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Fisher's perceptions and responses in management implementation

Evaluating fisheries management advice for some North Sea stocks: is bias inversely related to stock size?

Martin Pastoors [1]

Abstract

Biological scientific advice is often used as input into fisheries management of commercially exploited fish stocks. The quality of that advice is often debated in public discourses but is much less often formally evaluated. We looked at the scientific advice provided by the International Council on the Exploration of the Sea (ICES) for some North Sea stocks (cod, haddock, plaice and sole) over the period 1980-2002 in order to assess the quality of the scientific advice. We compared the predicted landings from the scientific advice with the realized landings in the fishery and also evaluated the estimates of fishing mortality and spawning stock biomass in predictions and in the most recent stock assessments. We found that for North Sea stocks considered, there have periods of overestimation and periods of underestimation of spawning stock size. As can be expected, bias in fishing mortality is generally opposite to the bias observed for SSB. Bias tends to be larger in the short term forecasts compared to the stock assessment results. For the two flatfish stocks, there appears to have been a negative relationship between the bias in SSB and the size of the stock, indicating that low stocks are overestimated and large stocks are underestimates. This relationship is less clear for the two roundfish stocks.

Keywords

fisheries management – stock assessment – evaluation – retrospective error – recruitment – TAC – cod – haddock – plaice – sole - gadus morhua – melanogrammus aeglefinus - pleuronectes platessa – solea solea

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[1] Netherlands Institute for Fisheries Research (RIVO), The Netherlands. martin.pastoors@wur.nl

Introduction

Around the world, fisheries are regulated by management measures in order to achieve general management objectives. In the North Sea context, fisheries management has mainly been implemented in the form of Total Allowable Catches. The scientific basis for these management measures are provided by the Advisory Committee on Fisheries Management (ACFM) of the International Council on the Exploration of the Sea (ICES). Errors from different sources can occur in the process of the providing scientific advice for fisheries management. The most prominent errors are over- or underestimation of stock size and fishing mortality and errors in the estimation of mean weight at age. All these sources of error need to be taken into account when evaluating the adequacy of fisheries management advice.

A general method for evaluating the role of the scientific advice for management is by modelling the whole management process using closed loop models (Kell et al. 2001; Sainsbury 1998) or operating models (Butterworth and Punt 1999). These approaches have been applied to North Sea stocks like North Sea cod (Kell et al. in press) and North Sea plaice (Kell et al. 2001; Kell and Bromley 2004; Kell et al. 2004). The implicit assumptions in these methods is that the dynamics of the operating model can capture the essential dynamics in the biological and economic systems that form the basis of the simulation. The focus of these studies is mostly on evaluating the efficacy of management measures rather than evaluating the role of scientific knowledge in decision making per se.

A second approach to evaluating scientific advice is by analyzing the historical realizations: what has been advised in the past and how can that advice be interpreted with the present understanding of the stock dynamics. Analysis have been presented that focus on either the retrospective errors in stocks assessments or on the adequacy of the catch forecats. Mohn (1999) and Rosenberg et al. (2002) investigated the retrospective error in stock assessment models and found that the most important sources of error could be ascribed to changes in catch data, the quality of the abundance indices and the model assumptions. Several metrics for the measurement of retrospective error have been proposed (Evans 1996; Jonsson and Hjorleifsson 2000; Mohn 1999). The accuracy of catch forecasts has been investigated with emphasis on predicted landings (Gascuel et al. 1998), predicted fishing mortality (Van Beek and Pastoors 1999), predicted stock size (Sparholt 2001) and measures of uncertainty (Cook 1993). There general conclusion from these papers has been that the relationship between the catch forecasts and the realizations has been rather weak. Daan (1997) evaluated the historical performance of the North Sea flatfish management and found that have been problems in the consistencies of stock assessments and advice, in the linkages between advice and decisions and in the enforcement of regulations.

However, no study has been presented so far that evaluated the scientific basis of management advice over a range of different fish stocks . We present such an analysis of fisheries management advice on some North Sea fish stocks (cod, haddock, plaice and sole) as provided by ICES. We also attempt to disentangle the different sources of error that arose in the historical advice.

