF=taf*(TAC/tac)	Total Allowable F implied by the TAC according to the prediction (advice)
TAE	TAE=tae*(TAF/taf)	Total Allowable Effort implied by the TAC
C	input	actual catch in year t
Fc	Fc=TAF*(C/TAC)	F implied by C according to the prediction (advice)
E	input[1)]	actual effort in year t
Ecor	Ecor= Ecor(t-1)*x	effort in year t corrected for x=2.8% increase in efficiency
Ec	Ec=TAE*(C/TAC)	effort implied by C according to the prediction (advice)
F	input	F for year t as estimated by assessment in year t+1
Ffin	input	F for year t as estimated in the last assessment available

[1)]Total international effort has been calculated as $E=E_{BT}*(C/C_{BT})$, where BT stands for the Dutch beam-trawl fleet.

Table 2. Spreadsheet information to calculate the various parameters (input in bold; information collected from ACFM reports).

A	**B**	**C**	D	**E**	F	G	**H**	I	**J**	K	L	**M**	**N**
year	**tac**	**taf**	tae J(-2)*(C/M(-2)	**TAC**	TAF C*(E/B)	TAE D*(F/C)	**C**	Fc F*(H/E)	**E**	Ecor K(-1)*x	Ec G*(H/E)	**F**	**Ffin**
1990	**25.0**	**0.45**		**25.0**	0.45		**35.1**	0.63	**161**	161		**0.55**	**0.45**
1991	**27.0**	**0.43**		27.0	0.43		33.5	0.53	**131**	134		**0.47**	**0.45**
1992	**21.0**	**0.42**	123	**25.0**	0.50	146	**29.3**	0.59	**113**	119	172	**0.50**	**0.43**
1993	**29.0**	**0.47**	131	**32.0**	0.52	144	**31.5**	0.51	**114**	124	142	**0.46**	**0.51**
1994	**31.0**	**0.50**	113	**32.0**	0.52	116	**33.0**	0.53	**121**	135	120	**0.50**	**0.56**
1995	**28.0**	**0.46**	114	**28.0**	0.46	114	**30.5**	0.50	**130**	149	125	**0.51**	**0.53**
1996	**23.0**	**0.50**	121	**23.0**	0.50	121	**22.7**	0.49	**109**	129	120	**0.54**	**0.70**
1997	**14.6**	**0.41**	104	**18.0**	0.51	128	**15.0**	0.42	**108**	131	107	**0.51**	**0.60**
1998	**18.1**	**0.40**	81	**19.1**	0.42	86	**20.9**	0.46	**104**	130	94	**0.54**	**0.64**
1999	**20.3**	**0.40**	86	**22.0**	0.43	93	**23.4**	0.46	**105**	135	99	**0.47**	**0.57**
2000	**19.8**	**0.40**	77	**22.0**	0.44	86	**22.5**	0.45	**106**	140	88	**0.46**	**0.60**
2001	**17.7**	**0.40**	90	**19.0**	0.43	97	**19.8**	0.45	**103**	140	101	**0.52**	**0.57**
2002	**14.3**	**0.37**	86	**16.0**	0.41	96	**16.9**	0.44	**91**	126	102	**0.48**	**0.55**
2003	**14.6**	**0.40**	79	**15.9**	0.43	85	**17.9**	0.49	**90**	128	97	**0.44**	**0.54**
2004	**17.9**	**0.40**	76	**17.0**	0.38	72	**17.1**	0.38			73	**0.35**	**0.35**
2005	**17.3**	**0.40**	82	**17.7**	0.41	83							