The analysis are based on the historical material as recorded in the ICES documentation and published in advisory and working group reports for the years 1985- 2002 (e.g. ICES 2003). We found that in general there has been a tendency to overestimate stock size in the 1990s and accordingly to provide too high catch advices. Bias in fishing mortality was generally opposite to the bias observed for SSB. Bias tends to be larger in the short term forecasts compared to the stock assessment results. For the two flatfish stocks, there appears to have been a negative relationship between the bias in SSB and the size of the stock, indicating that low stocks are overestimated and large stocks are underestimates. This relationship is less clear for the two roundfish stocks.

Methods

Data

The data for the analysis presented is paper are derived from the ICES advisory reports on fisheries management 1980-2004 (ICES 1981; ICES 1982; ICES 1983; ICES 1984; ICES 1985; ICES 1986; ICES 1987; ICES 1988; ICES 1989; ICES 1990; ICES 1991; ICES 1992; ICES 1994; ICES 1995; ICES 1996; ICES 1997; ICES 1998; ICES 1999; ICES 2000; ICES 2001a; ICES 2002; ICES 2003; ICES 2004a; ICES 2005a)

Data for cod were transformed to North Sea data only. Since 1997, the stock assessment included subdivisions VIId and IIIa Skagerrak. We calculated the catches and stock size of the North Sea component for those years by using the ratio in the landings between different areas.

Historical retrospective analysis

An historical restrospective analysis is defined here as the comparison between stock assessments carried out in the past with the most recent stock assessment (ICES 2005b), which is here considered to be the "truth". Measures for bias and deviations were calculated based on Jonsson and Hjorleifsson (2000). Let $a_{y,ay}$ equal the interest variable *a* (e.g. SSB or F) in year y, as estimated in assessment year ay. Thus, for example, $SSB_{1991,1999}$ would refer to the SSB estimated for 1991 during the assessment year 1999. The assessment bias (*b*) of the individual year *y* in assessment year *ay* can be written as the log ratio between the first estimate for that year and the most recent estimate for that year:

$$b(a)_{y=y,ay=n} = \ln(\frac{a_{y=y,ay=y}}{a_{y=y,ay=n}})$$

Jonsson and Hjorleifsson (2000) calculated the average log deviance (ab) over the time-series as and indicator of bias and derived the measure of absolute deviance from the difference between the individual deviances and the mean deviance. Here, we are more interested in the time trends in bias, than in the overall mean. We calculated the running mean deviance with a span of a defined number of years (e.g. 3 or 5 years):

$$ab(a)_{ay=n} = \frac{1}{span}\sum_{i=n-span/2}^{n+span/2}\ln(\frac{a_{y=i,ay=i}}{a_{y=i,ay=n}})$$

A measure of variance is calculated as the average deviation (asd) between bias in individual years and the mean bias from the running means:

$$asd(a)_{ay=n} = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n-1}\left(\ln(\frac{a_{y=i,ay=i}}{a_{y=i,ay=n}}) - ab(a)_{ay=n}\right)^2}$$

Analysis of short term forecasts

The advisory report on fisheries management usually contains a short term forecasts for the different stocks. These forecasts contain catch options for different F-multipliers on the fishing mortality pattern that is perceived in that year of the advice. The implied fishing mortality in the TAC year and the SSB surviving after the TAC year were back-calculated, by substituting the observed catch (human consumption landings) into the original forecasts.

The measures for bias and deviations in the catch forecast analysis are similar to the measures used for the historical retrospective analysis. For each TAC year y, C_y is the catch in year y used in the forecast procedure, and Cy,obs is the Catch that is observed for that year in the most recent assessment.

$$F_{y,est} = f(C_y, F_y \mid C_y = C_{y,obs})$$

$$SSB_{y+1,est} = f(C_y, SSB_{y+1} \mid C_y = C_{y,obs})$$

We thus calculate the implied F and SSB given the observed landings (or catches) and the original forecasts as presented in the ACFM report.

Results

Historical retrospective analysis

The historical retrospective analysis on cod, haddock, plaice and sole (figures 1 and 2) indicate that for each of the stocks, periods over overestimation and underestimation of SSB have occurred. Bias in SSB appears inversely related to bias in fishing mortality, as could be expected from the dependency of fishing mortality and stock numbers. The variances of estimated SSB and F are generally of the same order of magnitude in individual years, although some deviations to this rule occur (e.g. plaice in the early and mid 1990s). Cod and plaice appear to suffer from higher biases than sole and haddock. The perceived bias is dependent on the assumption about the recent “truth” as shown in figure 3 for North Sea plaice as an example.

The occurrence of periods of overestimation and underestimation of SSB can be considered as tacit knowledge within the domain of fisheries management advice, but explicit examples of these processes have hardly been documented (however, see Gascuel et al. 1998; however, see Rosenberg et al. 2002 for some documented exceptions). In most cases, previous analysis on flatfish stocks (Daan 1997; Van Beek and Pastoors 1999) have not been analyzed in terms of bias and variance as has been done here. However, the level of bias found in this study is similar to the results obtained by Jonsson and Hjorleifsson (2000).

Historical retrospective analysis always suffer from the confounding effects of changes in data, changes in model and changes in nature. In order to separate out these confounding factors, simulation studies (Mohn 1999; Rosenberg et al. 2002) can be carried out. In practice it has been found difficult in these simulation studies to mimick the types of errors found actual advisory process (ICES 2004b), but the results obtained can still be illustrative to the type of processes that could be co-occurring. The main cause for retrospective error has been stated as the analytical technique used (Mohn 1999; Rosenberg et al. 2002) and the non-stationarity of the data (Mohn 1999).

Retrospective errors in stock assessments are an important component of fisheries management advice and should be clearly communicated to the customers of the advice. In many cases, stock assessments are treated as best possible representation of the current status of fish stocks (Corkett 2002; Finlayson 1994). Errors in the past are often ignored as non-informative, but unless they can be clearly explained, I argue that they should be presented as integral part of the assessment of the status of the stock.

Analysis of short term forecasts

The basis for a short term forecast is that there is a relationship between stock size and exploitation and that the stock size can be projected forwards using an assumed exploitation pattern. The quality of the forecasts can be evaluated by retrospectively substituting the observed catches (i.e. landings) into the original forecasts and calculating the implied fishing mortality and SSB (Van Beek and Pastoors 1999), which can then be compared to the estimates of these variables in the most recent stock assessment (loosely called "observed SSB" and "observed F").

The relationships between implied and observed SSB and F is often far from the assumed 1:1 ratio (figure 4). In the case of cod and sole, for example, the relationship between implied and observed F appears to be negative, which indicates that a high implied F corresponds with a low observed F and vice versa. Only for haddock has a reasonable relationship between implied and realized fishing mortality materialized.

SSB has been overpredicted in most of the cases which have been analysed. The slope of the implied/observed SSB regression is positive for all stocks, but the slope is substantially less than 1, so that a high prediced SSB corresponds to a much lower realized SSB as indicated by the recent stock assessment.

The findings in this study are similar to earlier results (Gascuel et al. 1998; Sparholt 2001; Van Beek and Pastoors 1999) and the extension of the time series – compared to the earlier studies – has not altered the qualitative conclusions.

Bias propagation

Given the uncertainty in the estimates of stock size in the most recent years, which is inherent in many of the assessment models used (Shepherd 1988), one may expect that a bias in a stock assessment result is exacerbated in the short term forecast. A comparison of biases in SSB in the final data year, in the assessment year and in the year after the TAC (figure 5) confirms this expectation: bias in the short term forecast (i.e. after the TAC year) is generally larger than the bias in the former two instances. This applies both to overestimations and underestimations.

Bias in short term forecasts in relation to stock size

Figures 4 and 5 have shown that large biases exist in predicted SSB for the stocks considered. Because the time series available for these analysis are long enough and cover periods of both high and low stock sizes, one may wonder whether bias could be related to stock status. The scatter plot of bias in forecast SSB against "observed" SSB (figure 6) suggests that at least for the two flatfish stocks, a negative relationship between stock size and bias may exist (plaice: r^2=0.72, sole: r^2=0.65). The relationship appears to be much weaker for the two roundfish stocks.

Discussion

We developed a relatively simple diagnostic of bias in historical assessments and forecasts of stock assessments. This could be used as a general diagnostic to judge the quality of the historical advice. This, in itself, does not imply that the future bias will be the same as in the past. However, we believe that it is useful information in providing advice.

Cod and plaice appear to have suffered from higher biases than sole and haddock. The SSB bias in the example stock assessments in the 1990s was generally overestimated. The perceived bias is to a certain extend dependent on the assumption about the recent "truth" (figure 3, for North Sea plaice). As expected, the bias between assessment and forecasts propagates further, so that an overestimation in the assessment process, results in a even larger overestimation in the forecast.

There was no apparent relation between implied and observed F in the catch forecasts. This is a problematic issue given that the management of these fish stocks is heavily dependent on the level of fishing mortality in relation to the biological reference points.

We found indications of correlations between bias and stock size for the two flatfish stocks: small stocks were overestimated and large stocks were underestimated.

Acknowledgement

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Figure 1. Historical time series of assessments of cod, haddock, plaice and sole: SSB (left) and Fbar (right).

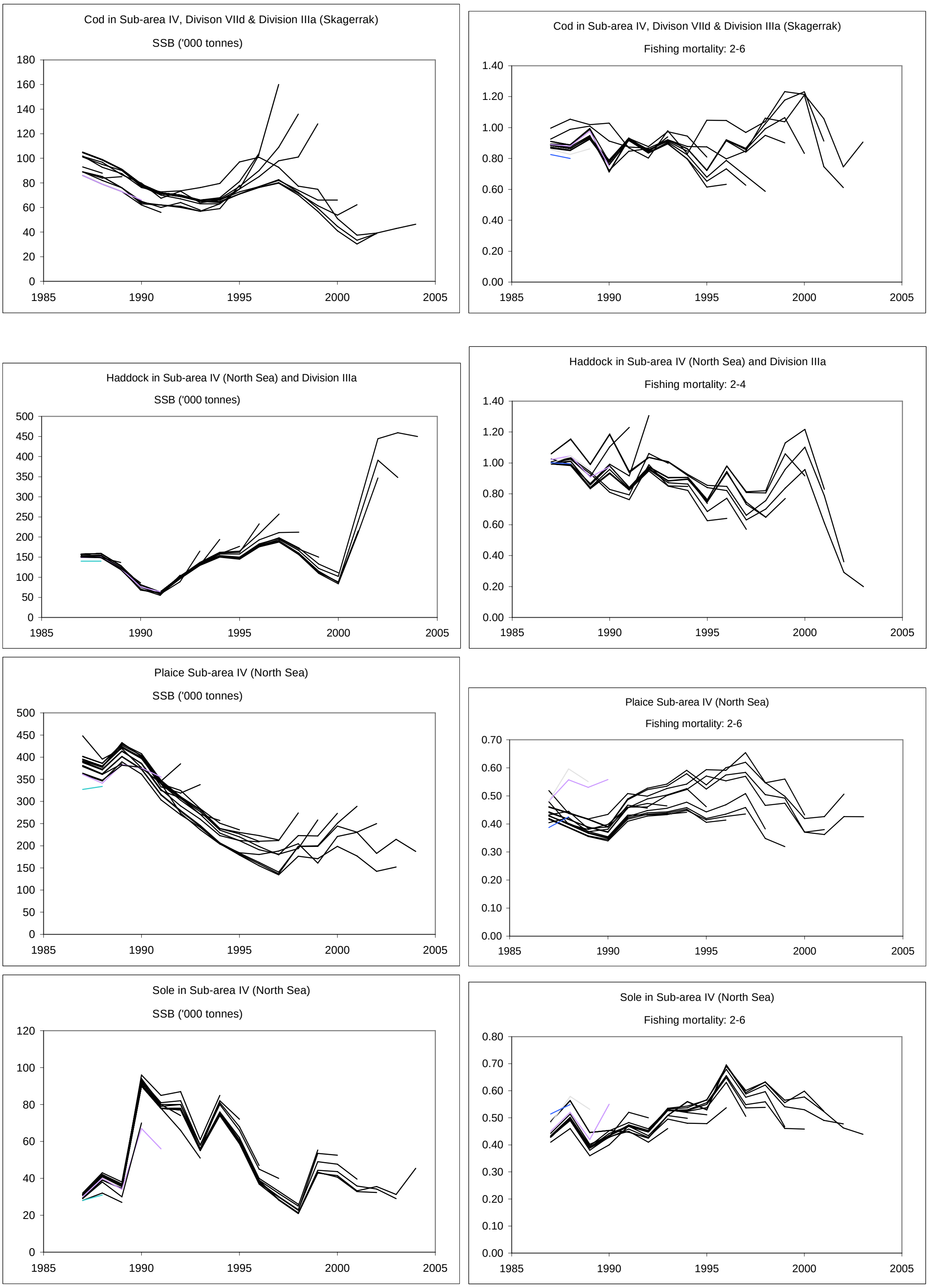

Figure 2. Retrospective bias (left) and deviation (right) in historical retrospective analysis of SSB and F for cod, haddock, plaice and sole. SSB is expressed as bias and deviation relative to the assessment year. F is expressed relative to the last data year.

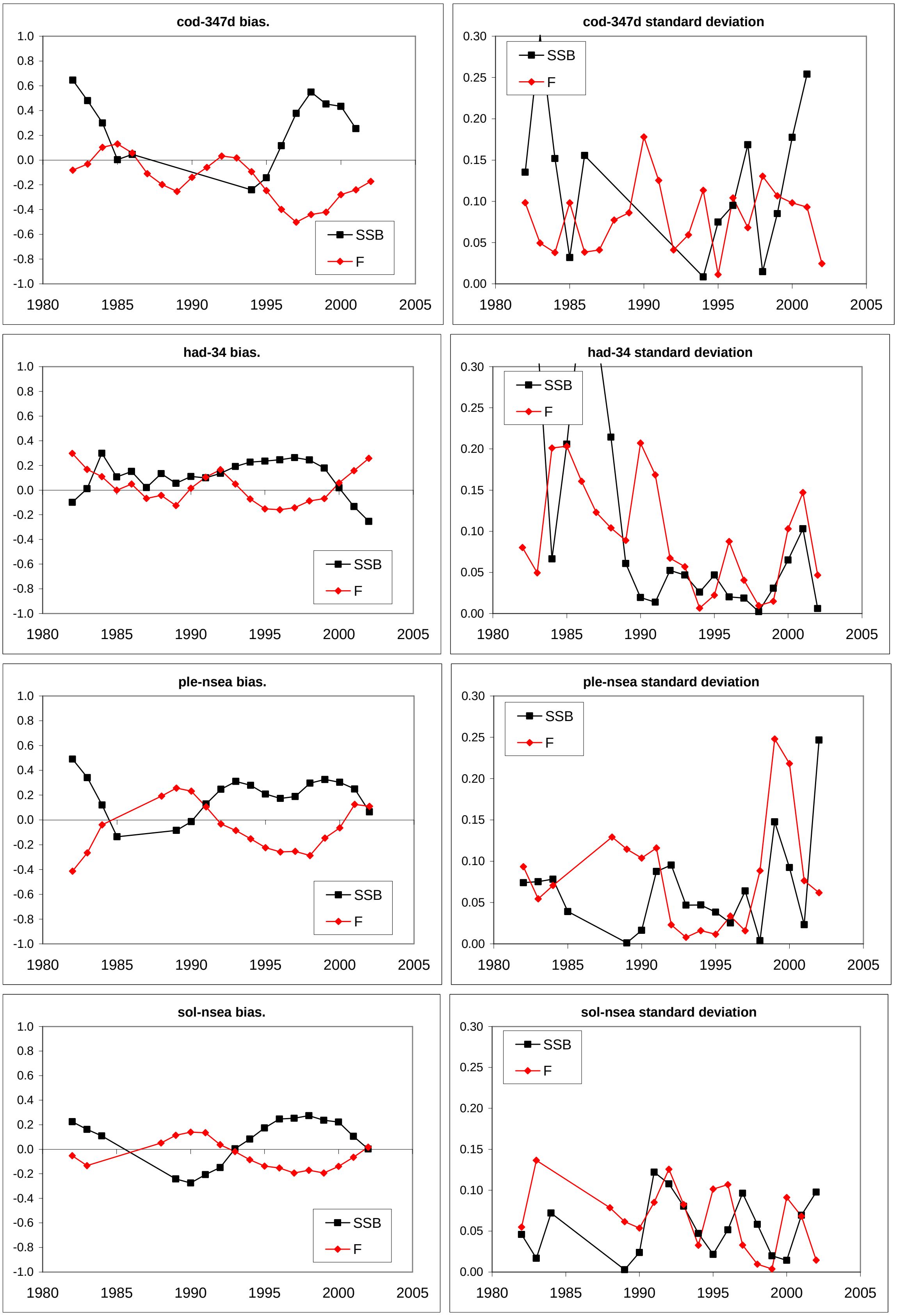

Figure 3. Dependency of retrospective bias on the latest "truth" for North Sea plaice. SSB bias is expressed relative to the assessment year 1998, 2000, 2002 and 2004

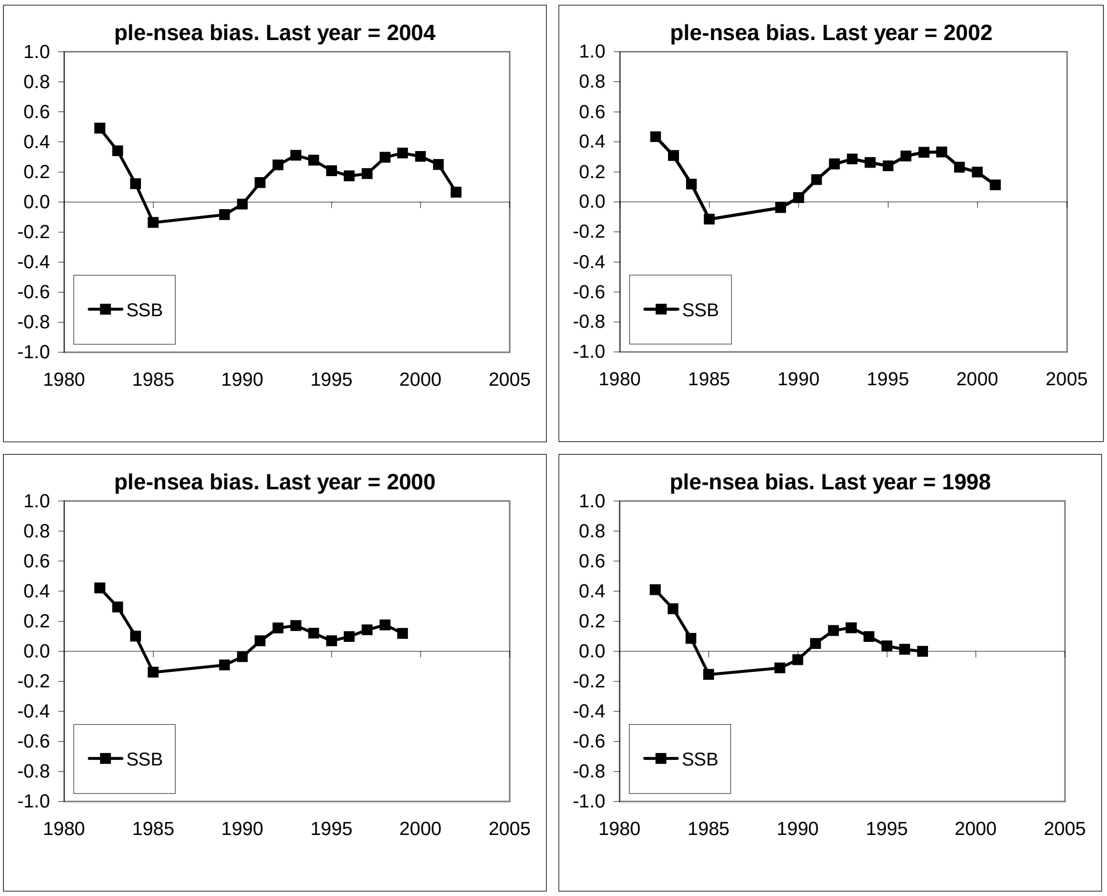

Figure 4. Relationships between implied and “observed” fishing mortality (left) and spawning stock biomass (right) in historical catch forecasts for cod, haddock, plaice and sole.

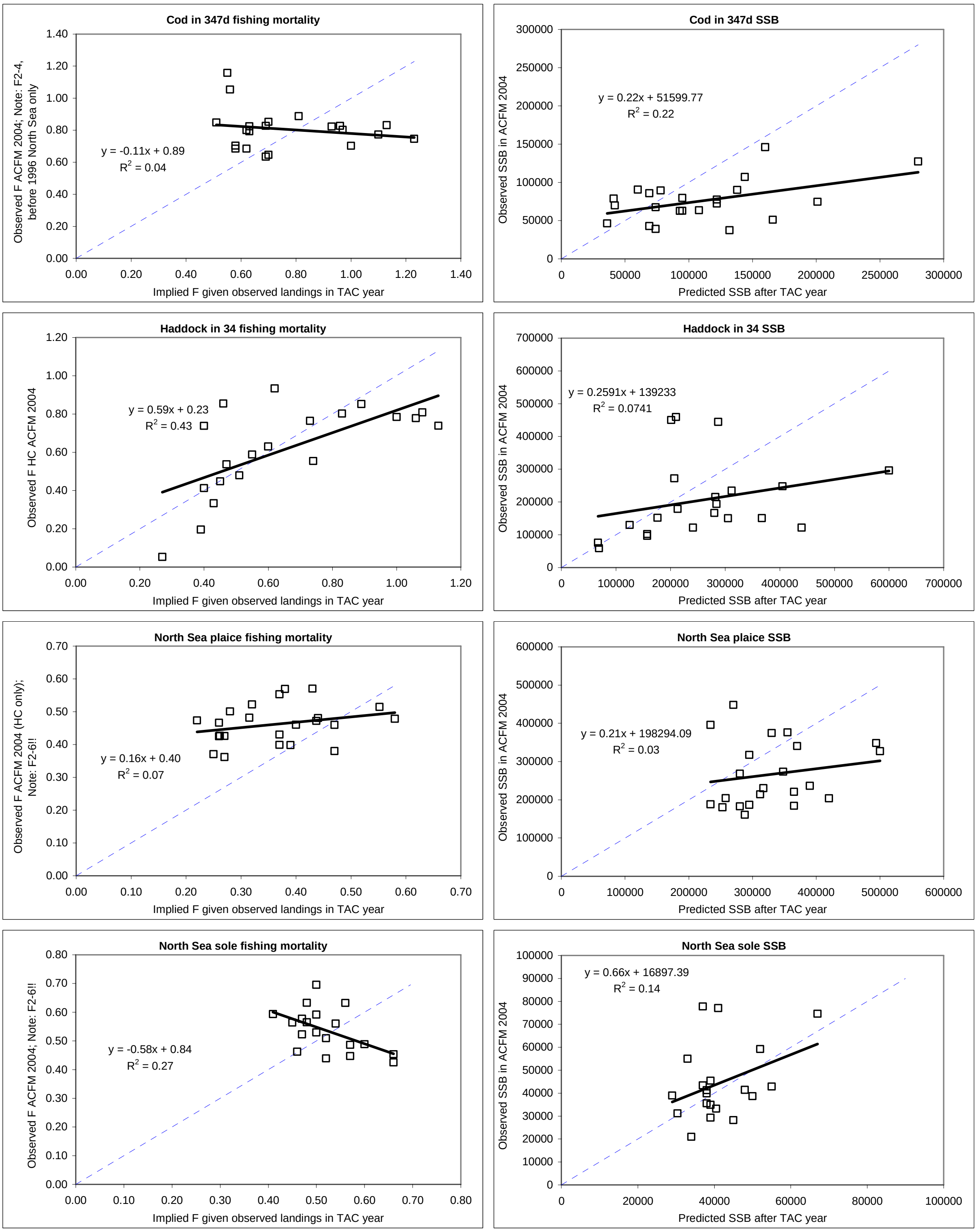

Figure 5. Bias propagation in SSB estimated in the last data year, the assessment year and the year after the TAC. Estimates in the last data year and assessment year based on historical stock assessments; estimates after the TAC year based on historical forecasts.

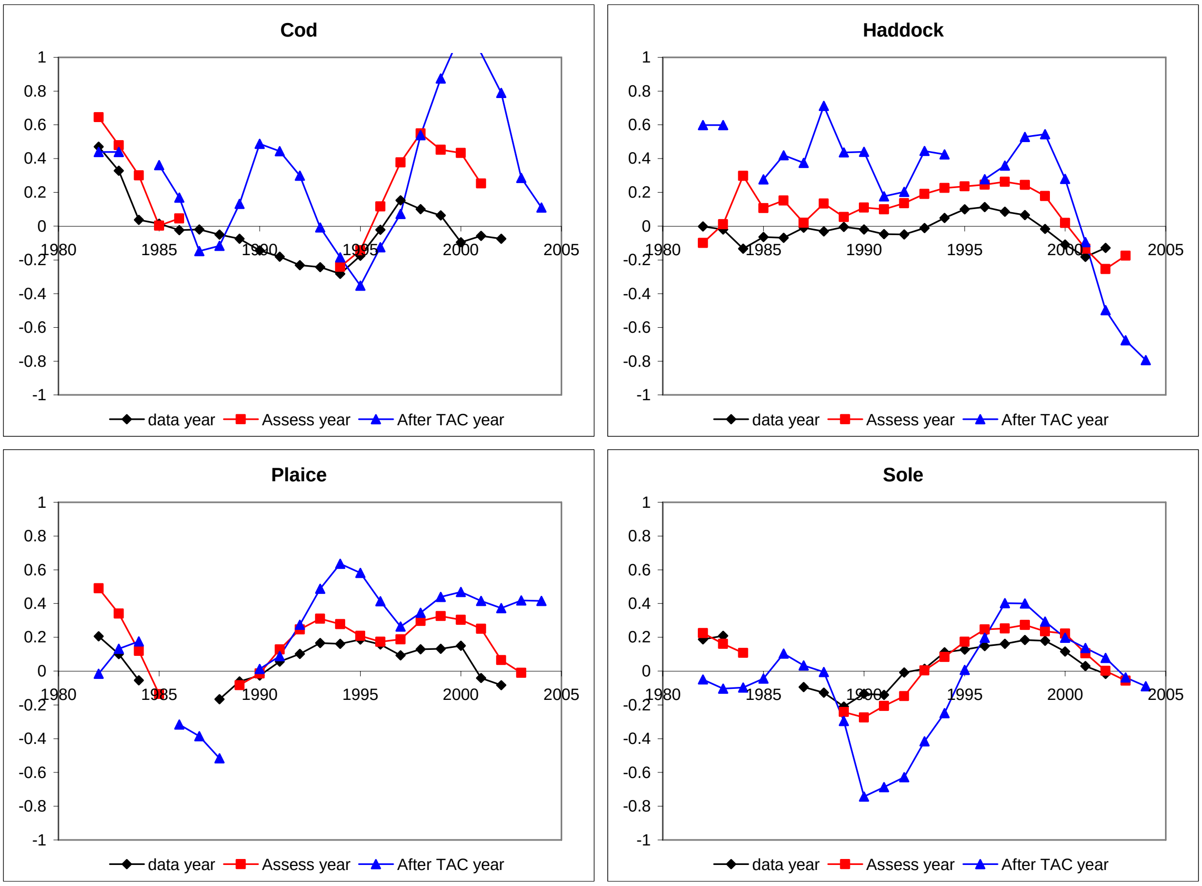

Figure 6. Relationship between bias in SSB and stock size in the historical catch forecasts for cod, haddock, plaice and sole.